Industrial Decarbonisation Frontiers Report

Green Finance and Economic Considerations

Since its launch in 2021, the Industrial Decarbonisation Research and Innovation Centre (IDRIC) has funded 100 projects, investigating and addressing the key dimensions of the whole system of industrial decarbonisation. This work has generated a vast body of knowledge, offering critical insights into the challenges we face in decarbonising and into the solutions – technical, economic and social – that are emerging. The *Frontiers Reports* series brings together all these insights to share with our industry and policy stakeholders.

Each report synthesises key findings from multiple projects conducted on a closely related theme, providing a comprehensive perspective on a specific aspect of industrial decarbonisation. Far more than simply research summaries, these reports translate academic insights into practical, evidence-based recommendations for our stakeholders. These recommendations are shaped by the expertise and evidence gathered by our research teams and are designed to support decision-makers in advancing their net zero goals.

The *Frontiers Reports* are anticipated to serve as catalysts for meaningful discussions between academia, industry, and policymakers on the most viable paths forward. We welcome constructive debate and are eager to support the implementation of recommendations that best align with our stakeholders' priorities and goals towards net zero.

This report brings together all IDRIC's research on Green Finance and Economic Considerations.

Published May 2025

Lead authors

Heather McGregor, Olive Bradshaw
Heriot-Watt University

Contributing authors

Christian Calvillo Munoz, Antonios Katris
University of Strathclyde

Nadine Moustafa
Imperial College London

Dimitris Christopoulos, David Dekker, Isobel Marr
Heriot-Watt University

Executive summary

Achieving net zero requires a strategic integration of economic policy, financial instruments, and innovation-driven solutions. This report synthesises research from IDRIC projects to examine three key themes: the economic impacts of decarbonisation, the role of green bonds in financing the transition, and the economics of innovation in driving industrial change.

Key findings

Section 1: The economic impacts of decarbonisation assesses the impact of decarbonising the economy on the workforce and geography. Labour shortages in highly skilled sectors risk inflating wages, increasing project costs, and delaying decarbonisation efforts. Effective sequencing of decarbonisation projects is crucial to prevent excessive labour competition, which could otherwise raise costs and disrupt economic stability. Targeted skilling and reskilling initiatives, in partnership with educational institutions, will be essential to ensure a steady talent pipeline. Industrial decarbonisation will impact regions differently, with green industry clusters benefiting while carbon-intensive sectors suffer. Investment into industrial clusters can enhance employment and Gross Value Added but these benefits will not be evenly distributed without tailored regional strategies.

Section 2: Green bonds examines the role of sustainable finance in accelerating decarbonisation. Green bonds have emerged as a crucial tool for directing capital toward low-carbon projects, yet challenges remain in standardising impact assessments and ensuring transparency. The success of green bonds depends on a strong regulatory framework that enhances investor confidence while maintaining alignment with net zero targets.

Section 3: The economics of innovation underscores the need for coordinated efforts across government, industry, and academia to drive technological progress. The UK's innovation ecosystem, centred around the "triple helix" model, demonstrates the critical role of research institutions in fostering knowledge diffusion and industrial partnerships. However, high-risk, capital-intensive technologies such as hydrogen distribution and carbon capture require substantial government support to mitigate investment barriers and enable large-scale adoption.

Recommendations for industry and policymakers

Workforce planning and labour constraints
- → Policymakers are advised to assess labour supply constraints and workforce challenges during the transition to net zero.
- → Industry is encouraged to engage in workforce planning, skills development, and partnerships with educational institutions.
- → Further research is needed on regional economic impacts and labour market dependencies.

Coordination and project sequencing
- → Policymakers should take an active role in coordinating industrial decarbonisation strategies as part of broader economic planning.
- → Industry should avoid unilateral decarbonisation actions that could undermine competitiveness and instead seek collaborative approaches.

Financial incentives and green finance
- → Policymakers must ensure finance is targeted at high-impact sectors, create de-risking mechanisms, and promote clear green taxonomies
- → Industry must adhere to green taxonomies in debt issuance and advocate for stable regulatory frameworks.
- → Research should examine the risks of green financial instruments, explore innovative finance mechanisms, and assess social justice aspects of green finance.

Regulatory frameworks and standardisation
- → Policymakers should create clear, consistent regulations to align decarbonisation with economic development.
- → Industry should push for stable regulations to facilitate long-term investment and mitigate policy uncertainty.

Innovation and technological development
- → Policymakers should incentivise technological innovation, particularly in hydrogen, CCUS, and low-carbon manufacturing.
- → Industry should invest in cross-sector collaborations to accelerate decarbonisation innovation.

Contents

Introduction 6
Section 1: The economic impacts of decarbonisation 8
Research findings: Economic impacts of decarbonisation on the workforce 9
Research findings: Economic impacts of decarbonisation on geography 12
Recommendations to policymakers, industry, and for further research 14
Section 2: Green bonds 16
Research findings: Green standards and a green taxonomy 19
Research findings: Pricing risk 20
Research findings: The availability of green financial assets 22
Recommendations to policymakers, industry, and for further research 23
Section 3: The economics of innovation 25
Research findings: The economics of innovation 27
Recommendations to policymakers, industry, and for further research 29
Moving forward 30
Contributing projects 32

Introduction

The transition to a low-carbon economy stands as one of the defining challenges of our time and will require substantial financial resources and careful economic planning.

As a global leader in climate finance, the UK has a unique opportunity to maintain its pioneering role and drive innovative solutions to support this critical shift.[1,2] Not only will the green projects driving this transition demand substantial and targeted funding, but the financial and economic impacts of decarbonisation and low-carbon reorientation of industries will be broad and significant. For this, we are not yet sufficiently prepared. The UK's decarbonisation transition requires a clear understanding of the intersectionality between industry, finance, and the economy.

Numerous comprehensive reviews exist of the literature on 'green finance', a term that broadly encompasses climate finance, decarbonisation finance, and related concepts.[2,3,4,5,6,7,8,9,10,11] These reviews highlight the most pressing and rapidly evolving challenges in green finance; areas that require greater focus if we are to effectively mobilise financial resources toward achieving net zero goals. Research conducted at IDIRC across eight projects contributes to this in the United Kingdom and underscores the critical collaboration between academia, government, and industry—the 'triple helix'—to drive progress toward these objectives.

Our financial system needs a dramatic green reorientation if the UK is to achieve its net zero goals. This report reviews where the UK currently stands in terms of its readiness for leveraging finance for the green transition; synthesising insights from IDRIC's research projects to explore challenges and opportunities in green finance, focusing on green bonds, impacts on the workforce, impacts on geography, and innovation. We present recommendations for policymakers and industry, and directions for future research and future funding.

The report is broken down into three sections:

→ Section 1:
The economic impacts of decarbonisation

→ Section 2:
Green bonds

→ Section 3:
The economics of innovation

The recommendations for policymakers and industry can be found at the end of each section.

1 Committee on Climate Change (CCC). (2019) Net Zero: The UK's contribution to stopping global warming. Climate Change Committee.

2 Bhatnagar, S., & D. Sharma. (2022) 'Evolution of green finance and its enablers: A bibliometric analysis.' Renewable and Sustainable Energy Reviews 162: 112405.

3 Fu, C., Lu, L. & Pirabi, M. (2023) Advancing green finance: a review of sustainable development'. DESD 1, 20.

4 Krastev, B. & Krasteva-Hristova, R. (2024) 'Challenges and trends in green finance in the context of sustainable development—A bibliometric analysis'. Journal of Risk and Financial Management. 17(7):301.

5 Cortellini, G. & Panetta, IC. (2021) 'Green bond: A systematic literature review for future research agendas'. Journal of Risk and Financial Management.14(12):589.

6 Gilchrist, D., Yu, J. & Zhong, R. (2021) 'The limits of green finance: A survey of literature in the context of green bonds and green loans'. Sustainability. 13(2):478.

7 Alsmadi, AA., Al-Okaily, M., Alrawashdeh, N., Al-Gasaymeh, A., Moh'd Al-hazimeh, A., Zakari, A. (2023) 'A bibliometric analysis of green bonds and sustainable green energy: evidence from the last fifteen years (2007–2022)'. Sustainability. 15(7):5778.

8 Zhang, D., Zhang, Z. & Managi, S. (2019) 'A bibliometric analysis on green finance: Current status, development, and future directions'. Finance Research Letters 29: 425-430.

9 MacAskill, S. et al. (2021) 'Is there a green premium in the green bond market? Systematic literature review revealing premium determinants'. Journal of cleaner production 280: 124491.

10 Debrah, C., Darko, A. and Chan, A. P. C. (2022) 'A bibliometric-qualitative literature review of green finance gap and future research directions', Climate and Development, 15(5), pp. 432–455.

11 Mohanty, S., Nanda, S. S., Soubhari, T., S, V. N., Biswal, S., & Patnaik, S. (2023). Emerging Research Trends in Green Finance: A Bibliometric Overview. Journal of Risk and Financial Management, 16(2), 108.

Section 1

The economic impacts of decarbonisation

Five IDRIC projects contributed to this section. They are referred to by their project IDs throughout.
→ See further information.

Project ID	Project name
MIP 1.7	An integrated framework for levelled up & low carbon industrial clusters
MIP 7.6	Low-carbon reorientation in steel, oil refining and chemical industries
MIP 9.3	Knowledge transfer & innovation Diffusion
MIP 9.7	Labour market and other wider economy challenges in decarbonising the UK's industry clusters [LAB-CLUSTER]
FF 2-1	The wider economy and competitiveness impacts of employing pre- and post-combustion carbon capture in UK industries (ECONCC)

Research findings:
Economic impacts of decarbonisation on the workforce

The green transition is reshaping workforce demands in the UK prompting significant adaptation across sectors with wide-ranging implications for jobs, regional economies, and industrial strategies. These changes present opportunities and challenges that must be addressed collaboratively by industry, government, and academia.

The National Grid (2020) projects the need to recruit for 400,000 new jobs in the UK in the low-carbon energy sector alone to meet net zero targets, while Grantham Research Institute analysis suggests a further 10% of UK jobs will require reskilling.[1,2] These figures, however, likely underestimate the wider demand for "green jobs," which span diverse fields including engineering, infrastructure, finance, policy, and communications—each integral to enabling a successful transition to a sustainable economy.

Careful consideration and planning are needed to address where the necessary talent for the transition will come from, as well as the impact of job losses in carbon-intensive regions on local economies. Additionally, the broader economic implications of this workforce shift—changes to the cost of goods and services, economic growth, and regional economies in the UK—must be thoroughly evaluated.

Decarbonisation will fundamentally transform the structure of the UK workforce, with impacts on both demand for specific skills and the geographic distribution of jobs. To navigate this transformation successfully, it is crucial to first understand how these changes will unfold and where their effects will be most pronounced. This understanding will then inform targeted measures to reduce friction during the transition and guide strategies for planning, training, and reskilling to meet future workforce needs.

IDRIC research highlights the importance of a detailed understanding of labour supply constraints and congestion effects to support industrial decarbonisation in the UK. Identifying where pressures will be most acute—such as in highly skilled trades, engineering roles, and emerging sectors like Carbon Capture, Utilisation, and Storage (CCUS)—is essential for pre-emptively addressing the challenges posed by labour shortages. Without such insights, competition for skilled workers could drive up wages, increase project costs, and delay critical decarbonisation efforts.

The green transition will fundamentally transform the structure of the UK workforce, with impacts on both the demand for specific skills and the geographic distribution of jobs.

Managing workforce transition: Structure and sequencing

IDRIC projects MIP 9.7 and MIP 1.7 underscore the importance of effective sequencing of decarbonisation projects to mitigate congestion effects, particularly in resource-intensive sectors like CCUS. For example, Figure 1 and Figure 2 demonstrate the potential impact of additive vs. simultaneous introductions of the UK CO_2 Transport and Storage (T&S) sector on wages, GDP and employment MIP 9.7.[3]

Poorly coordinated deployment of multiple projects could exacerbate competition for labour, leading to higher costs, displacement of workers from other sectors, and potential constraints on economic growth. The decline of the oil and gas extraction industries further amplifies these pressures, with projections indicating potential losses of 120,800 full-time equivalent (FTE) jobs and £26 billion in GDP annually by 2056 MIP 9.7.

The development of a nascent CO_2 Transport and Storage (T&S) sector could help mitigate job losses associated with the oil and gas decline, creating new job opportunities while contributing to net zero goals. However, this is not on a large enough scale—supporting only around 4,230 FTE jobs by 2035 and requiring substantial public support MIP 9.7.

Strategic planning—including the careful staging of regional subsectors—can help to minimise resource competition and ensure early economic gains are realised without jeopardising long-term objectives. To further reduce friction, government intervention may be required to incentivise optimal timings for individual activities, ensuring that workforce pressures do not peak simultaneously across different sectors. Close collaboration between governments and industries working with academic partners will be required to identify consistent approaches to analysing and assessing wider economic and cluster-specific dynamics. This approach would enable a smoother transition and help to maintain economic stability while delivering on the UK's industrial decarbonisation and broader net zero ambitions MIP 9.7.

Figure 1

Dynamic adjustment of UK real wage, nominal wage and CPI impacts due to the deployment and operation of the UK T&S sector - additive and simultaneous simulations results.[3] MIP 9.7.

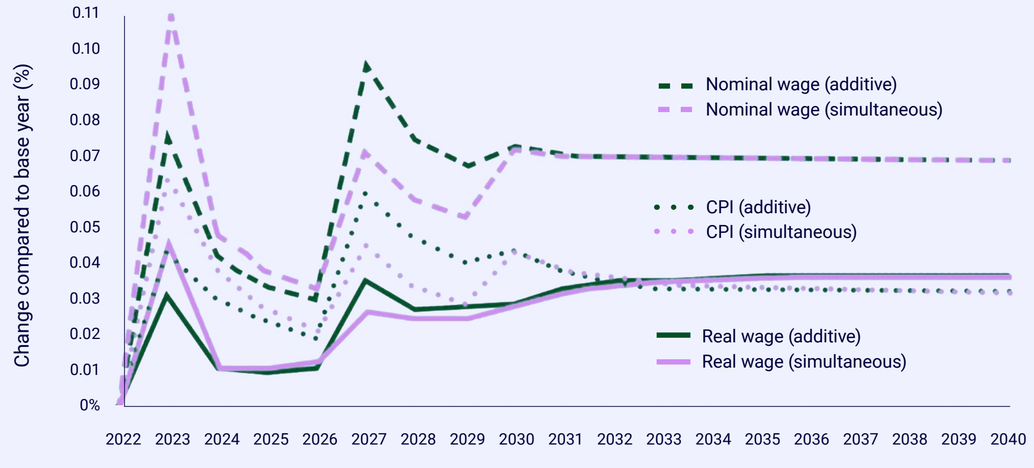
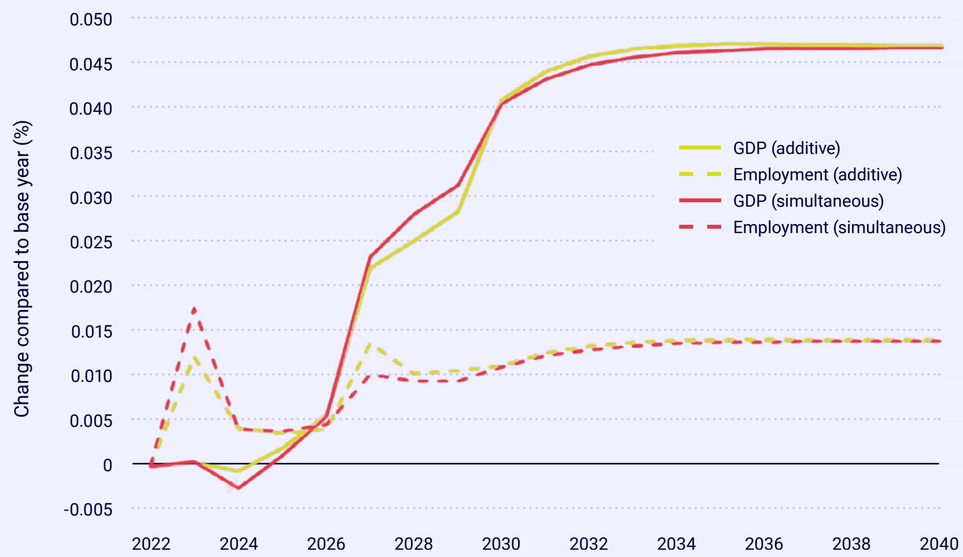


Figure 2

Dynamic adjustment of UK GDP and net employment due to the deployment and operation of the UK T&S sector – additive and simultaneous simulation results.[3] MIP 9.7.



Skilling and reskilling are critical for a just transition, spanning not only technical fields but also finance, communication, and behavioural sciences.

Workforce planning

Planning for the green transition must go beyond identifying labour needs to actively addressing how those needs will be met. This involves collaboration between industry, policymakers, and educational institutions to create a resilient talent pipeline capable of supporting a sustainable economy.

Skilling and reskilling efforts will be central to this process, ensuring that workers—both those entering the labour market and those already employed—are equipped with the necessary competencies to thrive in a green economy. This will require a diverse range of skills, not only in technical fields such as engineering and renewable energy but also in finance, communication, and behavioural sciences to address the broad demands of decarbonisation.

Equality, diversity, and inclusion (EDI) must also be prioritised to ensure fairness and enhance productivity. Early intervention, including engagement with schools and universities, internships, and outreach initiatives, will be key to broadening participation and fostering a workforce that reflects the diversity of society. IDRIC's flagship EDI project, 'You Can't Be What You Can't See', a series of interviews with 48 IDRIC colleagues, showcases the full range of diverse backgrounds and roles that can contribute to the climate transition, and provides role models for teenagers considering a career in decarbonisation.

Scarcity of talent poses a significant risk to economic growth and innovation, potentially driving up costs and limiting competitiveness. Proactive workforce planning, therefore, is not only a matter of meeting labour demand but also a critical economic factor in ensuring the UK remains competitive during the transition to net zero.

Industry should develop long-term strategies for building the talent pipeline, including establishing partnerships with universities, offering internships, and implementing on-the-job training programmes. Equality, diversity and inclusion (EDI) initiatives should be prioritised to enhance innovation and productivity. Policymakers must take a role in coordinating different elements of the transition as part of wider public policy decision-making. Initiatives such as the Green Jobs Delivery Group and frameworks, such as the Net Zero Workforce Action Plan, can align decarbonisation strategies with workforce needs. Additionally, regular assessments of job and investment requirements are essential to adapt to evolving conditions and ensure that economic and environmental benefits are maximised MIP 9.7.

Through coordinated effort across the triple helix, the UK can facilitate a just and efficient transition to a green economy, effectively balancing economic growth with the urgency of achieving net zero targets.

Research findings: Economic impacts of decarbonisation on geography

Sustainable fuels: Hydrogen, ammonia and biomass

IDRIC projects MIP 1.7, MIP 7.6, MIP 9.3, FF 2-1 assert that attention must be paid to the regional disparities in the economic impacts of decarbonisation across the UK.

There are significant financial benefits to be drawn from the move to net zero and the emergence of green industries and projects MIP 1.7. However, differences in industry structures, clusters, and socio-economic dependencies between UK regions mean that the costs and benefits will naturally be levied unevenly without appropriate measures.[3,4] This is particularly poignant in the UK, one of the most regionally unbalanced countries in the industrialised world.[5] The opportunities for growth in regions with strong green industry clusters contrast against challenges faced by carbon-intensive "brown industry" towns, disparities which could potentially be emphasised by the regional heterogeneity of green bond effects on CO_2/GDP production.[6] This necessitates advocacy for policies tailored to the specific energy structures of each region to ensure a just transition.[4]

IDRIC research highlights the uneven economic benefits of decarbonisation investments across UK regions. Investment into decarbonisation within the UK's industrial clusters can significantly enhance employment and Gross Value Added (GVA). However, certain regions persistently show higher returns on investments than others, and the scalability of decarbonisation technologies across regions is heavily influenced by interregional trade dependencies. Strategic, region-specific investments that consider local economic structures are required to maximise the national economic impact of the green transition MIP 1.7.

In the path of industrial decarbonisation, further efforts should focus on enhancing the integration of socio-economic impact analysis with decarbonisation strategies. This will require assessing the regional impacts of decarbonisation technologies and how the adoption of low-carbon solutions effect employment, GVA, and the wider supply chain. Filling data gaps in regional economic dependencies and improving access to granular, region-specific economic data will be necessary, as will aligning policy frameworks with specific regional and sectoral dynamics MIP 1.7.

Investment in industrial clusters can enhance employment and GVA, but some regions persistently show higher returns than others.

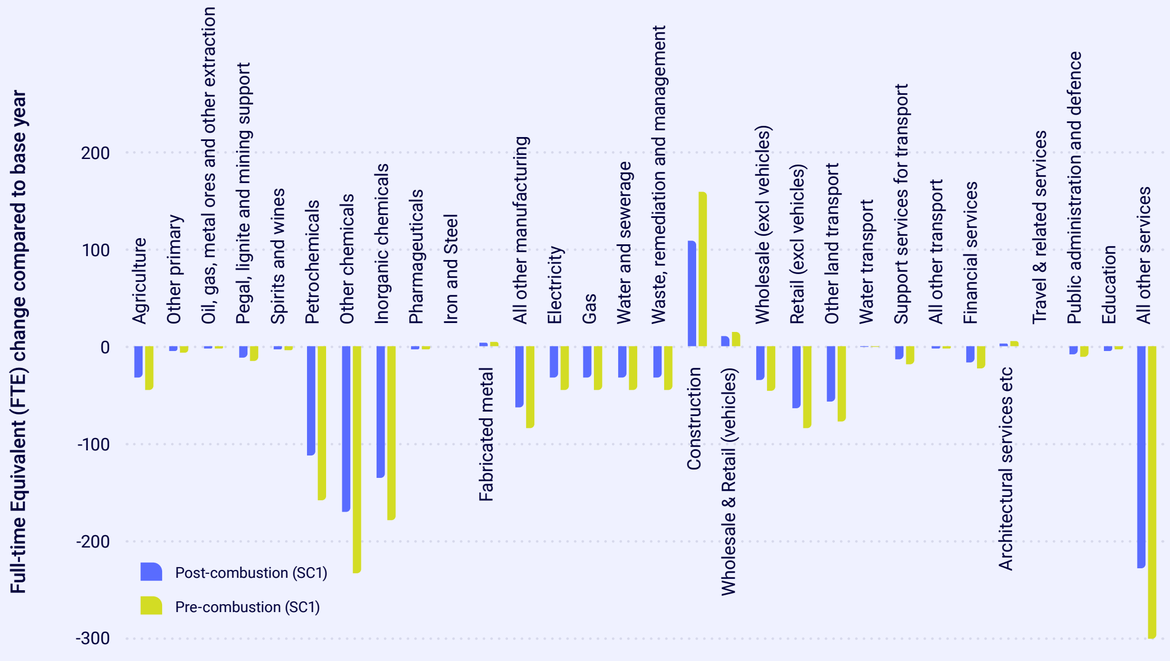
Lessons from the collapse of the UK's coal industry underscore the risks of deindustrialisation in communities reliant on carbon-intensive industries. Following the rapid deindustrialisation in the UK throughout the 1970s and 80s, wealth inequality between old coal mining towns and the rest of the UK became the most dramatic of anywhere in Europe, and the negative socio-economic consequences on health, wealth, and living standards persist today.[7] Learning from the UK's industrial history by providing targeted financial support to communities most affected by the transition must be a priority.

The pace of decarbonisation varies significantly across industries such as steelmaking, oil refining, and petrochemicals. For instance, since 2019 oil refining has advanced rapidly due to favourable policies, technical feasibility of technologies like CCS and blue hydrogen, stronger financial health, and the presence of industry mindsets more open to low-carbon transitions. Conversely, steelmaking and petrochemicals have lagged, hindered by international competition, weaker financial health, and less viable low-carbon alternatives like electric arc furnaces MIP 7.6.

In devolved nations like Scotland, whose petrochemical industry contributes significantly to its economy through exports and employment, unilateral decarbonisation efforts risk disproportionate economic impacts. Carbon capture introduction, for instance, could introduce competitiveness and price challenges for the Scottish chemical industry and wider economy due to additional capital and energy requirements, pushing prices upwards and reducing the sector's competitiveness FF 2-1. Other sectors will also face changes; the projected impact on employment of introducing pre- and post-combustion CCS across sectors in Scotland is shown in Figure 3, with the most notable impacts on the construction, chemical, and transport sectors FF 2-1.[8]

Figure 3

Projected 2050 changes (relative to base year) in sectoral employment when Scotland is the sole adopter for the case of post- and pre-combustion CCS application.[8] FF 2-1.

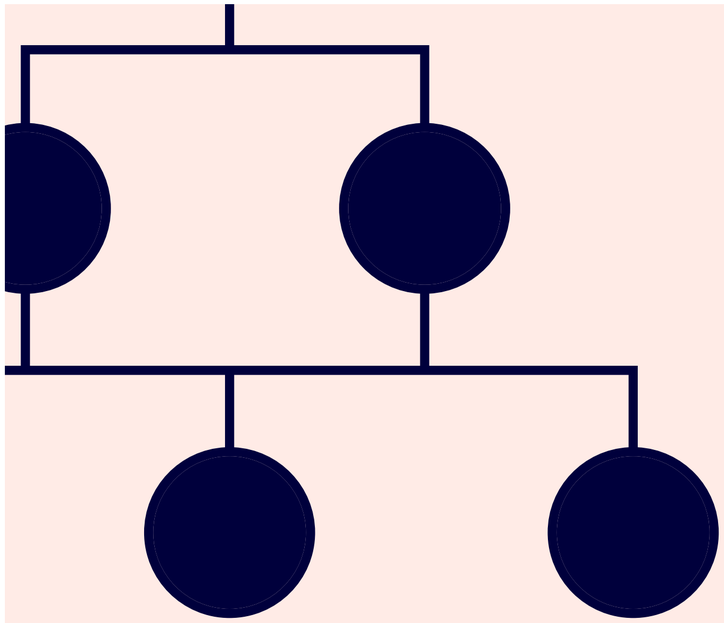


Coordinated UK-wide strategies could mitigate these disparities, though they may raise costs. Carefully chosen subsidies can play a critical role in offsetting the economic burden of technologies like carbon capture, with pre-combustion methods offering long-term benefits despite higher initial costs. However, clear policy objectives are essential to align financial support with strategic goals, including the development of a hydrogen economy and a skilled workforce for decarbonised industries. To achieve these goals, further research into the economic implications of hydrogen infrastructure is needed, alongside policies that provide the confidence and funding required for innovation. By integrating these elements, decarbonisation can advance equitably, balancing regional impacts while supporting long-term economic growth FF 2-1.

Geography also plays a critical role in the distribution of innovation. The presence of innovation hubs and research-intensive universities shapes the regional capacity for decarbonisation. These hubs foster collaboration, yet the geographical concentration of such resources risk deepening regional disparities. Regulatory certainty and robust support for innovation are crucial for mitigating these risks, as are policies designed to balance disruptive effects across industrial clusters MIP 9.3.

By prioritising region-specific strategies, targeted financial support, and policies that foster innovation and workforce development, the UK can mitigate inequalities while maximising the opportunities presented by the green transition. This approach will help ensure that all regions contribute to and benefit from the move to net zero, supporting a more balanced and inclusive national economy.

Recommendations to policymakers, industry, and for further research



Recommendations to policymakers

A strengthened understanding of labour supply constraints and congestion effects must inform efforts to decarbonise industry clusters in the UK. Governments, industries, and academic partners must collaborate to analyse and assess wider economic dynamics to inform project sequencing and mitigate risks in workforce planning.

Policymakers must carefully plan to address the workforce challenges posed by the transition to net zero. This includes identifying where talent for emerging sectors like CCUS will come from, while mitigating job losses in carbon-intensive regions to minimise local economic disruption. A thorough evaluation of the broader economic implications—such as wage pressures, changes to the cost of goods and services, and regional economic shifts—should inform policies to support a just and sustainable transition.

Policymakers must ensure that finance is targeted in key, high impact areas. Financial incentives should attract investment in high-impact industrial sectors, driving economic growth and decarbonisation. Cross-financing (public and private sector together) green venture capital funds is effective in leveraging impact.

Policymakers can and need to take a role in coordinating different elements of the transition as part of wider public policy decision making. Net zero actions, such as industrial decarbonisation, and their implications for the wider economy must be assessed and planned for, both individually and alongside each other as part of an integrated approach to public policy making and economic decision making.

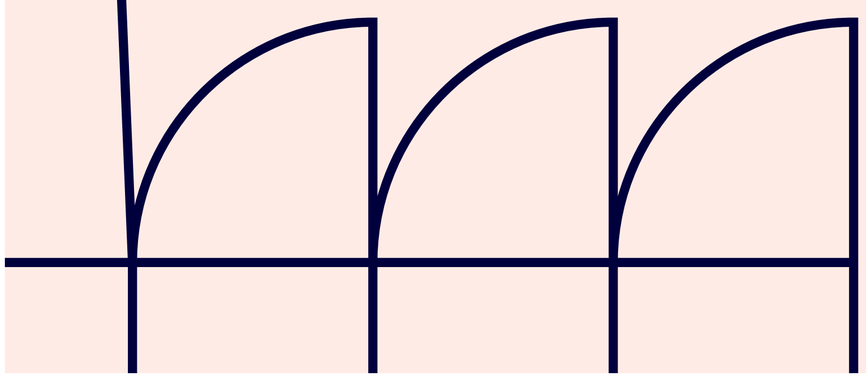
Policymakers must establish clear, consistent regulations that align decarbonisation goals with economic development. We recommend that a specific taxonomy is published and adopted as soon as possible in the UK, or that an EU-wide taxonomy is adopted with urgency to foster innovation in high-risk sectors and support regional clusters needing transition assistance.

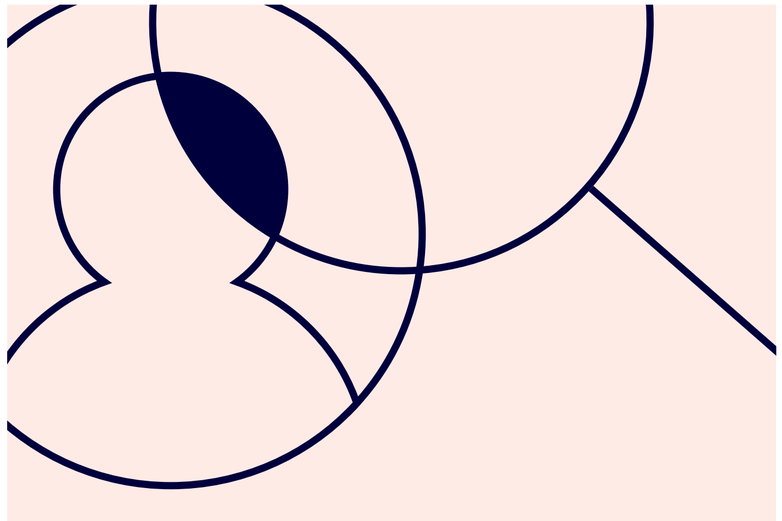
Recommendations to industry

Addressing persistent skills and worker shortages is essential to avoid constraints on industrial decarbonisation efforts and minimise wage-driven cost pressures that could affect all sectors. Proactive workforce planning and long-term strategies are needed to address workforce needs, including partnerships with universities, on-the-job training, and EDI initiatives, while aligning efforts with public frameworks like the Net Zero Workforce Action Plan to ensure a coordinated and adaptive approach to the green transition.

Industries should consider the timing of decarbonisation investments in relation to asset lifetimes and evaluate opportunities for strategic collaboration where it enhances competitiveness and efficiency, ensuring decarbonisation actions are both sustainable and commercially viable. Coordinated approaches, including collaboration across sectors and regions, are critical to ensuring a just transition and maintaining competitiveness in domestic and global markets.

The need for **understanding of the nature and timing of congestion and bottlenecks** if system-wide costs are to be minimised, potentially with intervention required to incentivise preferable timings of individual activities. Effective project sequencing and planning are essential to mitigate congestion and bottlenecks, minimise system-wide costs, and align decarbonisation efforts with broader net zero goals.





Recommendations for further research

Further research should enhance the integration of socio-economic analysis with decarbonisation strategies to evaluate regional economic impacts on employment, GVA, and supply chains.

Data gaps in regional economic dependencies should be filled, and better access to granular, region-specific economic data is crucial for improving the precision of impact assessments.

Further studies are needed to examine congestion effects and bottlenecks in industrial decarbonisation and across the net zero space. Dedicated research on developing a hydrogen sector and its economic implications is essential. This research can inform policies, which, in turn, enable more refined analyses, fostering a symbiotic relationship between research and policymaking.

1 National Grid. (2020) Building the net-zero energy workforce. National Grid.

2 Unsworth S et al. (2019) Decarbonisation of the UK economy and green finance: A submission to the UK's Treasury Committee by the Grantham Research Institute on Climate Change and the Environment. London: Grantham Research Institute on Climate Change and the Environment.

3 Corbett, H., Katris, A., Calvillo, C., & Gonzalez-Martinez, P. (2024). Policy Brief: Driving Effective Workforce Planning and Project Sequencing to Aid Efforts to Decarbonise UK Industry Clusters and Boost Associated Economy Wide Impacts. University of Strathclyde.

4 Committee on Climate Change (CCC). (2019) Net Zero: The UK's contribution to stopping global warming. Climate Change Committee.

5 McCann, P. (2019) "Perceptions of regional inequality and the geography of discontent: insights from the UK". Regional Studies, 54(2), 256–267.

6 Zhang, Y., Xu, T. & Wu, S. (2024) 'The promoting effect of green bonds on reducing carbon emission intensity through energy structure transition'. Sustainability. 16(21):9318.

7 Brey, B. & Rueda, V. (2024) 'The persistent human costs of deindustrialisation: Lessons from the collapse of the British coal industry'. VoxEU.

8 Katris, A., Zanhouo, A. K., Agyeman, S. D., Calvillo, C., & Corbett, H. (2024). Exploring the Impacts of the Adopted Carbon Capture Approach to the Scottish Chemical Industry and the Wider Scottish Economy. University of Strathclyde.

Section 2

Green bonds

Two IDRIC projects contributed to this section. They are referred to by their project IDs throughout.
→ See further information.

Project ID	Project name
MIP 3.3	Risks in decarbonisation finance
MIP 3.6	Opportunities in financing the green transition

Bonds are a debt instrument, issued by organisations or countries, with a redemption date and paying a specified rate of interest. Green bonds are designed to raise capital for projects with environmental benefits, such as renewable energy or sustainable infrastructure, although — as will be seen — definitions vary. They are the most widely used and well understood financial asset in the class of green financial assets and are playing a central role in financing the green transition.

Since their inception in 2007, green bonds have emerged as a vital financial instrument for channelling capital towards green projects. The introduction of the Green Bond Principles (GBP) in 2014 marked a turning point, offering internationally recognised standards that clarified issuance frameworks.[1]

These principles were further refined with the Climate Bond Standard (CBS), which set a taxonomy of eligible green projects and certification standards that has subsequently been used to inform an EU Taxonomy.2 Together, they fostered the rapid expansion of green bond markets, attracting governments, institutions, and investors, as shown in Figure 4 (a) and 4 (b) MIP 3.6.[3,6]

The 2015 Paris Agreement further amplified green bond issuance, with stock exchanges worldwide launching dedicated sections. Achieving the Agreement's targets demands enormous investment; the OECD predicts USD 6.9 trillion of annual investment through 2030 for global infrastructure, with an estimated EUR 179 billion annual shortfall in Europe alone.[4,5] Mobilising financial systems to attract climate-conscious investors and align financial flows with green objectives is crucial, and green bonds have the potential to serve as a key mechanism for achieving this.[3]

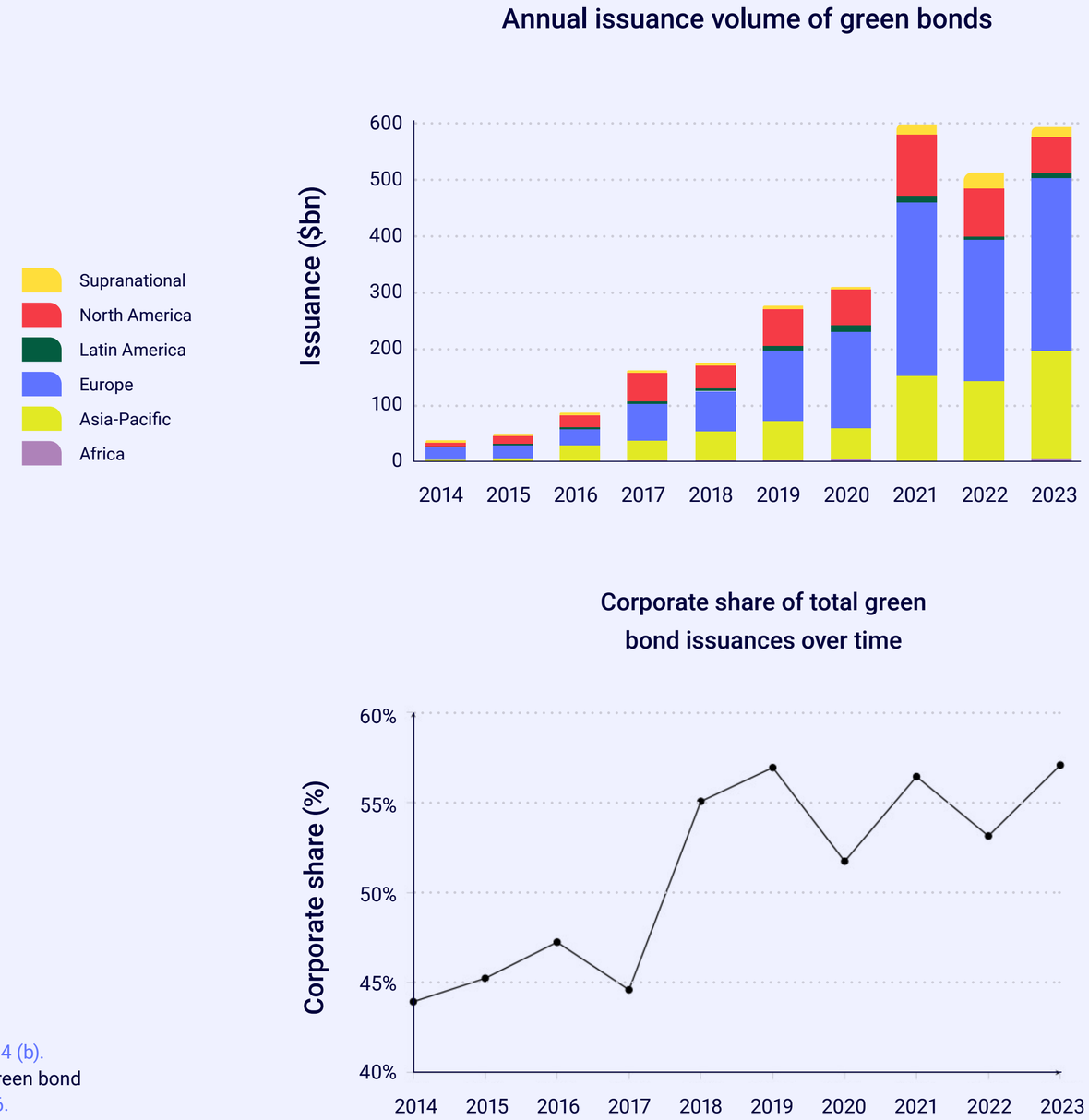


Figure 4 (a) and 4 (b). Growth of the green bond market.[6] MIP 3.6.

Green bonds (and green finance more generally) present the opportunity to promote decarbonisation by reshaping the structure of energy consumption, promoting the transition to low-carbon energy.[7,8,9] However, as it stands fragmented regulations, inconsistent validation standards, and ineffective taxonomies for use of proceeds—how the funds raised through the bonds are used—hinder the development of a cohesive global green bond market. This in turn contributes to instances of greenwashing and creates barriers to funding for authentic green projects MIP 3.3, MIP 3.6.

Inconsistent standards and fragmented regulations hinder the development of a cohesive green bond market.

Moreover, the prospect of a “greenium”—the premium investors pay for green bonds compared to traditional bonds—requires scrutiny. If a greenium exists, it will manifest as lower prices for coupons, allowing borrowers to access funds more cheaply. This should act as a strong incentive for companies to seek green funding for decarbonisation efforts. If the greenium is sustained, it could drive accelerated investment in clean energy projects, encouraging both companies and governments to prioritise sustainability initiatives. However, without careful oversight, the greenium raises concerns over the risk of an unstable green bond market or the development of a market bubble. To maximise its benefits, mechanisms must be put in place to ensure that the lower borrowing costs resulting from a greenium translate into tangible and effective decarbonisation outcomes.

The availability of green financial assets, the need for a consistent taxonomy for green bonds, and the pricing of risk for green financial assets, all of them important for financing industrial decarbonisation, will be reviewed in this section of the report.

While green bonds may not, as yet, have fully realised their potential in reshaping industrial decarbonisation, they are a critical tool in the transition to a low-carbon economy. Policymakers and industry stakeholders must work to address existing barriers, streamline taxonomies, and enhance the impact of this key financial instrument.

Research findings: Green standards and a green taxonomy

The literature on green finance consistently highlights the urgent need for harmonisation in green finance taxonomies; a unified framework defining sustainable and environmentally friendly economic activities which would offer transformative benefits for governments, businesses, investors, and society.

IDRIC projects MIP 3.3 and MIP 3.6 investigate green financial instruments and their associated risk. The study authors recommend that policymakers prioritise the introduction of consistent taxonomies and support, with regulation and the auditing of green instruments of finance. Both policymakers and industry embracing the use of a consistent taxonomy for identifying use of proceeds in green bond issuance will assist in regularising the market.

Research carried out beyond IDRIC backs up this point, stressing that a robust green taxonomy would serve as an essential tool for appraising instruments like green bonds, ensuring consistency and mitigating risks of 'greenwashing'—where use of funds do not align with genuine green classifications. Despite rising demand and a low rate of defaults in green finance, accusations of greenwashing have undermined market integrity, underscoring the need for regulation and consistent standards. As it stands, overly complex classification systems for use of proceeds, and a lack of international interoperability worsens vulnerability to greenwashing and prevents some genuine green projects from gaining the green label and thus accessing capital investment.

To date, around 20 jurisdictions have operational government-endorsed taxonomies—outlined in Figure 5—while the UK's Taxonomy is still under development.[10,11,12] Currently, the European Commission's EU Taxonomy, the taxonomy created by The International Capital Market Association, China's Green Bond Principles (China GBP), and the Climate Bonds Initiative (CBI)'s Climate Bonds Standard, lead as cornerstone systems of standards. However, collaboration between the UK and the EU, as well as with broader global frameworks, remains a critical but unresolved challenge. Initiatives such as the International Platform on Sustainable Finance's Common Ground Taxonomy demonstrate progress,[13] yet the absence of a universally agreed taxonomy persists.[3,14]

A well-designed green taxonomy must navigate diverse regional priorities and standards. Discrepancies, such as differing definitions of "corporate greenness" and varying environmental focuses, complicate the creation of interoperable taxonomies. Certification processes can be costly and time-consuming, imposing disproportionate burdens. To align with net zero targets, a dynamic taxonomy must be regularly updated to reflect scientific, technological, and policy advances and incorporate emerging financial instruments like green loans and equity.[3,10,14]

Such steps will enhance the UK's position in the global green finance transition, driving innovation and progress toward sustainable economic growth.

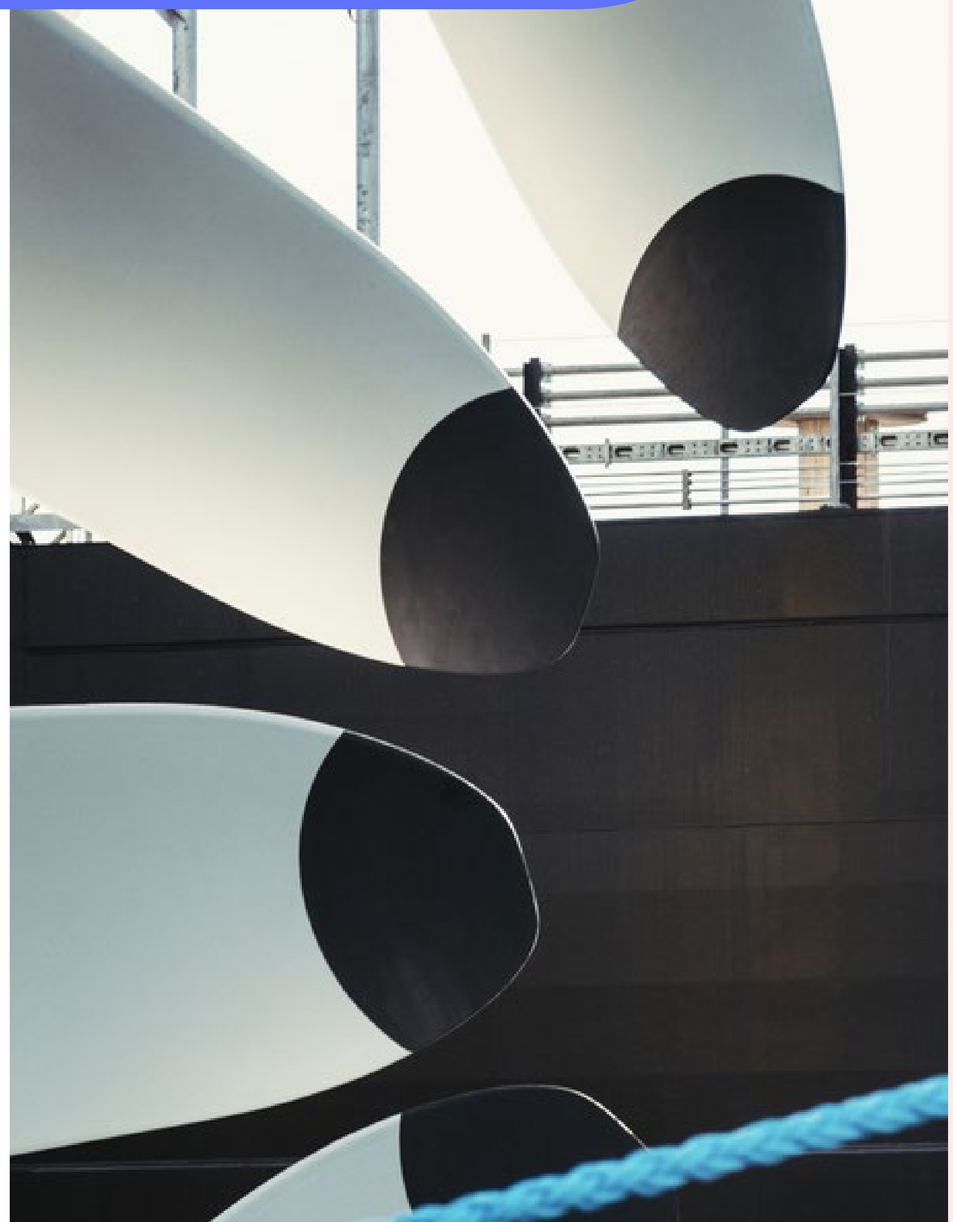
Figure 3

Table of jurisdictions with Green and Sustainable Taxonomies which are existing and under development.[10,11,12]

Research findings: Pricing risk

By 30 June 2024, Climate Bonds had recorded a cumulative issuance volume of USD 5.1 trillion in aligned green, social, sustainability, and sustainability-linked bonds (GSS+). This remarkable figure highlights the growing momentum of sustainable finance globally.15

Despite this progress, the characteristics of green bonds and the existence or non-existence of a 'green premium', or 'greenium', remain contested in the literature.[15,16,17] IDRIC projects MIP 3.3 and MIP 3.6 provide critical insights into the shape of the greenium curve that describes the lower yield or higher price that investors may be willing to accept for green bonds compared to traditional 'brown' bonds. The projects observe that the greenium appears to be contingent on specific bond characteristics including credit rating categories and use of proceeds. Projects MIP 3.3 and MIP 3.6 reveal that while demand for green finance is high, this is heavily reliant on clear certification of the green credentials of projects. The lack of such certification increases financial risk, demonstrating the critical role of signalling mechanisms in fostering investor confidence.



Where a greenium is observed, its existence may be attributed to several overlapping factors:

1. **Investor Preferences:** Some investors are willing to accept lower returns in exchange for the environmental and social benefits associated with green bonds. Studies suggest that non-economic factors, such as environmental preferences, are increasingly influential in bond pricing.[3] For some investors, this reflects a genuine mission-driven commitment to sustainability.

2. **Mandated Investment Strategies:** Many institutional investors, including pension funds and ESG-focused investment vehicles, have mandates requiring the inclusion of sustainable financial instruments in their portfolios, driving up demand and hence prices for green bonds.

3. **Material Benefits:** Green bonds are perceived to hold greater long-term resilience compared to their traditional counterparts. As global momentum towards a low-carbon economy accelerates, green bonds are seen as less susceptible to short-term market shocks, such as those caused by the COVID-19 pandemic or geopolitical crises like Russia's invasion of Ukraine. Further, green bonds may be used as a hedging strategy, serving as a precautionary measure for managing corporate environmental risks (e.g., ensuring alignment with new environmental regulations and standards that may be introduced). This was demonstrated in IDRIC projects MIP 3.3 and MIP 3.6 and supported by the literature.[3,6,14]

4. **Gratification and Signalling Effects:** Both investors and issuers may derive intangible benefits from participating in sustainable finance. Investors may pay a premium as a form of commitment to environmental goals, while both issuers and investors benefit from the reputational gains associated with sustainable projects.[14]

Despite the potential benefits, the green bond market is not without challenges. Green bonds are often used to fund innovative or less-established projects, such as renewable energy, sustainable agriculture, or emerging green technologies. These projects may carry higher risks of delays, cost overruns, or failure. Additionally, many green projects depend on substantial government support, leaving them vulnerable to shifts in policy. Such uncertainties are exacerbated by lingering scepticism towards new financial instruments, amplified by the 2008 financial crisis, and concerns over the potential for a green bond market bubble. This perception of risk can elevate the cost of green bonds for issuers, complicating their financial viability.

The challenge we face is to mitigate these risks and simultaneously increase investor confidence in green bonds to channel more capital into green projects and incentivise investment from both the demand and supply sides. To achieve this, the government, industry, and academia have roles to play.

The role of the government

The government can play a pivotal role, such as through loan guarantees and subsidies for green investments. By underwriting green loans for large, genuinely green projects, the government can boost investor confidence and embolden innovators in the green industry.

For example, the UK's support for the satellite industry, including its backing of an innovative company like OneWeb, and its active engagement in developing an effective market in orbital liability insurance. UK Space Agency demonstrated a commitment to emerging technology and positioned the UK as a leader in the nascent space sector.[18] Similarly, guarantees or partial guarantees for green loans could drive breakthroughs in renewable energy, sustainable infrastructure, and other cutting-edge green technologies.

Prioritising green projects that align with national and global climate goals will ensure investments target transformative industries, without which the UK is unlikely to reach our net zero goals. Left alone, actors in the financial markets are too risk-averse to effectively leverage capital into green market by use of financially innovative instruments.

The role of credit rating agencies

Notional demand for green finance is high, and while there does not appear to be a shortage of available finance, this is predicated on financial institutions receiving clear certification on the use of proceeds and the green credentials of companies and projects. Financial risk increases when these key signalling mechanisms are absent MIP 3.3, MIP 3.6. Credit rating agencies play a pivotal role in increasing investor confidence in green bonds by providing clear, reliable, and standardised assessments of both financial and environmental performance. Promoting transparency through detailed reporting on how proceeds are used and the environmental outcomes achieved ensures investors have access to reliable information, and make it easier for investors to compare green bonds across issuers and sectors

As green finance becomes a rapidly increasing share of global industrial finance (currently only 5% of the bond market), understanding green bonds and their associated risks is crucial, and research should be targeted in this area. As projects MIP 3.3 and MIP 3.6 highlight, ultimately, the green transition depends on the willingness of industries to take market risks and the ability of financial markets to underwrite those risks. To speed up industrial decarbonisation, the government must play an active and significant role in derisking green investments, while credit rating agencies must improve transparency in the green financial market, developing more robust methodologies for measuring and assessing the environmental impact of green investments.

Government guarantees for green loans could drive breakthroughs in renewable energy and green technologies

Research findings: The availability of green financial assets

The market for green financial assets is expanding at a rapid pace, as demonstrated in Figure 6 MIP 3.3. By mid-2024, cumulative issuance of green, social, sustainability, and sustainability-linked bonds (GSS+) had reached USD5.1 trillion, with green bonds alone accounting for USD3.2 trillion.[15] While demand for green finance is high, the availability of finance is contingent on financial institutions receiving clear certification regarding the use of proceeds and the green credentials of companies and projects. IDRIC projects highlight the urgent need to scale up green finance and better align investors with sustainable projects in order to leverage the full impact of these green financial instruments.

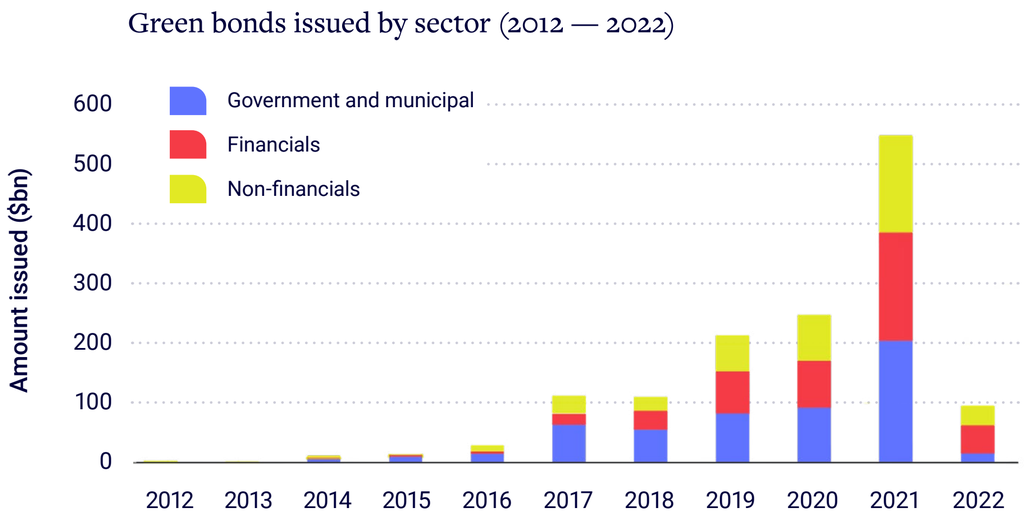
The mobilisation of private capital is essential to bridge the climate finance gap, which according to market commentators will need to increase to USD4–7 trillion annually by 2030 to stay within a 1.5°C pathway.[19] Barriers are particularly pronounced for smaller firms for whom the significant costs associated with transitioning—such as decarbonising supply chains or investing in renewable energy—are often prohibitive.[14] Government-backed green loans can help lower these barriers, making green finance more accessible to small and medium enterprises (SMEs) that may struggle to absorb the "greenium" or elevated risks tied to sustainable investments.

While green bonds dominate the market, there is a pressing need to expand research and understanding of emerging instruments like green equity—investments into the shares of companies that specifically prioritise environmental commitments—and green derivatives—swaps and futures linked specifically ESG factors. Projects MIP 3.3 and MIP 3.6 provide valuable insights into green bonds but call for further research to standardise taxonomies and ensure transparent use of proceeds. Such developments could reduce accusations of greenwashing and bolster investor confidence.[20,21]

The availability of green financial assets is also influenced by broader systemic factors. For instance, the UK's integration with EU markets means compliance with evolving ESG regulations will be crucial for accessing capital. Over 50,000 EU companies are now subject to enhanced ESG reporting standards according to the EU Corporate Sustainability Reporting Directive 2022/2464,[22] which significantly impact valuations and financial accessibility MIP 3.3, MIP 3.6. As these standards evolve globally, UK industry must adapt swiftly to maintain competitiveness and access to capital.

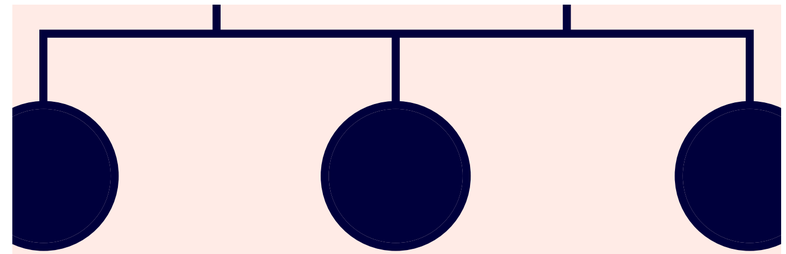
Figure 6

Issuance of green bonds by sector—Government & Municipal; Financials; and Non-financials—from 2012 to 22 March 2022 MIP 3.3.



The mobilisation of private capital is essential to bridge the climate finance gap and reach a 1.5°C pathway

Recommendations to policymakers, industry, and for further research



Recommendations to policymakers

Governments must establish clear, consistent standards for green activities, ensuring that green bonds and green financial products align with decarbonisation goals. An international, unified green taxonomy is crucial for reducing confusion and fostering investor confidence. A globally recognised framework for green finance would provide clarity on what qualifies as “green,” helping to mitigate greenwashing and ensuring more effective deployment of capital.

Policymakers should create mechanisms to de-risk and incentivise investments in green projects, such as underwriting loans for green technologies or offering guarantees to investors. These mechanisms would help drive capital into high-risk, high-impact decarbonisation sectors, and make green finance more accessible to small and medium enterprises.

Policymakers should promote the auditing of green financial assets to ensure transparency and accountability. This includes establishing robust auditing standards for green bonds, green loans, and other green finance instruments. Clear criteria and independent verification will help investors assess the environmental impact and financial integrity of green investments. Credit rating agencies have a significant role to play here.

Recommendations to industry

Industries must adhere to clear green taxonomies in any new green debt issuance. This will ensure that investors can trust the use of proceeds and that companies remain accountable to green finance standards. Publicly disclose the specific green frameworks or classification systems being used to enhance market transparency.

Given the complexities and risks associated with decarbonisation innovations, **industry must advocate for clear and consistent regulatory frameworks.** This will support scaling low-carbon solutions, mitigate financial risks, and reduce uncertainties around disruptive innovations and government interventions. Industries should state clearly which taxonomies or classification systems are being adopted in any new green debt issuance to ensure transparency and address cases where the use of proceeds from bonds do not appear to comply with a green classification.

Recommendations for further research

Research is needed to explore how the risks of green bonds and other green financial instruments differ from traditional assets. Understanding these risks will help in pricing green bonds more accurately, enabling more informed investment decisions and expanding green finance markets.

Further studies should explore innovative financial instruments, such as green venture capital, digital assets, or green securitization, to increase investment in sustainable projects. This includes investigating the role of social justice in green finance, to expand investment options and encourage sustainable green financial growth.

1 International Capital Market Association (ICMA). (2014) Green Bond Principles, 2014: Voluntary Process Guidelines for Issuing Green Bonds.

2 Climate Bonds Initiative (CBI). (2024c) Climate Bonds Standard. V 4.1.

3 Cortellini, G. & Panetta, IC. (2021) ‘Green bond: A systematic literature review for future research agendas’. Journal of Risk and Financial Management.14(12):589.

4 ECD. (2017) Investing in Climate, Investing in Growth. Paris: OECD Publishing.

5 uropean Commission. (2018) Putting the Financial Sector at the Service of the Climate. Brussels: European Commission.

6 Amel-Zadeh, A., Lustermans, R., Pieterse-Bloem, M., Dekker, D.J. & Christopoulos, D. (2024) ‘Are Green Bonds Special?’

7 Zhang, Y., Xu, T. & Wu, S. (2024) ‘The promoting effect of green bonds on reducing carbon emission intensity through energy structure transition’. Sustainability. 16(21):9318.

8 Tolliver, C., Keeley, A. R. & Managi, S. (2020) Policy targets behind green bonds for renewable energy: Do climate commitments matter? Technological Forecasting and Social Change. 157

9 Xu, T., Zhao, J. & Chen, T. (2024) The role of financial innovation in carbon intensity reduction: perspectives from energy structure transition and fiscal policies. Environ Sci Pollut Res 31, 38448–38464 (2024).

10 HM Treasury. (2024) UK Green Taxonomy Consultation.

11 Centre for Climate Engagement (2024) Summary report: Green Taxonomies – Global guidelines for the green transition?.

12 Natixis. (2023) The New Geography of Taxonomies: A Global Standard-setting Race.

13 International Platform on Sustainable Finance (IPSF). (2024) International Platform on Sustainable Finance Annual Report 2024.

14 Gilchrist, D., Yu, J. & Zhong, R. (2021) ‘The limits of green finance: A survey of literature in the context of green bonds and green loans’. Sustainability. 13(2):478.

15 Climate Bonds Initiative (CBI). (2024a) Sustainability Debt Market Summary H1 2024.

16 Larcker, D. & Watts, E. (2020) ‘Where’s the greenium?’ Journal of Accounting and Economics. 69: 2-3.

17 MacAskill, S. et al. (2021) ‘Is there a green premium in the green bond market? Systematic literature review revealing premium determinants’. Journal of cleaner production 280.

18 UK Space Agency. (2022) Government response: Call for evidence to inform orbital liability and insurance policy. HM Government.

19 Climate Bonds Initiative (CBI). (2024b) The Role of DFIs in Accelerating the Mobilisation of Green Capital.

20 Alsmadi, AA., Al-Okaily, M., Alrawashdeh, N., Al-Gasaymeh, A., Moh’d Al-hazimeh, A., Zakari, A. (2023) ‘A bibliometric analysis of green bonds and sustainable green energy: evidence from the last fifteen years (2007–2022)’. Sustainability. 15(7):5778.

21 Zhang, D., Zhang, Z. & Managi, S. (2019) ‘A bibliometric analysis on green finance: Current status, development, and future directions’. Finance Research Letters 29: 425-430.

22 EU Corporate Sustainability Reporting Directive (CSRD) 2022/2464. Official Journal of the European Union. pages 15–80 of OJ L 322

Section 3

The economics of innovation

Two IDRIC projects contributed to this section. They are referred to by their project IDs throughout.
→ See further information.

Project ID	Project name
MIP 5.5	The political economy of sunset versus sunrise industry strategies
MIP 9.3	Knowledge transfer & innovation diffusion

At the heart of the UK's innovation ecosystem is the "triple helix" model, where universities, private firms, and government form networks that disseminate knowledge and drive technological progress.

From power, to transport, to disposing of waste, high levels of innovation will be needed to meet net zero goals. While the opportunities are immense, so too are the challenges. Understanding the UK's innovation landscape is key to identifying where government support and strategic financial investment can drive progress, enabling industries and policymakers to overcome challenges and achieve net zero goals.

At the heart of the UK's innovation ecosystem is the "triple helix" model, where universities, private firms, and government form networks that disseminate knowledge and drive technological progress. The network diagrams shown in Figure 7 and Figure 8 reflect how UK universities, particularly those classified as research-intensive, play a central role in this system, contributing cutting-edge research and fostering industry-government partnerships. However, private firms dominate industrial decarbonisation research across the UK and Europe, as demonstrated in IDIRC project MIP 9.3.

Research findings: The economics of innovation

Figure 7 visualises the collaboration network of the Engineering and Physical Sciences Research Council (EPSRC) MIP 9.3.[1] Apart from the National Physical Laboratory, the most central universities are Russell Group members. The network exhibits significant degree centralisation, meaning collaboration is concentrated in a few key institutions rather than evenly distributed.

Figure 8 depicts the inter-organisational network of collaborative decarbonisation projects, where organisations are linked based on shared projects, with ties weighted by total project value.[2] Non-academic partners account for approximately 53% of collaborating organisations. However, a core-periphery structure remains, with UK universities at the centre, underscoring their pivotal role in the country's innovation landscape.

Knowledge diffusion across decarbonisation sectors, as demonstrated through patent citation analysis in MIP 9.3, shows a mixed picture. While some fields demonstrate steady progress, others face significant innovation bottlenecks. A key example is hydrogen distribution, where inadequate refuelling infrastructure and high transportation costs are delaying adoption, even as production technologies advance MIP 9.3.

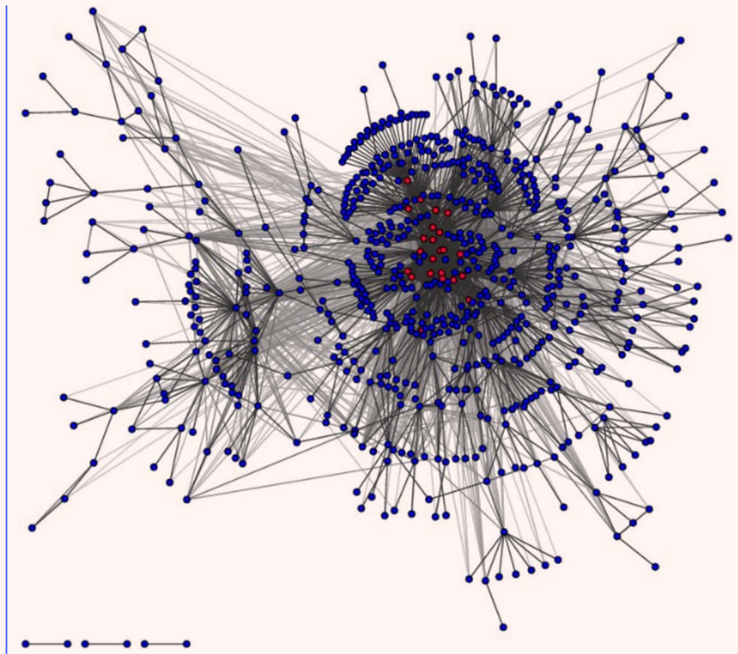


Figure 7

EPSRC collaboration network, where the red nodes represent members of the Russell group and the networks represent the backbone, the statistically significant collaborative ties, where isolated nodes have been removed from the visualisation and subsequent analysis.[1] MIP 9.3.

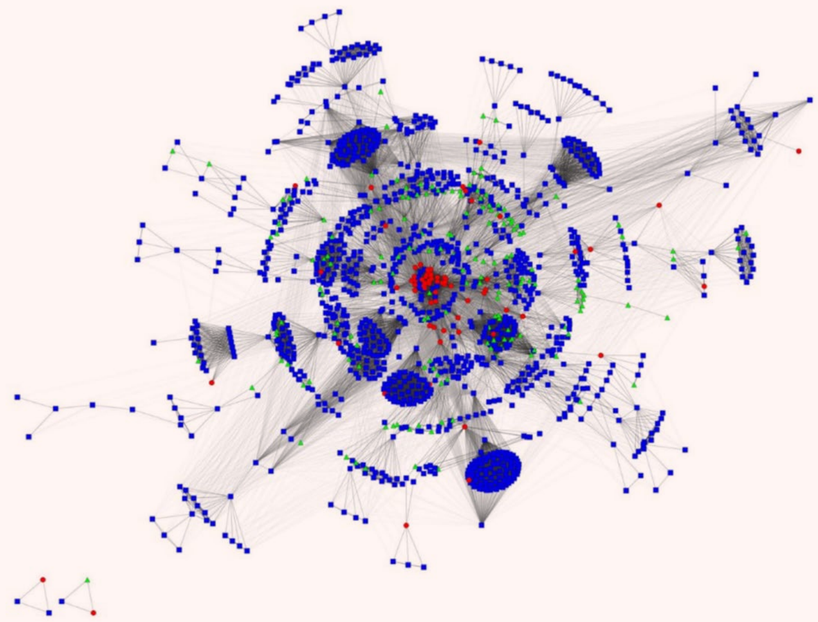


Figure 8

Inter-Organisational Collaboration Network (UK). Blue squares are non-academic organisations, green triangles are non-UK universities and red circles are UK universities. Organisations are linked if they have worked on the same project together, and the ties are weighted by the total value of the projects they have collaborated on together.[2] MIP 9.3.

The complexity of decarbonisation technologies strengthens the challenge to incentivising investment in environmental innovation. Innovations like hydrogen fuel systems and carbon capture demand sizeable infrastructural change and restructuring of distribution pipelines; disruptive technologies which can reshape markets but also pose risks for businesses and investors. For instance, the development of a new energy storage system could render existing battery systems obsolete faster than anticipated.

Given these risks, markets alone are unlikely to drive the bold investments required for the transition. High upfront costs, long payback periods, and the need for cross-sectoral coordination emphasize the critical role of government investment MIP 9.3. A whole-systems approach is essential to guide this process. By examining the interconnected elements of the economy, policymakers can identify the UK's key sectors and regions where innovation and investment will have the greatest impact.

Collaboration remains a cornerstone of successful innovation.

The role of government and industry in supporting innovation

Regulatory certainty is critical for mitigating market, enterprise, and financial risks associated with high-risk sectors, fostering an environment conducive to decarbonisation innovation and enabling businesses to innovate confidently. Policy interventions must be strategically targeted to address bottlenecks within the innovation landscape. For example, investments in hydrogen distribution infrastructure—a high-cost and low-attractiveness area for venture capital—are unlikely to materialise without substantial government funding MIP 9.3.

Corporate strategies play an equally vital role. IDRIC project MIP 5.5 showed that "sunrise" strategies, characterised by early and sustained investments in low-carbon technologies, training, and skills, enhance green technology credibility and provide stability to investors. Conversely, "sunset" strategies, which refer to the ways in which well-established, incumbent industries—often heavily linked to fossil-fuels—manage their decline as shifting market and socio-economic conditions reduce investment and demand, risk locking industries into carbon-intensive pathways, delaying transitions and exposing businesses to stranded assets.

In project MIP 5.5, the strategies that businesses may adopt when faced with changing landscapes and decarbonisation pressure are divided into three main shapes: defensive, exploratory, and offensive (Figure 10). IDRIC research supports that government policies should incentivise proactive corporate investments in green innovation to facilitate this transition, while ensuring a level playing field for all market participants.

Collaboration remains a cornerstone of successful innovation. Optimal partnerships between research institutions and corporations can accelerate the diffusion of green technologies. Additionally, leveraging complexity science and network analysis can help policymakers and industry leaders understand the socio-technical interconnections shaping the decarbonisation landscape. By aligning financial, industrial, and policy frameworks, the UK can drive the technological frontier of decarbonisation and achieve a sustainable, circular economy.

Recommendations to policymakers, industry, and for further research

1 Smith M, Sarabi Y, Christopoulos D. Understanding collaboration patterns on funded research projects: A network analysis. Network Science. 2023;11(1):143-173.

2 Smith, M., Christopoulos, D. Collaboration in Decarbonisation Research: Comparing the UK and European Funding Landscape. Int J Environ Res 18, 53 (2024).

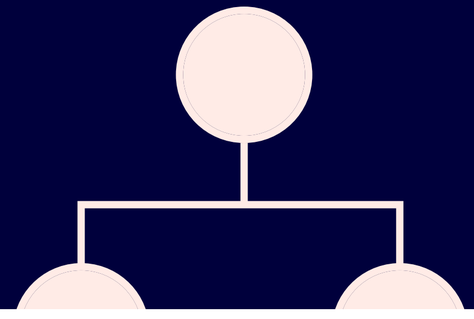
3 Dekker, D., Christopoulos, D., & McGregor, H. (2025). Dynamic Structures of Knowledge Production: Citation Rates in Hydrogen Technologies (Version 1).

4 Verrier, B., & Strachan, N. (2024). Sunset and sunrise business strategies shaping national energy transitions. Renewable and Sustainable Energy Reviews, 195, 114330.

Recommendations to policymakers

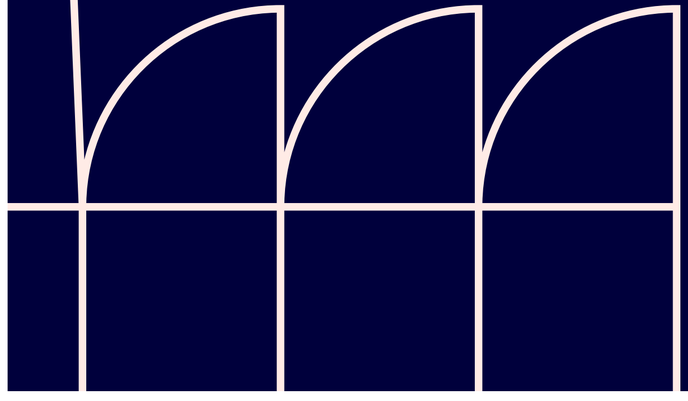
Policymakers should introduce incentives and targeted funding to drive technological innovation in decarbonisation, particularly in hydrogen, CCUS, and low-carbon manufacturing. Clear regulations and financial support can reduce investment risks, address high-cost bottlenecks, and encourage corporate engagement in green innovation.

Foster collaboration between research institutions, private companies, and government to create ecosystems that drive innovation, share knowledge, and improve efficiency in decarbonisation technologies.



Recommendations to industry

Industries should invest in cross-sector collaborations to accelerate decarbonisation innovation and reduce the risks associated with new technologies.



Recommendations for further research

Research should focus on how innovation patterns emerge in the decarbonisation space, examining successful collaborations between UK geographies and the role of policy in incentivising this.

Research analysing emerging frontiers of decarbonisation technologies, particularly those with high potential but high upfront costs, such as hydrogen and carbon capture technologies.

Moving forward

A whole-systems approach that integrates cross-sectoral coordination is essential to drive transformative change.

The UK's pathway to net zero requires a comprehensive approach that integrates economic policy, sector-specific strategies, and innovation-driven solutions. Industrial decarbonisation is not just a technological challenge but an economic and systemic one, requiring alignment across government, industry, and academia.

Economic levers such as carbon pricing, direct subsidies, and green finance play a pivotal role in incentivising businesses to transition to cleaner technologies. However, these financial mechanisms must be complemented by targeted government interventions to address high-cost barriers in sectors such as hydrogen and carbon capture. Without clear regulatory certainty, and a robust green taxonomy, the pace at which finance is channelled into key industrial sectors will likely fall short.

The challenges facing energy-intensive industries, from cement to steel, highlight the need for strategic investment in infrastructure, skills development, and market mechanisms that reduce financial risks. A whole-systems approach that integrates cross-sectoral coordination is essential to drive transformative change, and support the workforce and knock-on effects to the wider economy in the transition.

Innovation remains at the heart of the UK's decarbonisation strategy. The research underscores the importance of collaboration between universities, private firms, and government agencies in fostering knowledge diffusion and technological breakthroughs. Yet, structural barriers persist, particularly in emerging low-carbon technologies that require high initial investment. Policymakers must create an enabling environment that de-risks innovation, supports early-stage deployment, and ensures long-term stability for investors and businesses alike.

Ultimately, achieving net zero is not just about reducing emissions but also about ensuring economic resilience in a rapidly evolving global landscape. By aligning financial incentives, regulatory frameworks, and innovation ecosystems, the UK can lead the way in industrial decarbonisation, positioning itself as a global frontrunner in the green economy.

Contributing projects

IDRIC projects included in this report

IDRIC ran three complementary strands of projects:

1 In-depth research projects embedded within nine Multidisciplinary Integrated Programmes (MIPs), each programme tackling a key challenge or pathway for industrial decarbonisation;

2 Shorter-term Flexible Fund (FF) projects designed to rapidly address emerging or urgent opportunities identified directly by industrial clusters;

3 Impact Accelerator (IA) projects aimed at maximising the impact of existing IDRIC projects.

Projects discussed within the report are referred to by their project number.

◔ — Principal investigator

Project ID	Project name	Researchers	
MIP 1.7	An integrated framework for levelled up & low carbon industrial clusters	Niall Mac Dowell ◔, Nadine Moustafa, Mai Bui	Imperial College London
MIP 3.3	Risks in decarbonisation finance	Dimitris Christopoulos ◔, Heather McGregor ◔, David Dekker, Ragnar Gudmundarson, Chih Yueh Huang, Stefan Koeppl, George Tzougas	Heriot-Watt University
		Gareth Peters	UC Santa Barbara
		Marta Campi	Institut Pasteur
MIP 3.6	Opportunities in financing the green transition	Dimitris Christopoulos ◔, Heather McGregor, David Dekker, Ragnar Gudmundarson, Stefan Koeppl, George Tzougas	Heriot-Watt University
		Kostas Bisiotis	University of Athens
		Rik Lustermans	University of Amsterdam
		Despoina Makariou	University of St Galen
		Mary Pieterse Bloem	University of Rotterdam
		Andreas Tsanakas, Rui Zhu	City, University of London
		Amir Amel-Zadeh	University of Oxford
MIP 5.5	The political economy of sunset versus sunrise industry strategies	Neil Strachan ◔, Brunilde Verrier	University College London
MIP 7.6	Low-carbon reorientation in steel, oil refining and chemical industries	Frank Geels, Julian Gregory	University of Manchester
MIP 9.3	Knowledge transfer & innovation Diffusion	Dimitris Christopoulos, David Dekker, Yasaman Sarabi, Matthew Smith, Heather McGregor, George Tzougas	Heriot-Watt University
MIP 9.7	Labour market and other wider economy challenges in decarbonising the UK's industry clusters [LAB-CLUSTER]	Karen Turner, Christian Calvillo, Antonios Katris, Julia, Abdoul Karim Zanhouo, Hannah Corbett	University of Strathclyde
FF 2-1	The wider economy and competitiveness impacts of employing pre- and post-combustion carbon capture in UK industries (ECONCC)	Antonios Katris, Christian Calvillo Munoz, Abdoul Karim Zanhouo, Agyeman	University of Strathclyde

Project ID	Project Name	Outputs	
MIP 3.3	Risks in decarbonisation finance	Rethinking greenium	Journal
		Green bond premiums in segmented markets reveal market inefficiencies	Journal
MIP 3.6	Opportunities in financing the green transition	Are green bonds special?	Journal
		Corporate bonds trading more certainly realised at short notice	Journal
MIP 5.5	The political economy sunset versus sunrise industry strategies	Definition of sunset and sunrise industries: The interplay of industries and their strategies at different stages of their evolution	Briefing Paper
		"Sunset and sunrise": Offensive, exploratory, and defensive industry strategies in socio-technical energy transitions	Briefing Paper
		The political economy of sunset and sunrise corporate strategies: risks and opportunities for business and society	Briefing Paper
		Sunset and sunrise business strategies shaping national energy transitions	Journal
MIP 7.6	Low-carbon reorientation in steel, oil refining and chemical industries	Conflicts between economic and low-carbon reorientation processes	Journal
		Low-carbon reorientation in a declining industry?	Journal
		Explaining varying speeds of low-carbon reorientation in the United Kingdom's steel, petrochemical, and oil refining industries	Journal
		Policy brief - Low-carbon reorientation in steel, oil refining and petrochemical industries	Policy brief
MIP 9.3	Knowledge transfer & innovation diffusion	Understanding collaboration patterns on funded research projects	Journal
		GVC participation and carbon emissions	Journal
		Dynamic structures of knowledge production: Citation rates in hydrogen technologies	Journal
		Collaboration in decarbonisation research	Journal
MIP 9.7	Labour market and other wider economy challenges in decarbonising the UK's industry clusters [LAB-CLUSTER]	Industrial carbon capture utilisation and storage in the UK	Journal
		The importance of early employment and government revenue gains in governing the wider economy costs and benefits of deploying UK CCUS	Policy brief
		Understanding jobs demand and displacement outcomes of decarbonising UK industry clusters	Policy brief
		Assessing the role that a CO2 transport and storage sector could play in transitioning away from oil and gas extraction	Policy brief
		Driving effective workforce planning and project sequencing to aid efforts to decarbonise UK industry clusters and boost associated economy wide impacts	Policy brief
		Understanding and addressing labour supply constraints and their impact on efforts to decarbonise UK industry clusters and the wider economy	Report
FF 2.1	The wider economy and competitiveness impacts of employing pre- and post-combustion carbon capture in UK industries (ECONCC)	Cost and energy input requirement assessment of carbon capture and storage technology application in the Scottish Chemical industry	Policy brief
		Exploring the impacts of the adopted carbon capture approach to the Scottish chemical industry and the wider Scottish economy	Policy brief
		Providing certainty and acting with urgency – addressing skills and worker shortages for industrial decarbonisation	Policy brief
		The wider economy and competitiveness impacts of employing pre- and post-combustion carbon capture in UK industries	Webinar

IDRIC

Engineering and Physical Sciences Research Council

Green Industrial Futures Realised.

Published by
The UK Industrial Decarbonisation Research and Innovation Centre (IDRIC)

Find out more
idric.org

Frontiers Report series
idric.org/frontiers

This work was supported by the UK Industrial Research and Innovation Centre (IDRIC), through awards EP/V027050/1 under the UKRI ISCF Industrial Challenge/ Industrial Decarbonisation Challenge (IDC) and also EPSRC award EP/Z53125X/1.