Next Steps for Decarbonising UK Industry

IDRIC Policy Synthesis Report 2022

Anna Pultar and John Ferrier

December 2022

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IDRIC - Industrial Decarbonisation Research and Innovation Centre

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Foreword

Industry plays a vital role in society, contributing to 9% of the UK's GDP: from producing steel and cement, the building blocks of our cities, streets and bridges, to the chemicals, glass and ceramics products we use in our every-day-lives. Industry is also responsible for manufacturing the solutions we look to in fighting climate change, such as wind turbines and solar panels. And yet, industrial decarbonisation rarely features in the news.

Producing these vital materials and products can require vast amounts of energy and collectively industrial sectors contribute around 25% of global greenhouse gas emissions, and thereby, to climate change. While calls for emissions reduction have long focused on sectors such as power generation, transport and domestic heating, energy-intensive industries are very challenging to decarbonise and have so far received less support.

We must tackle this important source of greenhouse gases but do so in a way that avoids simply outsourcing industrial production to other countries, as these industries provide hundreds of thousands of jobs and make important contributions to regional and national economies.

The exciting news is that we have the tools to transform industry and make it an engine of green growth. Innovation is progressing fast and thanks to a huge joint effort by industry and academia, practical solutions for industrial decarbonisation are advancing across the UK. Progress is spurred by ambitious targets for emissions reductions by the UK and devolved governments and ground-breaking programmes such as the UKRI Industrial Decarbonisation Challenge (IDC).

The challenge is: how fast can we roll out and scale low-carbon solutions? Policy and regulation are critical by providing direction, kickstarting private investment and removing roadblocks, as well as ensuring green industries can make a wider positive contribution to our communities. However, the Climate Change Committee has recently warned that current policy measures across the UK are not sufficient to create the foundations for decarbonisation over the next two decades needed to achieve Net Zero by 2050.

When I became Champion for Industrial Decarbonisation and was tasked to develop IDRIC, funded as part of the IDC, I wanted it to become the go-to-centre for industrial decarbonisation: a centre that links up the best of our academic minds with the can-do attitude in our industry. And in doing so, we are also co-creating a shared understanding with policymakers across the UK about what we need to do to tackle industrial emissions quicker and more effectively. These joint endeavours are key to capture the social and economic opportunities of the transition of our industrial heartlands.

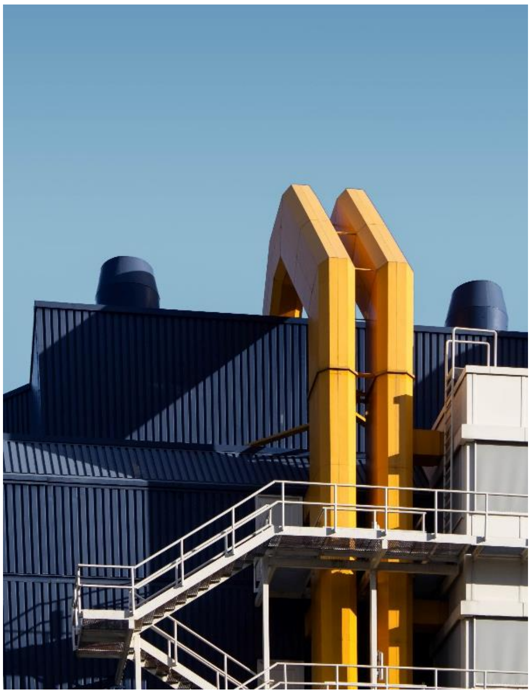
So we need to act now, and we need to act together. We have the expertise and practical knowledge in the UK to deliver industrial decarbonisation at pace and at scale. For the past year, IDRIC has brought together a large network of academic, industry, and government expertise to identify priority avenues for policy action. This report is the outcome of this dialogue and research by the IDRIC policy team and sets the framework for joint action for industrial decarbonisation in 2023.

Let's tackle this together and realise our green industrial futures!

Prof. Mercedes Maroto-Valer

IDRIC Champion and Director

1. Introduction and summary



Policy and regulation play an important role for accelerating industrial decarbonisation and enabling innovative solutions in sectors where emissions reductions have so far been difficult to realise. Effective policy and regulation can incentivise and support industry in taking advantage of innovative low carbon technologies and practices. It can reduce investment risk and build sustainable market arrangements and help to ensure a just transition to net zero – one that benefits local economies and communities. But policy can also be a barrier for innovation and change, for example when policy and regulatory frameworks are not aligned with requirements for the application of emerging low-carbon technologies and approaches.

Developing effective and integrated policy and regulatory frameworks to support industrial decarbonisation across a range of sectors and value chains is therefore crucial to support and accelerate industrial decarbonisation.

This report aims to aggregate the key priority areas where policy and regulatory change can make a difference in supporting industrial decarbonisation. Further to this, we present policy considerations which have emerged from extensive discussions with stakeholders in industry, academia and government, as well as targeted research by the IDRIC Policy Team.

This work is being conducted as part of IDRIC's mission to support the decarbonisation of the UK's largest industrial clusters. IDRIC[1], the UK Industrial Decarbonisation Research and Innovation Centre, was established in 2021 as part of the Industrial Decarbonisation Challenge, which supports the development of low-carbon technologies and infrastructure to enable the UK's largest industrial clusters in their mission to decarbonise at scale.

IDRIC provides a multidisciplinary research program to advance and support the scale up of key enabling low-carbon technologies, as well as to provide insights into the social, economic and policy aspects involved in the industrial transition.

As of December 2022, IDRIC manages an initial portfolio of over 40 research projects, involving academic experts from 23 UK universities and research centres, with a second wave of research projects due to start in early 2023. IDRIC also works closely with representatives from the UK's major industrial clusters and key industry sectors, ensuring that industry needs are at the core of the programme, whether it relates to early stage or applied research, pilot projects, demonstration or deployment. As such, IDRIC itself represents a unique combination of industry and academic expertise, able to provide a reliable evidence base for public policy.

IDRIC's biannual Industrial Decarbonisation Policy Forum, first held in March and October 2022, brought together a wealth of expertise from academia, industry, and policymakers to address cross-cutting policy challenges and identify gaps where further policy action and collaboration could accelerate progress in industrial decarbonisation. In particular, the Forum aimed to explore

[1] Further information on IDRIC's research portfolio can be found here: https://idric.org/research-programme/

how collaboration between government, academia and industry can support the development of effective policy and regulation in key areas of industrial decarbonisation. The IDRIC Policy Forum aims to act as a catalyst by providing a setting where key players involved in developing and implementing policies for industrial decarbonisation can come together. The forum seeks to reduce barriers to communication and collaboration, and thereby enabling faster and more efficient policy activities than if all participants were to work in isolation.

The Policy Synthesis Report 2022 takes stock of IDRIC's engagement with industry, academic and policy stakeholders on policy for industrial decarbonisation over the past year, collating insights from the IDRIC Policy Forum and several other relevant discussions and research throughout 2022. Annex 1 provides further details on the stakeholder engagement that underpins this report.

Seven priority areas are discussed in this report:

1. Business model support for scaling up low-carbon technologies
2. Enabling fuel switching and electrification
3. Supporting Infrastructure for transport and storage of energy and CO_2
4. Timely planning, consenting, and permitting processes
5. Comprehensive carbon accounting and standards
6. Resilient low-carbon supply chains
7. Net zero skills and workforce

The selection of priority areas focused on cross-cutting policy issues which affect industrial decarbonisation in a holistic, integrated approach, rather than one based on technological or sector-specific considerations. Following an initial ranking of priority areas with industrial cluster representatives, IDRIC's research co-directors and academic cluster leads in January 2022, the policy team subsequently developed these findings, drawing on stakeholder consultations, invitations for feedback and additional policy research. This report also benefited from the insights of several recent reports on industrial decarbonisation[2], as well as emerging findings from across IDRIC's research network.

It should be noted that many of the policy considerations presented here were voiced by a subset of industrial, academic or policy stakeholders, often those with specific expertise or involvement in an area, and therefore, may not always be representative of the entire sector. As far as possible, for all emerging findings feedback was sought from across IDRIC's stakeholder community, and supplemented with references to existing research evidence, where relevant. As such, this report aims to be both reflective of the diversity of perspectives in the industrial decarbonisation community, as well as to promote a degree of shared understanding of the key cross-sectorial priorities for industrial decarbonisation.

Our aim is to present the first installation of a living document, that both takes stock of learnings from 2022 and stimulates future discussion by bringing together key expertise from across the industrial decarbonisation community. In particular, we intend to develop practical tools to support policy development in specific policy areas for industrial decarbonisation through a program of subject-specific roundtables in 2023.

[2] This includes: Garvey and Taylor (2020) Industrial Decarbonisation Policies for a UK Net Zero Target, Element Energy (2020) Deep decarbonisation pathways for UK industry, Accenture (2021) Industrial clusters Working together to achieve net zero; Energy System Catapult (2022) Towards Industrial Decarbonisation

Structure of the Report

- Section 2 provides a brief overview of the opportunities and challenges or industrial decarbonisation, as well as the current policy landscape in the UK and devolved administrations.
- Section 3 of the report discusses the seven priority policy areas, takes stock of recent developments and outlines the key policy considerations identified through IDRIC's stakeholder engagement and research.
- The final section of this report discusses the role of collaboration between relevant government bodies, industry and academia in supporting the development of effective policy and regulation for industrial decarbonisation.

2. Industrial decarbonisation in the UK

2.1. UK climate targets and industrial decarbonisation

The UK has enshrined in law its commitment to reduce greenhouse gas emissions. The Climate Change Act 2008 initially required the UK to reduce greenhouse gas emissions by 80% relative to 1990 levels by 2050. Following advice from the Climate Change Committee in 2019[3], the target was raised to reducing greenhouse gas emissions by 100% relative to 1990 levels by 2050 ('Net Zero'). To reach this target, the government defined a pathway of legally-binding 'carbon budgets' which set legal restrictions on the total volume of greenhouse gases the UK can emit over five-year periods until 2050.

The increase in the UK's ambition from 80% emissions reduction to Net Zero emissions brought industrial decarbonisation into stark focus. Currently responsible for around 15% (78 $MtCO_2e$) of the UK's overall CO_2 emissions[4], energy intensive industries (steel, cement, chemicals, food and drink, paper and pulp, ceramics, glass, oil refineries and other manufacturing sectors) were previously considered, 'hard to abate' with their emissions continuing as part of the residual 20% previously 'allowed'.

To meet net zero by 2050, as well as the target of reducing emissions by 78% compared to 1990 levels by 2035 set out in the UK's 6th Carbon Budget, industry emissions must now reduce by more than two-thirds by 2035[5]. This has driven urgent exploration of how to enable deep decarbonisation across UK industry and the technological, behavioural, policy and regulatory changes needed to facilitate this transition.

Decarbonisation pathways for industry

Energy-intensive industry sectors contribute £180 billion to the UK economy, account for 8% of GDP and provide 2.5 million direct jobs[6], and over 5 million jobs across the wider value chain[7]. In decarbonising these sectors it is therefore not only essential to reach overall climate targets, but to ensure industry continues to make significant contributions to the UK's economy and employment through developing low-carbon job opportunities, as well as spearheading the development of low carbon solutions, which themselves will create new markets with potential to drive the decarbonisation of other sectors, such transport and heating.

To meet this ambition, a range of innovative approaches and technologies are being pursued to reduce industry's dependence on fossil fuels and help to cut greenhouse gas emissions arising from industrial processes. These include improving energy and resource efficiency, supporting the development of shared infrastructure, measures to electrify industrial processes where

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[3] CCC (2019) Net Zero: The UK's contribution to stopping global warming,
[4] BEIS (2021) Net Zero Strategy Charts and Tables,
[5] BEIS (2021), Net Zero Strategy, 2021,
[6] ONS, Annual Business Survey, 2021,
[7] UK in a Changing Europe (2020), Manufacturing and Brexit

possible and switching to other low-carbon fuels such as hydrogen. Capturing CO_2 emissions and either converting them into usable materials and fuels (carbon capture and utilisation, CCU) or storing CO_2 permanently underground (carbon capture and storage, CCS), will be especially important for tackling emissions which cannot easily be mitigated, such as unavoidable emissions from chemical processes necessary for steel or cement production. Emerging Greenhouse Gas Removal technologies, such as Bioenergy with Carbon Capture and Storage (BECCS) and Direct Air Capture (DAC), actively remove CO_2 from the atmosphere to offset residual emissions which cannot be directly captured.

The decarbonisation route most suitable in any given context depends on the characteristics and needs of particular industrial sectors and processes in different regions. As such, a portfolio of technologies will be required to help decarbonise UK industry as a whole[8].

Industrial clusters

About 50% of industrial emissions in the UK are produced by industrial sites which are co-located in discrete geographical areas or clusters. Industrial clusters, which often represent multiple industrial sectors and operations, are seen as attractive starting points for the deployment of decarbonisation solutions as they offer opportunities to aggregate energy and resource demand, enable sharing of low-carbon infrastructure in a cost-effective way, such as infrastructure for CCUS and hydrogen, and benefit from economies of scale and reduced risk[9].

Figure 1 maps key industrial centres in the UK, which form the basis of the main industry clusters:

- Scotland: This cluster includes industrial sites at Grangemouth and the southern coast of the Firth of Forth, along with those on the northeast coast of Scotland at St Fergus, Aberdeenshire. Key sectors include refining, chemicals and fertilisers.
- Teesside is a very compact cluster with 66 companies within a 5-mile radius. 90% of the cluster's industry is in chemicals and fertilisers.
- Humber: Spanning both banks of the Humber Estuary, this cluster is the biggest CO2 emitter in the UK, with 20% of the Humber region's economic value coming from energy-intensive industries, supporting over 360,000 jobs. Key sectors include iron & steel, refining and chemicals.
- The North West cluster region spans Cheshire, Lancashire, Merseyside and northeast Wales and includes the cities of Manchester and Liverpool. Key sectors include refining, chemicals, fertilisers, glass and cement.
- Black Country: This cluster is home to over 3,500 energy-intense manufacturing businesses, spread across Wolverhampton, Walsall, Sandwell and Dudley. Employing over 65,000 people, and formed mostly of SMEs.
- Solent: This cluster runs along 50 miles of the south coast of England, spanning Heathrow to Bournemouth, and including the Isle of Wight, with the main sector being refining.
- South Wales: covering a total area of 7,614 km^2, the South Wales industrial cluster runs from the Pembrokeshire coast to the Severn Bridge, responsible for over 100,000 jobs. The main industrial sectors include steel and metals, chemicals and petrochemicals, cement, paper and other general manufacturing.

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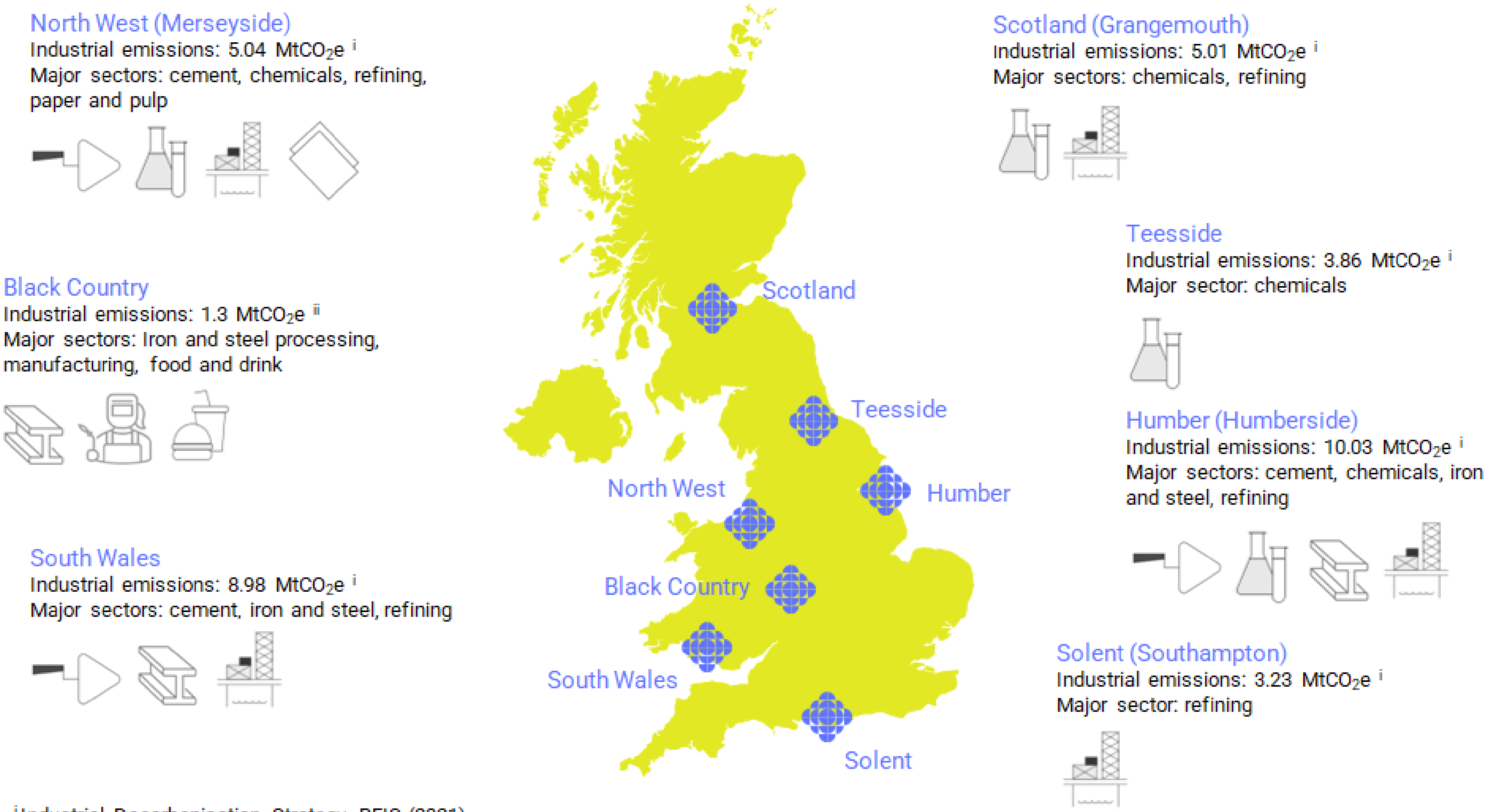
[8] For more information on decarbonisation routes for different sectors, see for example Element Energy (2020) Deep decarbonisation pathways for UK industry, and DECC/BIS (2015) Industrial Decarbonisation and Energy Efficiency Roadmaps to 2050, For international perspectives see also Bataille et al (2018).
[9] See also recent IDRIC research output, Sovacool et al. (2022): Industrial clusters for deep decarbonization, and Rattle & Taylor (2022) Decarbonising industry through industrial clusters

Figure 1.1 – Location, total industrial emissions and key industrial sectors of the largest UK industrial clusters



[i] Industrial Decarbonisation Strategy, BEIS (2021)
[ii] Black Country have stated their emissions as 1.3 $MtCO_2e$

The UK Government's Industrial Clusters Mission[10] focuses on accelerating decarbonisation at scale in the UK's largest industrial clusters with the ambition to develop four low-carbon industry clusters by 2030, and at least one net-zero cluster by 2040[11].

This ambition is supported by the Industrial Decarbonisation Challenge[12], led by UKRI, which funds three main activities:

- Cluster plans, in which set out a roadmap for each cluster for reducing cluster emissions to net-zero.
- Deployment projects, key enabling technology and infrastructure such as CCUS and hydrogen fuel switching which supports the delivery of significant emissions reductions across sites in an industrial cluster.
- IDRIC, the Industrial Decarbonisation Research and Innovation Centre, which supports cluster activities and wider industrial decarbonisation through multidisciplinary academic research and knowledge exchange.

Challenges for industrial decarbonisation

Given the scale of innovation and planned infrastructure deployment to realise the changes needed, industrial decarbonisation has a strong potential to increase productivity and create new jobs while safeguarding existing skilled jobs in these industries. However, accelerating progress in industrial decarbonisation faces numerous challenges.

- Many low-carbon technologies are only beginning to be deployed at a commercial scale, with almost 60% of global industrial emissions reductions by 2050 likely to come using technologies that are currently under development (prototype or demonstration scale), according to the IEA's global Net Zero 2050 scenario[13].
- Industrial assets also tend to be long-lived and capital-intensive, highlighting the need for strategic and timely decision-making. Barriers to investment due to policy and regulatory uncertainty can introduce years of delays, as decarbonisation projects must be redesigned, internal approval and external planning and consenting processes undertaken. Such delays not only threaten the achievement of the UK's statutory emissions reduction targets, but also of the first-mover opportunities in emerging international markets for hydrogen, CO_2-storage etc.
- The introduction of a carbon price, in addition to other policy-driven costs, can create risks of production moving to countries with less stringent emissions policies ('carbon leakage').
- There is also a risk that multinational companies divert low-carbon investment toward facilities in regions/countries where it is cheaper to decarbonise ('investment leakage').
- The current energy crisis has strengthened the economic case for industry to reduce its energy intensity and its dependency on fossil fuels. However, at the same time, the adverse financial environment created by a steep increase in prices puts a financial constraint on the availability of the necessary capital for investment in energy efficiency and/or low-carbon projects.

[10] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/803086/industrial-clusters-mission-infographic-2019.pdf

[11] see also UK Government (2018) Ten point plan for a green industrial revolution

[12] https://www.ukri.org/what-we-offer/browse-our-areas-of-investment-and-support/industrial-decarbonisation/

[13] IEA (2021) Net Zero by 2050 A Roadmap for the Global Energy Sector

Industrial sectors, and the businesses and processes they entail are diverse and embedded in specific geographical, social and economic circumstances, and therefore, require tailored approaches to decarbonisation. Dispersed sites, or industrial sites located away from industry clusters, face particular challenges as they cannot easily access emerging clustered low-carbon infrastructure, such as that for hydrogen and CCS.

2.2. The policy landscape of industrial decarbonisation

Supportive policy and regulation are crucial in helping to overcome technical, financial and social barriers to the adoption of new technologies and practices. Governments can support the scale up of low carbon technology and help develop emerging markets, e.g. by incentivising energy and resource efficiency through standards and mandatory emissions reductions. At the same time governments must ensure the costs and benefits of the transition are spread equitably across sectors and communities.

This section provides a brief overview of major policy initiatives by the UK and devolved governments.

UK Government

The UK Government's initial targets and policy framework for industrial decarbonisation were first laid out in the Industrial Decarbonisation Strategy in March 2021[14]. At the core of its net zero roadmap for UK industry, the strategy set out a process of 'CCUS cluster sequencing' to identify and sequence clusters most suitable for deploying CCUS with the aim of creating four low carbon clusters by 2030 and at least one net zero cluster by 2040.

Following a competitive application process in 2021 ('Track-1, Phase 1'), the government selected two clusters: HyNet, based in Northwest England, and the East Coast Cluster, linking both the Humber and Teesside clusters with CCS infrastructure. The Scottish Cluster was named as reserve cluster. Subject to successful negotiation, these two 'Track-1' clusters will receive government funding to spearhead the deployment of CCS transport and storage infrastructure in the mid-2020s, in particular from the £1bn CCS Infrastructure Fund. Subsequently, 20 projects were selected in August 2022 to connect to this infrastructure for deploying carbon capture for power, industrial use and waste applications as well as for low-carbon hydrogen production ('Track 1, Phase 2')[15]. Subject to successful negotiations, these projects will have access to the government's CCS and hydrogen business model support (further discussed in section 3.1. below). Further details on how additional clusters will be selected ('Track-2'), including the future of the Scottish 'reserve' cluster, are expected in 2023.

Alongside the cluster sequencing process, the Department for Business, Energy and Industrial Strategy (BEIS) have since set out further policy initiatives and increased targets, e.g. in the UK Hydrogen Strategy, the Net Zero Strategy and the Energy Security Strategy[16].

[14] BEIS (2021) Industrial Decarbonisation Strategy
[15] https://www.gov.uk/government/publications/cluster-sequencing-phase-2-eligible-projects-power-ccus-hydrogen-and-icc/cluster-sequencing-phase-2-shortlisted-projects-power-ccus-hydrogen-and-icc-august-2022
[16] BEIS (2021) UK Hydrogen Strategy, BEIS (2021) Net Zero Strategy, BEIS (2022) British Energy Security Strategy,

Current government targets for 2030 include:

- 6 $MtCO_2$/year of industrial CCS,
- 10GW of hydrogen production capacity, with at least half from electrolytic generation,
- 5 $MtCO_2$/year of engineered greenhouse gas removals.

To accelerate the maturation of these low-carbon technologies to commercial stage, a range of competitions is providing grant funding for innovation, energy efficiency and fuel switching projects within the 1bn Net Zero Innovation Portfolio[17] and for first deployment projects of infrastructure for hydrogen and CCUS across all industry clusters within the Industrial Decarbonisation Challenge Fund (discussed above).

To accelerate the scaling up of low carbon technologies and develop markets, the government intends to provide revenue support in form of 'business models' for carbon capture, hydrogen and greenhouse gas removal technologies, which have seen considerable development throughout 2022, (further discussed in section 3.1. and 3.3.) as well as the Net Zero Hydrogen Fund. The legislative basis for the associated commercial arrangements and other key measures for low-carbon technology deployment will be established by the Energy Bill[18] which was introduced to parliament in July 2022 and is expected to be passed in 2023. Furthermore, the independent Net zero review, commissioned by the BEIS Secretary of State in September 2022 and led by Chris Skidmore, has heard from stakeholders across the sector and is expected to publish its recommendations in early 2023, ahead of an expected update of the Net Zero Strategy by the end of March 2023.

Other significant policy developments in 2022 occurred in areas such as planning policy and carbon pricing, which will be discussed in the relevant sections below.

Devolved administrations

While key policy areas of relevance for industrial decarbonisation are mostly reserved to Westminster (e.g. economic and fiscal policy, energy supply policy, and other industry-related policy, including for business model support), other relevant policy areas are either fully or partially devolved, including for economic development, some aspects of energy policy, transport, waste, as well as the provision of education and skills. In addition, devolved governments have significant powers over environmental permitting as well as planning and consenting regulation for infrastructure, which are mostly devolved[19]. Annex 2 provides an overview of the areas of competency for each of the devolved legislatures of relevance to industrial decarbonisation.

In line with their variously devolved powers, the administrations in Scotland, Wales and Northern Ireland have developed their own initiatives for coordinating and supporting industrial decarbonisation and innovation. This report focuses on developments in Scotland and Wales only[20].

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[17] https://www.gov.uk/government/collections/net-zero-innovation-portfolio
[18] https://bills.parliament.uk/bills/3311
[19] with some exceptions, e.g. reserved power for planning of nationally significant infrastructure in Wales. See also: CCC (2019) Net Zero – The UK's contribution to stopping global warming
[20] Due to the relatively small share of industrial activity in Northern Ireland, the Industrial Clusters Mission and subsequently the Industrial Decarbonisation Challenge has not identified an industry cluster in

Scotland

The Climate Change (Emissions Reduction Targets) (Scotland) Act 2019 increased Scotland's emissions reduction targets to net zero by 2045 (from previously 80%) and revised interim and annual emissions reduction targets. The 2019 Act also reiterated the principles of a just transition as being at the core of Scotland's approach to reaching net zero and renewed the mandate of the Scottish Just Transition Commission. In response to the findings of the first Just Transition Commission, the Scottish Government laid out a National Just Transition Planning Framework[21] in September 2021. This includes a commitment to developing sectorial Just Transition Plans, the first of which will be an Energy Strategy and Just Transition Plan, which is expected to be published in January 2023. Further action announced in the 2022/23 Programme for Government[22] in September 2022 includes a Just Transition Plan for the Grangemouth Industrial Cluster, £20 million allocated through the North East and Moray Just Transition Fund, and the extension of the Green Jobs Workforce Academy.

The Scottish Government also set out a road map for developing the Scottish hydrogen economy with an ambition of reaching installed renewable and low-carbon hydrogen production capacity of 5GW by 2030. The recently finalised Hydrogen Action Plan[23] includes an Investment Proposition including £100m in funding for renewable hydrogen projects and £80m in support for accelerating CCUS and greenhouse gas removal technologies in the Scottish Cluster. The Scottish Government has also established the Grangemouth Future Industry Board to coordinate activity around decarbonisation in Scotland's main industrial region[24].

Wales

Following from the decision by the Welsh Senedd in 2021 to set a legally binding net zero target for Wales by 2050 (and a 63% reduction target by 2030), the Welsh Government set out its emissions reduction plan for its second carbon budget (2021-25)[25]. For industrial decarbonisation, the plan outlines measures for resource and energy efficiency, fuel switching, CCUS, and measures to support a hydrogen sector in Wales. This includes a proposed a pathway for hydrogen sector development in Wales, which has recently been submitted to consultation[26]. To further support the decarbonisation of Welsh Industry, Net Zero Industry Wales[27] has been established with Government support.

The Welsh Government identified Just Transition as a key priority area for addressing social and economic challenges of decarbonisation and has recently opened a consultation for developing a Just Transition Framework for Wales[28].

Northern Ireland. This report therefore does not discuss policy developments in Northern Ireland. However, IDRIC has engaged with representatives from the Northern Ireland Executive and aims to support knowledge exchange in innovation areas of relevance to Northern Ireland's decarbonisation plans.

21 https://www.gov.scot/publications/transition-fairer-greener-scotland/pages/5/

22 https://www.gov.scot/programme-for-government/

23 Scottish Government (2022) Hydrogen Action Plan.

24 https://www.gov.scot/groups/grangemouth-future-industry-board/

25 Welsh Government (2021) Net Zero Wales Carbon Budget 2 (2021 to 2025)

26 See also the Welsh Government's response to the consultation 'Hydrogen in Wales' in June 2022

27 https://gov.wales/net-zero-industry-wales-established-support-decarbonisation-welsh-industry

28 https://www.gov.wales/just-transition-net-zero-wales

The role of collaboration and dialogue in policy development

Governments hold key levers for helping to overcome the technical, financial, and commercial barriers for the adoption of new technologies and practices. Governments can provide a clear sense of direction, incentivise and de-risk investment in decarbonisation, and help to create markets for emerging low-carbon technologies and services. Moreover, governments play a key role in ensuring costs and benefits of the transition are distributed equitably across society.

However, despite ambitious targets and the development of sector strategies, the Climate Change Committee recently warned that planned policy across the UK is at risk of not delivering sufficient emissions reductions, with urgent policy action still needed to deliver key areas of policy such as hydrogen and CCS, and major policy gaps identified regarding electrification and energy and resource efficiency[29].

Collaboration and dialogue across stakeholders are crucial resources for supporting the development of effective and concerted policy action. Over the past few years, increased collaboration between industry and academia, within and between clusters, has created a strong shared ambition for reaching net zero and enabled mutual learning about the cross-cutting changes and tailored solutions needed to reach this goal. The drive to decarbonise industrial clusters has therefore opened an opportunity not only to spearhead the deployment of low carbon technology and shared infrastructure, but also to develop knowledge networks for the communication of best practice and shared learning between clusters and beyond.

In this spirit, IDRIC aims to foster dialogue and collaboration between government, industry, academia and other stakeholders to create a shared understanding around opportunities and trade-offs, practical solutions and thereby supporting the development of joint-up approaches across policy areas and organisations.

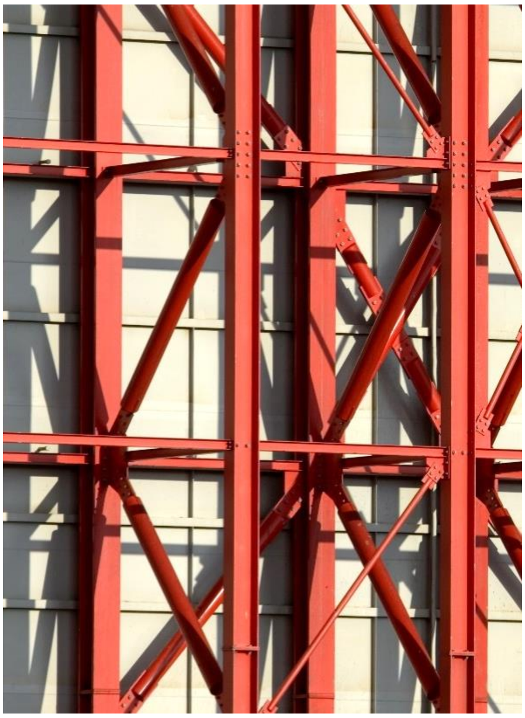
[29] Climate Change Committee (2022) Progress in Reducing Emissions and Progress in Reducing Emissions in Scotland

3. Priority areas for industrial decarbonisation policy

Building on IDRIC's stakeholder engagements and consultations throughout 2022 (for further details see Annex 1), we have collated insights from seven priority areas where policy and regulation can accelerate industrial decarbonisation and ensure the social and economic opportunities presented by the transition are realised. Rather than being exhaustive, this collation aims to take stock of discussions within the wider IDRIC network during 2022 and encourage further dialogue about practical steps for effective policy and regulatory action going forward.

3.1. Business model support for scaling up low-carbon technologies

Context and policy developments



Reducing industry's dependence on fossil fuels and tackling emissions from hard-to-electrify processes will rely to a considerable extent on the deployment of new technologies, such as hydrogen and CCUS, as well as greenhouse gas removal technologies. As well as support for innovation and capital investment in new production facilities, additional revenue support is seen as necessary to incentivise private investment and create markets in these areas.

BEIS is currently developing several business models to help reduce price and demand risk for producers of emerging technologies by providing temporary revenue support to help meet the cost of production or service provision during an initial period while markets are developing and innovation is reducing the costs of technologies.

Business models currently in development for carbon capture (for power, industrial use and waste applications), low-carbon hydrogen production and greenhouse gas removal technologies foresee contractual arrangements similar to the 'Contracts for Difference' (CfD) mechanisms which underpinned the scaling up of renewable energy generation since 2013. At their core, these business model schemes provide subsidies to producers equal to the difference between the 'strike price', informed by the cost of production, and a 'reference price', based on the producer's achieved sales price.

Additional business models are also being developed for the provision of transportation and storage infrastructure for carbon dioxide (as part of Track-1 Phase 1 of the CCUS Cluster Sequencing Process) and the transportation and storage of hydrogen, which will be discussed in section 3.3.

Industrial Carbon Capture

The *Industrial Carbon Capture (ICC) business model*[30] aims to support industrial emitters who have few viable alternatives to achieve deep decarbonisation. It comprises revenue support to

[30] BEIS (2022) Carbon Capture, Usage and Storage. Industrial Carbon Capture business models summary

cover operational costs of carbon capture, transport and storage fees and a rate of return, as well as a capital grant (for initial projects only). The business model will be funded by the *Industrial Decarbonisation and Hydrogen Revenue Support* (IDHRS) Scheme and the £1 billion *CCS Infrastructure Fund (CIF)*. In the long run, the viability of CCS as a service is expected to be sufficiently enabled by the UK ETS CO_2 price without the need for subsidy.

Initial projects receiving ICC business model support need to be able to connect to the transport and storage infrastructure in development in the Track-1 clusters. The first 20 projects have been selected in summer 2022 and are expected to be awarded contracts from mid-2023[31]. Key design aspects of the *ICC business model* as well as a generic ICC contract were published end of 2022[32] and will form the basis for these negotiations.

Hydrogen

Business models are also recently finalised for providing revenue support for hydrogen production, with the publication of the Heads of Terms for business model contracts in December 2022[33]. First allocation rounds are planned for 2023 and 2024, with initial funding coming from the *Industrial Decarbonisation and Hydrogen Revenue Support* (IDHRS) Scheme, which also funds the ICC business models. From 2025, all revenue support for hydrogen production is expected to be levy funded, subject to consultation and legislation being in place. Initial hydrogen production projects will receive capital grants from the *CCS Infrastructure Fund* and the *Net Zero Hydrogen Fund* (£240 million), with a recently finalised *Low Carbon Hydrogen Standard* setting a maximum threshold for the amount of greenhouse gas emissions allowed in the production process for hydrogen to be considered 'low carbon hydrogen'.

To be eligible for *Hydrogen Production Business Model* support, CCUS-enabled hydrogen projects need to be able to connect to the CCUS transport and infrastructure in Track-1 clusters. Four projects have recently been shortlisted and moved to due diligence phase[34]. For electrolytic hydrogen projects, a joint Hydrogen Business Model and Net Zero Hydrogen Fund allocation round was launched in July 2022.

Greenhouse Gas Removal (GGR)

BEIS has recently consulted on which contract mechanisms would provide most appropriate business model support for engineered greenhouse gas removals[35] to balance residual emissions from hard-to-abate sectors that are unlikely to achieve full decarbonisation. In the long-term it is expected that emitters will bear the costs for the removal of their remaining emissions via a carbon price set in the UK Emissions Trading Scheme (UK ETS) or a separate market for negative emissions. In the near-term, BEIS suggests providing business model support to bring early projects online from mid-to-late 2020s. Given the uncertainty regarding future costs and scale-up potential of individual technologies, the proposal foresees a technology-neutral scheme that supports a broad portfolio of engineered GGR (such as DACCS, BECCS, carbon-negative

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[31] https://www.gov.uk/government/publications/cluster-sequencing-phase-2-eligible-projects-power-ccus-hydrogen-and-icc/cluster-sequencing-phase-2-shortlisted-projects-power-ccus-hydrogen-and-icc-august-2022

[32] https://www.gov.uk/government/publications/carbon-capture-usage-and-storage-ccus-business-models

[33] BEIS (2022) Hydrogen strategy update to the market: December 2022

[34] https://www.gov.uk/government/publications/cluster-sequencing-phase-2-eligible-projects-power-ccus-hydrogen-and-icc/cluster-sequencing-phase-2-shortlisted-projects-power-ccus-hydrogen-and-icc-august-2022

[35] BEIS (2022) Business models for engineered greenhouse gas removals

concrete and seawater CO2 removals, among others, not however bio-char and enhanced weathering at this point). Alongside business model support, the Government aims to take steps develop a robust system for monitoring, reporting and verification (MRV) of negative emissions.

While legislative and regulatory powers to provide revenue support through business models and underwriting of liabilities are reserved to Westminster, devolved administrations can support innovation and capital expenditures for low carbon technologies. In Scotland, the £180 *Emerging Energy Technologies* Fund will provide £100m funding for renewable hydrogen projects in Scotland and £80m to support the development of CCUS and CCS-enabled negative emissions technologies[36].

Policy considerations

The following policy considerations have been identified in IDRIC's stakeholder discussions:

- To ensure timely investment in decarbonisation activities across all UK clusters, clarity of how and when the next clusters will be selected for CCUS deployment (Track-2 / reserve clusters) and thereby eligibility for business model support is needed.
- There is a general consensus that business models will be a crucial means by which government can provide long-term clarity and credibility to de-risk financial decision-making and planning. There has been concern regarding the delay in the development of the business models and a prompt finalisation of models has been highlighted as important to allow timely investment decisions. In cases where businesses may be reliant on multiple CCS business models in development, they are unable to make investment decisions until final details are published for every model. Clarity over timescales and detailed mechanisms involved is seen as vital for creating confidence and certainty for investors, producers, and large industrial users.
- Several stakeholders raised the need for different business models to be sufficiently integrated and coordinated, as industrial sites are often dependent on several business models. For example, linking ICC business models and Renewable Transport Fuel Obligation could stimulate cross-sectoral development of a UK hydrogen economy. Consideration should also be given to how business models can strengthen industrial symbiosis and circular economy practices.
- In designing the business models, careful consideration should be given to the longer-term financing mechanisms beyond initial projects and the distributive implications, e.g. of funding through levies compared to general taxation.
- Design of business models should involve careful weighing-up of costs and needs for different producers and users, industrial and domestic consumers, and seek the right balance against other policy instruments, e.g. UK ETS.
- It should be considered how UK business models and international financial support schemes can coordinate. For example, under California's Low Carbon Fuel Standard, revenue can be claimed for geological CO_2 storage in other countries, but the storage must be onshore.
- There was much support for including low carbon hydrogen production as feedstock (rather than just fuel) in hydrogen business models, as currently considered by BEIS[37],

[36] Scottish Government (2022) Hydrogen Action Plan.
[37] BEIS (2022) Government response to the consultation on a Low Carbon Hydrogen Business Model

which could help to overcome the current ‘chicken and egg’ dilemma by taking advantage of existing demand for hydrogen as a feedstock in the chemical and fertilizer industry.

- To enable future hydrogen export, the UK’s low-carbon hydrogen standard needs to align with emerging EU and other international standards.
- While long-term clarity and credibility are seen as essential for both economic and financial decision-making, policy mechanisms also need provisions for flexibility to ensure policies do not ‘lock-in’ undesirable pathways. These provisions should include clear principles and processes for assessing and dealing with change.
- A stronger coordination of financial support policies across the UK and devolved governments could help to identify any gaps or conflicts across the value chain, particularly with respect to hydrogen and CCUS, and help to address these gaps.

3.2. Enabling fuel switching and electrification

Context and policy developments

Addressing the affordability of electricity and low carbon fuels such as hydrogen and bioenergy is an important step in making the case to reduce the use of fossil fuels in industry. However, enabling industrial users to switch to these low carbon alternatives requires overcoming several other barriers such as developing technological solutions tailored to particular production processes, replacing or retrofitting existing equipment, and crucially, ensuring access to appropriate and affordable supply of alternative energy as well as certainty to enable planning and investment.

Hydrogen

Fuel switching to hydrogen is considered a promising and technically feasible option for many industrial processes, and particularly as a least-cost option for high-temperature processes that rely on gas combustion, which cannot be easily electrified. The Net Zero Strategy (2021) predicts hydrogen use of up to 50 TWh by 2035 will be required to meet the 6th Carbon Budget, meaning an exponential growth in the use of hydrogen as industrial fuel will be needed. However, reaching such growth targets faces significant barriers:

- The cost of hydrogen relative to alternative fossil fuels.
- Costs relating to the upgrade of equipment from natural gas to hydrogen.
- Access to sufficient supply of hydrogen in the quantity and quality needed.
- Regulation and permitting, e.g. regarding hydrogen-ready equipment as well as demonstrating safety in design and asset integrity in operations.[38]

Existing policy measures to support fuel switching include grant funding via various *Industrial Fuel Switching competitions* (£55m) and Phase 2 of the *Industrial Energy Transformation Fund* (£315m), as well as the *Scottish Industrial Energy Transformation Fund* (£34m). The UK Government's Hydrogen Strategy (2021) introduced further support for the demonstration of fuel switching to low carbon hydrogen on industrial sites during the 2020s, including through additional research & development (R&D) support within the *Net Zero Innovation Portfolio* (£1bn). The *Industrial Hydrogen Accelerator* (£26m) provided innovation funding to demonstrate end-to-end industrial fuel switching, and BEIS has recently consulted on hydrogen-ready industrial boiler equipment, including the possibility for mandating hydrogen-readiness for new boilers[39].

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[38] Energy Institute (2022), Review of Directives/Regulations relevant to the safe and environmentally compliant production, transportation, and storage of hydrogen

[39] https://www.gov.uk/government/consultations/enabling-or-requiring-hydrogen-ready-industrial-boiler-equipment-call-for-evidence

Electrification

For many sites, fuel switching will entail a choice between hydrogen and electrification. With electrification already a mature technology for many low temperature processes, powering industrial processes using electricity is, in principle, a realistic option for some industrial users. Earlier government modelling work indicated that, although to different degrees, all industry sectors have the potential to electrify at least parts of their operation[40]. The Net Zero Strategy (2021) expects electrification to have the potential to abate between 5 and 12 $MtCO_2e$ of industry emissions by 2050, which equates to an increase in electricity demand of 15-44 TWh.

Key challenges for electrification remain, including:

- Technical challenges associated with electrifying many high-temperature processes and the logistical and capital cost of replacing and retrofitting equipment to make use of electricity.
- The need to establish new and upgrade existing grid connections to support step-change increases in demand.
- Comparatively high costs of electricity for UK industrial users compared to other countries, including the high electricity prices relative to natural gas prices.

The wholesale price of electricity is currently determined by the last and most expensive unit of energy generated in the system, most commonly gas. Large increases in gas prices following the Russian invasion of Ukraine have therefore led to significant increases in wholesale electricity prices. The decoupling of electricity and national gas prices is currently under review in the Review of Electricity Market Arrangements (REMA)[41]. UK industry also pays comparatively higher prices for electricity due to the different way in which taxes and policy costs are added to wholesale prices[42].

Further to electricity prices, a key issue for industrial electrification will be the ability of electricity networks to support the increase in electricity demand as large-scale energy intensive industrial processes switch from gas to electricity. Such capacity issues will be amplified due to the simultaneous electrification of heat and transport. Expanding and strengthening the grid will be key, but will require considerable investment by network companies, who in turn face uncertainty over the scale, location and timing of future demand increases as well as the planning and consenting challenges for their investments.

Uncertainty, therefore, is a key challenge for all industrial fuel switching options. While many sites have a choice between hydrogen and electrification in principle, key factors are not just the cost but also the timing and availability of future supply. In addition to technology and cost questions, fuel switching involves important place-based considerations, i.e. specifically where hydrogen networks and/or electricity grid upgrades will be needed. For many sites, these challenges are interlinked, and are leading to a delay in investment decisions.

Policy considerations

The following policy considerations have been identified in IDRIC's stakeholder consultation:

- Policy can provide important clarity and continuity for enabling industrial users in making investment decisions about the most appropriate fuel switching option for their

[40] Department of Energy and Climate Change and the Department for Business, Innovation and Skills (2015) Industrial Decarbonisation & Energy Efficiency Roadmaps to 2050,

[41] https://www.gov.uk/government/consultations/review-of-electricity-market-arrangements

[42] Drummond et al/Aldersgate (2021) Delivering competitive industrial electricity prices in an era of transition

operations and managing the risk involved. In addition to the design of the business models, clarity is particularly needed regarding the longer-term design goals and funding for the development of the hydrogen economy and roadmaps for other decarbonisation pathways. Developing infrastructure plans in collaboration with industry and local actors (e.g. local authorities and enterprise agencies) could help to ensure that needs of industry users inform the development of the hydrogen economy and electricity networks.

- Having access to suitable technologies and infrastructure, in addition to support with capital and operational costs involved in fuel switching, were seen as key challenges. A degree of flexibility in funding mechanisms would be advantageous in supporting the integration of new technologies into existing industrial processes, which often require bespoke arrangements.
- While the current focus on developing the hydrogen economy has been widely welcomed, concerns have been raised that an effective funding mechanism for supporting electrification as a decarbonisation option for industrial processes is currently lacking. This echoes the CCC's recommendation to develop clearer mechanisms which support the early deployment of electrification[43]. IDRIC will convene a policy roundtable on electrification in early 2023 which will assess options for suitable financial support mechanisms.
- Changes in the economics of electricity use will be important to incentivise electrification of industry, but also to support the production of green and blue hydrogen as well as CCUS, which all rely on electricity.
- Increased support for electrification, including R&D, operational and capital costs, as well as investment in network infrastructure to improve capacity, could help it to compete on a level playing field with hydrogen, allowing industrial users to choose the most suitable fuel-switching pathway for their operations. Support for research and development into electrification technologies that are not yet commercial, including sector-specific solutions would be desirable.
- In tandem with fuel switching, resource and energy efficiency practices across the economy can make a significant contribution to emissions reduction, both at an industrial site/process level, as well as through a wider suite of interventions to support the development of a circular economy. The lack of equivalent policy focus given to energy efficiency relative to other decarbonisation pathways should be addressed.

Modelling of network developments and anticipating planning and investment lags is vital for governments and industry to increase understanding of fuel-switching options and priorities for policy and regulatory action. IDRIC is currently supporting several projects on fuel switching to hydrogen and other low carbon fuels[44], while cluster roadmaps, funded by the Industrial Decarbonisation Challenge Fund, have been aggregating information to better understand the potential for different fuel switching pathways within clusters and dispersed sites and are due to be published in early 2023. We will continue to bring this expertise together in upcoming IDRIC policy events.

[43] See also CCC (2022) Progress in Reducing Emissions
[44] In particular, research on designing and evaluating low carbon infrastructure for industrial clusters (IDRIC MIP 2.1.), designing low-carbon infrastructure for dispersed sites away from clusters (IDRIC MIP 2.3.), ammonia and hydrogen use for industrial use (IDRIC 5.1.) and integration of electrolysers in industrial clusters (IDRIC 7.2.)

3.3. Supporting Infrastructure for transport and storage of energy & CO_2

Context and policy developments

As discussed in the previous section, developing an effective system of supporting infrastructure in a timely manner is crucial for enabling businesses to make decisions about the most adequate decarbonisation route. This requires critical infrastructure to transport hydrogen and electricity to industrial users (transmission and distribution), as well as for transporting captured CO_2 from hard-to-abate processes to permanent storage sites. Storage infrastructure will also need to include temporary storage for CO_2 in port facilities before shipping to permanent storage, as well as temporary operational storage for hydrogen, close to industrial end users not connected to pipelines, in addition to larger temporary stores for hydrogen for energy system balancing purposes.

Putting this infrastructure in place involves addressing a range of technical issues relating to the repurposing of existing infrastructure, such as pipelines and ports and deploying new infrastructure. It also needs a systemic view that ensures that different transport and storage networks are integrated and effectively link up supply and demand, as well as considering wider economic and social aspects.

CCUS Transport and Storage

Core part of the CCUS Cluster Sequencing Process is the development of transport and storage (T&S) networks, with the initial aim to have these networks operational in Track 1 clusters in the mid-2020s. The current proposal for T&S business models[45] aims to provide revenue support pipeline transport and linking up the largest UK clusters with geological storage, mostly in sandstones and depleted oil and gas fields in the North Sea and Irish Sea. The conditions for accommodating dispersed sites and non-pipeline transport of CO_2 in the future are currently being assessed, with further updates expected in due course. Further support is provided by the CCS Infrastructure Fund. BEIS is currently working towards confirming a regulator and establishing a licensing regime.

Hydrogen Transport and Storage

While some industrial users will benefit from proximity to large hydrogen producers in the industrial clusters or be able to produce their own hydrogen (especially through onsite electrolysis), ensuring widespread industrial hydrogen availability will require the development of an appropriate system of transmission and distribution. Some of the required pipeline network can be repurposed from existing and decommissioned gas networks in the UK. However, more pipeline infrastructure as well as above-ground storage of hydrogen will be needed to connect industrial clusters with dispersed industrial sites.

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[45] BEIS (2022) Transport and storage business model: January 2022 update

In addition to powering industrial applications, it is anticipated that hydrogen can play a key role in accommodating seasonal variation in energy supply and demand. This will require storage of large quantities of hydrogen. Hydrogen could be stored in salt caverns, which are a well-established gas storage option, but which are not available in sufficient quantity across the UK to accommodate anticipated hydrogen storage needs. The UK also has abundant additional offshore geological storage potential in porous rocks, disused gas and oil fields as well as saline aquifers. Hydrogen storage in these is still at a low technology readiness level, and more investment in research and innovation, as well pilot demonstration projects will be needed to mature the use of such facilities for hydrogen. Ongoing research supported by IDRIC[46] as well as the HyStorPor project[47], is advancing different options for above ground and subsurface hydrogen storage. Recently, Centrica has entered talks with the UK Government on plans to convert the *Rough* offshore gas storage site (a depleted gas field) to store hydrogen[48].

To support the development of a hydrogen transport and storage network in the UK, BEIS has recently published a consultation on hydrogen T&S business models[49] which closed end of November 2022. The proposed staged development foresees:

- For the mid-2020s: mainly small-scale pipeline transport for individual producers to pipe hydrogen to users co-located on the same or close industrial sites, as well as expanded trucking and small-scale storage to support large-scale CCUS-enabled production in at least one location, as well as electrolytic production (up to 2GW of total production capacity),
- By the late 2020s, larger within-cluster networks supported by both small and large-scale hydrogen storage, potentially some early off-cluster pipelines and storage development centred on electrolytic production in areas with constrained electricity grid capacity.
- From the mid-2030s onwards, regional and/or national scale networks, supported by systemic large-scale storage infrastructure and integrated with CCUS, gas and electricity networks. Operation at this stage will be regulated, but largely subsidy-free.

In the long-run, BEIS suggests a 'regulated asset base' business model would be most suitable to support this network in the long-term, similar to current natural gas network where owners and operators of a hydrogen pipeline are allowed to earn a regulated return on costs, which would be determined by a regulator. For the early stages of network development, BEIS invited views on various options for providing interim support in its recent consultation (including regulated returns, contractual payments, and direct government co-investment) and will publish its response to the consultation in Q2 2023, aiming to have the business models in place by 2025.

As discussed in a recently published BEIS-commissioned study on hydrogen T&S infrastructure needs up to 2035[50], several other key factors will need consideration for the development of a hydrogen network: the cost and viability of different options for transport (pipelines, trucking, shipping) and storage (offshore, onshore), the demand from and priority given to different sectors (industry, energy storage, transport, domestic heating), the particular commercial configurations

[46] For example, research on hydrogen storage in porous rocks (IDRIC MIP 3.2. and IDRIC MIP 7.4.)
[47] https://blogs.ed.ac.uk/hystorpor/
[48] https://www.centrica.com/media-centre/news/2022/centrica-and-equinor-sign-co-operation-agreement-for-east-yorkshire-hydrogen-hub/
[49] BEIS (2022) Hydrogen transport and storage infrastructure consultation
[50] Frazer Nash & Cornwall Insight (2022). Hydrogen Transportation and Storage Infrastructure - Assessment of Requirements up to 2035

for hydrogen production and use (centralised/decentralised) as well as the role of a system operator.

Electricity

Industrial decarbonisation will also require increased (renewable) electricity provision, both for the electrification of industrial sites where this is most appropriate decarbonisation option, but also to power green hydrogen production and CCUS operations. Planning and investment in network infrastructure for increasing grid capacity will be necessary (as discussed in section 3.2.).

Policy considerations

The following policy considerations have been raised during IDRIC's stakeholder engagement:

- More work is needed for creating a shared long-term vision for transport and storage infrastructure. An improved understanding of supply and demand scenarios which incorporate real-world project pipelines and timelines would be helpful to inform interventions and enable all industrial users to access the low carbon infrastructure needed to decarbonise. This should include assessment of where non-network solutions will be required (e.g. CO_2 shipping), identifying opportunities for repurposing or upgrading existing infrastructure, and ensuring storage provision is sufficient to accommodate step-changes in demand as new off-takers come online.
- Greater detail on how non-pipeline CO_2 transportation (shipping, road and rail) will be supported through CCS Transport & Storage business models would be beneficial for dispersed sites and clusters without access to geological storage. Additional regulation for non-pipeline transport will be required, including for the temporary onshore storage of CO_2 at marshalling yards for rail transport, at ports for transfer to ships, which might pose cross-boundary regulatory issues and the need to align specifications internationally. Any future CO_2 shipping market will likely be competitive, requiring a consistent national and international approach to standards and specifications, in line with International Maritime Organisation requirements[51].
- While the focus is currently on large offshore CO_2 storage, industry is starting to consider possibilities for onshore storage. While in principle allowed by legislation, relevant authorities (NSTA in England and Wales, Scottish Ministers in Scotland) would need to develop processes for considering onshore storage in practice. Particularly for dispersed clusters, CO_2 storage in small depleted inland hydrocarbon fields may be an option, which would however require change of use permissions and awareness of societal perceptions and potential resistance.
- Responsibility for investing in and operating network infrastructure lies in large part with regulated monopolies. Close coordination between these network operators, government and regulators is therefore important to develop appropriate legislative and regulatory frameworks. In addition, ensuring the support of a suitable economic regulator will enable network operators to make timely capital investments and fund operational costs associated with new and refitted network infrastructure for hydrogen and CO_2, as well as upgrades to electricity networks to accommodate increased capacity.
- The timely development of the hydrogen transport and storage business models is crucial in laying the foundations of the future hydrogen economy and its role in the

[51] Recommendations for the regulation of CO2 transport by ship are currently being developed by IDRIC funded research on CO2 transport from ports to pipelines (IDRIC MIP 2.2)

decarbonisation of industry, if possible bringing forward the publication of business models from the envisaged date of 2025.

- Following successful proof of concept, the timely development of new and diverse geological storage capacity for hydrogen will become necessary to accommodate the large quantities of hydrogen likely needed across a net zero economy. Permits for developing new salt caverns will likely be needed, in addition to considerable research effort for maturing geological storage technology in depleted oil and gas fields.
- There is potential for future logistical and economic conflicts for subsurface facilities (offshore and onshore), between windfarms, storage for nuclear material, geothermal energy, permanent CO_2 storage and temporary hydrogen storage as they compete for locations (and volume)[52]. Plans should be developed now to avoid potential conflicts of subsurface use with clear guidance and resolution mechanisms developed, such as a hierarchy of technology prioritisation within planning policy.
- To ensure interoperability of infrastructure and equipment, common hydrogen purity standards may be required.
- To support industrial electrification, anticipatory electricity network upgrades will be vital to meet future demand increases. Modelling the electrification potential for energy intensive industries and learning from previous experiences (e.g. the expansion of solar PV and more recently battery storage) could help to prepare transmission and distribution networks, planning and system governance for future waves of demand increase.

IDRIC's research portfolio contains several ongoing projects addressing the technical, economic and regulatory aspects of CO_2 and hydrogen transport and storage infrastructure[53] and we will share policy relevant findings as they become available.

[53] In particular, projects evaluating carbon dioxide storage in saline aquifers (IDRIC MIP 1.2.), non-pipeline CO_2 Transport (IDRIC MIP 2.2), Hydrogen transport and Storage (IDRIC MIP 3.2.), Optimisation of CO_2 Transport and storage networks (IDRIC MIP 6.3.), Development of a CO_2 Storage database (IDRIC MIP 6.4), Hydrogen storage in rocks (IDRIC MIP 7.4.)

3.4. Timely planning, consenting, and permitting processes

Context and policy initiatives

Planning, consenting, and permitting rules play an important role in assessing social and environmental implications associated with large-scale technology and infrastructure deployment. In many instances, however, the timescales involved in planning and consenting processes and securing necessary permits can be considerable. Complex planning applications, permitting rules not yet adapted for emerging low carbon technologies, as well as lack of awareness and training for new types of developments among often under-funded local authorities and other statutory consultees are major challenges that can delay and stifle important decarbonisation activities.

Recent policy initiatives have sought to streamline and speed up planning processes. The UK Government has launched repeated initiatives to streamline the planning system, going back to the Planning Act 2008, which introduced the designation of 'nationally significant infrastructure projects' (NSIPs) such as energy infrastructure, for which Developing Consent Orders (DCO) replaced the need to obtain several planning and non-planning consents. Several subsequent attempts have since been undertaken to reduce the still often lengthy planning processes for nationally significant infrastructure projects, most recently in the Levelling Up and Regeneration Bill introduced to parliament earlier this year (2022). The Growth Plan ('Mini-Budget') in September 2022, announced further plans to speed up consenting for major infrastructure projects, including CCUS and hydrogen projects, a revision of environmental assessment rules, and new Investment Zones which will be subject to further deregulation. No further developments have emerged since the change in UK Government in October 2022.

In Scotland, the current draft Fourth National Planning Framework (NPF4)[54], which will guide spatial development until 2045, the year of Scotland's Net Zero target, aims to accelerate the planning process for renewable energy generation and emerging low-carbon technologies. It aims to give priority status to hydrogen and CCUS projects in 'industrial green transition zones' which are classed as 'national development'. This intends to establish the needs-case of such developments, so that it is not necessary to consider the issue of need at later decision-making point (but without removing the requirement to gain appropriate public consents). Further consenting guidance on developing large-scale hydrogen production facilities is expected for 2023.

Similarly, planning policy in Wales has recently been updated to support the consenting and development of large-scale renewable and low carbon energy developments and the Government announced further legislation to unify the consenting of energy generation projects and provide a quicker and more proportionate consenting regime for devolved energy infrastructure[55].

[54] https://www.gov.scot/news/planning-for-net-zero/
[55] Welsh Government (2021) Net Zero Wales Carbon Budget 2 (2021 to 2025)

Securing public consent is a requirement for successful planning applications. Decarbonisation activities in clusters take place in localities with diverse communities, relationships and historic backgrounds, which can engender both support for, and opposition to planned developments. While renewable energy projects have frequently faced opposition from local residents, there are indications that industrial decarbonisation activities may find more public support where these are perceived as improving the environment around industrial sites and align positively with local identity and 'sense-of-place'[56]. However, social research funded by IDRIC[57] into the social and spatial aspects of technology deployment suggests that attention to local concerns, the political dynamics driving industrial decarbonisation projects, and the varying impacts of decarbonisation on different groups over time, are important considerations for successful public engagement and obtaining public support or 'social license to operate'[58].

Policy considerations

The following policy considerations have been identified in IDRIC's stakeholder consultation:

- Past experience suggests that delays in the deployment of low-carbon infrastructure are likely if the planning system for critical infrastructure is not optimised and unnecessary barriers in the process removed. A review of planning legislation, such as during the announced reworking of EU legislation, may provide an opportunity to explore how procedures could be streamlined while securing an effective balance between climate change mitigation and conservation goals in planning critical net zero infrastructure.
- An integrated planning framework which establishes the needs case for net zero infrastructure from the outset, thereby removing such requirements at subsequent stages, would be an important step to prevent significant delays to deployment. Such a framework should integrate all elements of a system, from production to end-user equipment as well as the supporting infrastructure, both onshore and offshore. Such a framework should also facilitate close collaboration across government departments and regulators, between UK and devolved governments and, crucially, with local authorities and planners, especially where infrastructure spans multiple jurisdictions (e.g. cables, pipelines). There are also other elements of planning guidance which have an impact on industry, such as flood mitigation measures, which need joined up thinking across the planning sector.
- Agreeing new national planning frameworks now is important as it will take time for this to filter down into local planning cycles and practices. Many low carbon technologies will be new to local authorities and planning officials, so it is also essential that governments provide support in training and capacity building to create a common understanding of the risks, challenges and opportunities among everyone involved in planning and consenting of low carbon equipment and infrastructure.
- A range of specific regulatory and permitting changes required for the roll out of low-carbon infrastructure have been highlighted by stakeholders. Examples include:
    - Above ground hydrogen storage, which may be needed to supply dispersed industrial sites, is likely to involve additional planning issues, especially for any

[56] Devine-Wright (2022), Decarbonisation of industrial clusters: A place-based research agenda
[57] Several IDRIC research projects are exploring the social and spatial dimension of decarbonisation to understand public responses to industrial decarbonisation (IDRIC MIP 1.5.) and conditions under which decarbonisation receives a social licence to operate (IDRIC MIP 6.5.), exploring lived experience and sense of place in industrial communities (IDRIC MIP 2.4.), as well as creating community-engaged frameworks for Just Transition (IDRIC MIP 3.4.).
[58] Gough & Mander (2022) CCS industrial clusters: Building a social license to operate

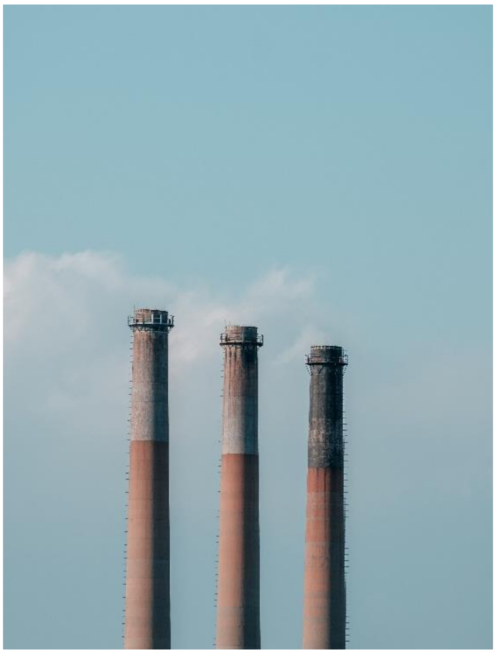
related pipeline developments across areas of outstanding beauty, National Parks, SSSI etc. with stricter planning regimes and potential public resistance.
   - Specific guidance and clarification on permitting will likely be needed for emerging activities such as onshore CO_2 storage (both temporary and permanent) and associated change of use policy of onshore depleted hydrocarbon fields, as well as the prioritisation of developing new salt cavern storage for hydrogen to speed up the permitting process.
   - Strong engagement between industry and regulators, such as the Health and Safety Executive, will be important for the development of operational guidance and best practice, especially on hydrogen. Furthermore, close engagement with environment agencies and statutory consultees is needed for developing environmental permitting rules and guidance, for example, on proprietary solvents for advanced capture technologies, among others.
- There was a widespread consensus that public support will be key for realising decarbonisation infrastructure projects and that public concerns over the costs involved, and issues such as secure containment of gases, need to be addressed. Adequate and credible information for local communities and the public, backed by trusted independent voices, was seen as essential. Academics have a role in providing independent assessment and evidence-based insight to support a variety of stakeholders involved in delivering, regulating and living with industrial decarbonisation measures.

To further discuss effective policy measures for addressing the challenges involved planning, consenting and permitting of low carbon technologies, the IDRIC Policy Team will organise a policy roundtable on this topic in Spring 2023.

3.5. Comprehensive carbon accounting and standards

Context and policy initiatives

Carbon Accounting



Appropriate methodologies for the monitoring and calculation of carbon emissions from companies or countries are vital for accurate assessment of decarbonisation activities and measurement of progress towards the UK's climate targets, as well as for the effective implementation of carbon pricing as driver of investment in decarbonisation.

Accurate carbon accounting is important for comparing the effectiveness of different pathways to decarbonisation and guiding decision-making. In addition to accounting for emissions from production, comprehensive carbon accounting should account for 'embedded' carbon - emissions generated across the supply chain and arising from consumption of products. The Climate Change Committee estimated that consumption-based emissions are around 70% higher than territorial-based emissions[59]. However, insufficient understanding of supply chain emissions associated with certain industrial processes, and a lack of accounting for consumption emissions, can promote decisions which reduce emissions in the UK, but results in industrial activity moving overseas, increasing global emissions (carbon leakage).

A lack of adequate methodologies and data to measure and monitor for carbon emissions is particularly visible at the cluster level, as existing methodologies are ill-equipped to account for multiple 'system-boundary' effects, including embedded emissions (or savings) that are imported into, or exported from a cluster. Revised accounting methodologies are needed to assess the potential for shared solutions across sectors and recognise industry's contribution to wider economic decarbonisation. Ongoing IDRIC research and work in several clusters is currently assessing options for improved monitoring and reporting of emissions, which can act as a driver for decarbonisation at the cluster level and for specific decarbonisation pathways, such as CCU [60].

Carbon Pricing

Sound carbon accounting methodologies are also fundamental for effective carbon pricing, which creates a financial incentive to reduce emissions associated with business decisions by putting a price on emissions. Since 2005, UK energy intensive industry and power generation have been covered by cap-and-trade emissions trading schemes, initially through the EU ETS, followed by the UK ETS which was launched by the UK Government and Devolved Administrations (collectively making up the UK ETS Authority) in January 2021. Cap-and-trade schemes incentivise investment in low carbon alternatives by limiting the total level of emissions allowed

[59] CCC (2019) Net Zero – The UK's contribution to stopping global warming

[60] Research in collaboration with the Black Country Cluster is exploring effective methodologies for carbon accounting (IDRIC MIP 3.2.), with similar efforts taking place in the South Wales Cluster (Energy Systems Catapult (2022) Carbon Accounting in Industry) and Teesside.

in the system, and dividing this total into allowances, which can be traded between participants. High emitting companies must purchase additional allowances to cover their emissions, while companies reducing their emissions may sell any unused allowances. To give industry time to decarbonise their operations and mitigate against the risk of carbon leakage, some companies receive a certain level of free allocation, which is then gradually decreased over time to maintain low carbon investment incentives.

Changes to the UK ETS announced in the Net Zero Strategy, which included an objective to align the cap on free allowances with a net zero consistent trajectory by 2024, have recently been submitted to consultation, with further development to be expected shortly[61].

To further prevent carbon leakage into countries with less stringent emissions restrictions, a Carbon Border Adjustment Mechanism (CBAM) is currently being discussed in the UK, following more advanced talks in the EU where initial terms for such a mechanism were agreed at the end of 2022[62]. In general terms, a CBAM applies a carbon tariff on certain imported carbon intensive products. The price of CBAM certificates is linked to domestic carbon prices, which in the UK is set by the price of emissions allowances under the UK ETS. The introduction of a CBAM has been recommended by the CCC[63] and the House of Commons Environmental Audit Committee[64]. In its response to the committee's report, the government announced to hold a consultation on a range of carbon mitigation options, not precluding the possibility of introducing a CBAM[65].

The UK ETS currently covers energy intensive industries[66], the power generation sector and aviation. For smaller manufacturing businesses outside the scope of the UK ETS, the Climate Change Levy, an environmental tax charged on the business' energy use, has been a key instrument for driving energy efficiency improvements and decarbonisation. In addition, the voluntary Climate Change Agreements scheme provides reduced Climate Change Levy rates for energy-intensive businesses which commit to meet energy efficiency targets. The measure has recently been extended until 2025.

As highlighted in a recent report by the Energy Systems Catapult for the South Wales Industrial Cluster[67], the combined administrative burden of monitoring, reporting and verification (MRV) requirements for the various compliance-based and voluntary emissions reduction schemes that industries are subject to can be substantial, particularly for SMEs with limited staff capacity. The report called for a simplified framework for industry that uses the UK ETS to cover all territorial point-sources of emission (with complementary measures to account for supply chain emissions), with oversight from a new Carbon MRV and Accounting Regulator and improved digitalisation of emissions data.

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[61] UK ETS Authority (2022) Developing the UK ETS: initial UK ETS Authority response covering proposals to be implemented by 2023,

[62] The EU CBAM will cover imports of iron and steel, cement, aluminium, fertilisers and electricity, as well as hydrogen, indirect emissions under certain conditions and some downstream products, for more info see https://www.euractiv.com/section/energy-environment/news/eu-seals-agreement-on-worlds-first-carbon-tariff/

[63] Climate Change Committee (2022) 2022 Progress Report to Parliament

[64] House of Commons Environmental Audit Committee (2022) Fifth Report - Greening imports: a UK carbon border approach

[65] Government Response to the Committee's Fifth Report of Session 2021–22

[66] The UK ETS applies to activities which result in greenhouse gas emissions, including combustion of fuels on a site where combustion units with a total rated thermal input exceeding 20MW are operated, see also https://www.gov.uk/government/publications/participating-in-the-uk-ets/participating-in-the-uk-ets

[67] Energy Systems Catapult (2022). Carbon Accounting in Industry

Policy considerations

The following policy considerations have been identified in IDRIC's stakeholder consultation:

- Comprehensive, standardised and accurate carbon accounting is needed to assess the origins and scale of emissions associated with industrial production and use, support informed decision-making regarding decarbonisation options, enable accurate monitoring and assessment of decarbonisation progress, as well as efficacy of policy options and incentives.
- Developing more timely, granular and reliable data is needed to support the assessment of upstream and downstream impacts associated with manufacturing and inform interventions. In addition to production emissions, consistent methodologies should consider the emissions impact of the whole supply chain. Approaches currently being developed and tested at the cluster level could inform the development of national methodologies.
- If engineered carbon removals are allowed to count against carbon budgets, as recently recommended by the CCC[68], developing accurate methods of carbon accounting will also be needed for biomass and corresponding land use to enable realistic assessment of the deployment potential and contribution of BECCS on a regional and UK basis[69].
- Setting effective carbon standards will be important, for example, the development of appropriate standards for the carbon associated with hydrogen inputs into industrial processes and greenhouse gas waste stream outputs (e.g. CO_2). Those standards should be consistent and integrated across the UK to support accurate accounting across boundaries (e.g. clusters, regions and over time) and across supply chains.
- Considering demand-side policies such as product labelling and working with local authorities to establish public procurement targets may provide additional tools to drive consumer demand and create a market for low carbon products.
- The timely development of a new UK ETS cap consistent with net zero targets is important to provide incentives for carbon reductions in line with the UK's net zero plans.
- A Carbon Border Adjustment Mechanism (CBAM) should be considered to support the development of domestic supply chains and markets, incentivise fuel switching to clean energy by managing international competition, and improve upon the free allocation system for managing carbon leakage from the UK ETS. International agreement on the standards used for a CBAM will be important, for example alignment between the UK ETS and the EU ETS are necessary to ensure UK industrial exports to the EU will not be adversely affected by the EU CBAM.

2023 will likely see increased attention to carbon accounting, the UK ETS and a possible CBAM. To facilitate discussion across stakeholders and explore the particular implications for industrial decarbonisation, the IDRIC Policy Team plans to organise a round table on carbon accounting and carbon pricing in the first half of 2023.

[68] CCC (2022) Progress in reducing emissions
[69] See also IDRIC research on life-cycle analysis (IDRIC MIP 1.3) and modelling the spatial implications of BECCS (IDRIC MIP 8.4.), see also Donnison et al (2021) Land-use change from food to energy,

3.6. Resilient low-carbon supply chains

Context and policy initiatives

To underpin a successful net zero transition, strong supply chains are needed to secure a manufacturing base and create jobs, benefit the local economy, and must be resilient to global economic and geopolitical disruption. It is also important not to miss the opportunity presented by technology transition to develop domestic manufacturing.

Common concerns among stakeholders include that current manufacturing capacity for machines, tools, wind turbine blades etc. might not be able to meet future demand created by decarbonisation ambitions across the sector. Furthermore, they highlighted that UK investment in research, development and demonstration facilities in key low carbon technologies may lag behind European research efforts. An underdeveloped UK supply chain may therefore hamper future progress in industrial decarbonisation and negate comparative advantages that the UK's net zero leadership may have created so far.

Targeted government support for developing domestic supply chains has historically needed to adhere to EU State Aid regulation. Similarly, 'local content requirements' in supply chains, e.g. required in recent offshore wind CfD auctions, have previously clashed with European procurement law[70]. While WTO rules still need to be adhered to, there may now be greater opportunities under the EU-UK Trade and Cooperation Agreement to incentivise the use of local supply chains.

Key to industrial decarbonisation efforts is also a secure supply of critical minerals, including rare earth elements, cobalt, lithium and nickel which are needed to manufacture and deploy low carbon technologies, including wind turbines, solar panels, electrolysers and batteries. These materials are termed "critical" due to their economic and strategic importance, supply chain vulnerability and a lack of adequate substitute materials for their key applications[71]. Geological reserves and production of critical minerals are geographically concentrated which introduces geopolitical risk – for example, China controls, directly or indirectly:

- 60% of global extraction capacity for rare earth elements,
- 50% of global lithium reserves,
- 40% of cobalt reserves in the Democratic Republic of the Congo[72].

In addition, the mining and production practices for many critical minerals are often poorly regulated, and are associated with environmental damage as well as human rights abuses[73].

[70] https://www.windpowermonthly.com/article/1751177/eu-takes-uk-offshore-wind-local-content-fight-wto
[71] Graedel, T. et al (2015). Criticality of metals and metalloids
[72] Green Alliance (2021). Critical point Securing the raw materials needed for the UK's green transition
[73] Parliament Office for Science and Technology (2022). Mining and the sustainability of metals

In 2022 the UK launched its first critical minerals strategy[74], which places an emphasis on maximising domestic production, accelerating a circular economy for critical minerals through innovation, signposting financial support, and regulation, as well as improving supply chain resilience through diversification, developing international partnerships and standards.

Policy considerations

The following policy considerations have been identified in IDRIC's stakeholder consultation:

- A strategic balance between taking advantage of global markets to import components while strengthening domestic manufacturing is needed to realise domestic supply chain opportunities whilst ensuring that a pipeline of key components of low-carbon technology remain available and economic.
- Circular economy frameworks and measures to improve energy efficiency are widely considered an important means of reducing dependence on primary supplies of critical minerals. Such measures include implementing producer responsibility rules and product design standards that incentivise the recycling and reuse of components, as well as investment in developing and scaling up technologies for the recovery and reprocessing of critical raw materials. In addition, supporting innovation that reduces reliance on globally scarce critical materials, for low carbon technologies is an important element of developing resilient supply chains.
- Following the UK's exit from the EU, limitations on state aid and local content requirements have softened, which may open additional opportunities to provide financial support for the development of domestic manufacturing and supply chains.
- Continued investment in innovation is important to ensure a strong pipeline of new and improved solutions as well as key components for low-carbon technologies, infrastructure and equipment. Sustained support is needed to enable collaborations between academia and industry for testing, piloting and demonstration of solutions. In parallel there is still a clear need to maintain the pipeline of fundamental and early-stage research.

[74]BEIS (2022). UK Critical Minerals Strategy

3.7. Net zero skills and workforce

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Context and policy initiatives

A cornerstone of industrial decarbonisation, both for ensuring that the benefits of this transition reach local communities and for practical supply chain considerations, is ensuring the availability of a skilled workforce to deliver decarbonisation projects and infrastructure. A shortage of the necessary skilled workforce will also hamper the development of domestic supply chains and discourage inward investment.

According to a recent study by the University of Chester and MACE, supported by IDRIC, the decarbonisation of the UK industrial clusters is estimated to require £515 billion of new infrastructure by 2050[75]. To support this, an estimated 350,000 workers will be required across all levels. Both technical and professional roles are required, with the split expected to be approximately 72% technical and 28% professional. While these demand estimates include many generalist skills in areas such as accounting, marketing, and administration, most skills will be required in design, engineering, manufacturing, and construction[76].

In a 2022 report for IDRIC by the Energy Institute and Catch, a large employment gap for the prospective hydrogen sector was highlighted, in particular they noted the need for a significant increase in the number of technicians and engineers to realise the delivery of key infrastructure. Although this will require new skills, predominantly relating to safety and data, it was found that the biggest challenge is the limited base of workers with pre-existing skills on the engineering and construction sectors, as well as competition from other sectors drawing on this base[77].

Multiple large decarbonisation projects are due to start construction in the next few years in the clusters with a serious risk of delays if skills shortages are not addressed. Emerging evidence from the Humber Cluster shows that industry stakeholders are already experiencing significant challenges staffing existing operations, retaining their current workforce, and recruiting experienced individuals. There is a particular shortage of workers with both technical skills (e.g. welders) and professional skills (e.g. process engineers).

The need for reskilling is taking place in a wider context of a shortfall of skilled capacity following the UK's exit from the European Union, which is also challenged further by national infrastructure projects that are competing for the same cohort of workers (e.g. HS2 rail and Hinkley Point). While there is potential to transfer skill sets from current oil and gas jobs, this sector will continue operation for the immediate future, therefore only part of the net zero workforce can come from such transition sectors.

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[75] Energy Institute & CATCH (2022). Hydrogen skills gap study landscape review
[76] University of Chester & Mace (2022). Enabling Skills for the Industrial Decarbonisation Supply Chain
[77] Energy Institute & CATCH (2022). Hydrogen skills gap study landscape review

Skills development and the availability of a trained workforce is also affected by the pace of progress in the other priority areas discussed throughout this report. For example, certainty around business models and regulation interacts with workforce considerations. Businesses need to be confident they can invest in a project before they can also invest in the skills required for its delivery. The development of other policy areas, such as carbon pricing, and relevant standards and permitting, will have direct implication on skills, as these policy areas need to be defined in order train prospective workers in their implementation.

With education and training policy being a devolved area, high-level Net Zero skills and workforce ambitions have been set out in policy statements at both a UK (England) and devolved Government level. The Ten Point Plan for a Green Industrial Revolution (2020)[78] set out the UK Government's approach to developing a Net Zero workforce, stating an initial ambition to realise 250,000 green jobs by 2030 and establishing the Green Jobs Taskforce to develop plans, provide advice and support the creation of green jobs. The Taskforce reported their recommendations to Government in July 2021[79]. The subsequent Net Zero Strategy included a reform of the skills system as a key policy focus, increased ambition to 480,000 green jobs across the UK, and announced the creation of the Green Jobs Delivery Group, a successor to the Taskforce. The Delivery Group met for the first time in Spring 2022[80]. Specifically regarding the energy transition, the North Sea Transition Deal includes a commitment to facilitate reskilling and skill transfer from within the oil and gas to the wider energy sector.

In Scotland, the Climate Emergency Skills Action Plan 2020-2025[81] set out national priority focus areas with the potential to make a significant contribution to the Net Zero Transition, these included energy transition, construction, transport, manufacturing, agriculture and land use management. In general, the action plan set out an intention to better understand future skills needs, drive awareness of the need to reskill and upskill, and develop the future workforce for these sectors. The Action Plan also includes a commitment to establishing a Green Jobs Skills Hub, with a remit to provide information on the number and type of green jobs that will be needed by 2045. The 2022 Programme for Government published in September 2022 committed to commission an independent review of the skills landscape in Scotland, and to develop a refreshed Climate Emergency Skills Action Plan by the end of 2023.

In Wales, Net Zero Industry Wales was established to support the decarbonisation of Welsh industry, with the creation and retention of high-skilled jobs as a short to medium term priority[82]. The Welsh Government have also committed to publishing a Wales Net Zero Skills Plan by the end of 2022.

Specific structures and initiatives exist and are emerging across the UK to address skills needs for Net Zero. In England, specific mechanisms include T-Levels, Higher Technical Qualifications, Skills bootcamps, and in the Lifelong Learning Entitlement from 2025[83] [84]. In Scotland, initiatives include the Green Jobs Workforce Academy, intended to provide information and tools for workers looking to transition to green careers. In addition, OPITO have been supported through

[78] UK Government (2018) Ten point plan for a green industrial revolution,
[79] https://www.gov.uk/government/groups/green-jobs-taskforce
[80] https://www.gov.uk/government/news/green-jobs-delivery-steps-up-a-gear
[81] Skills Development Scotland (2020). Climate Emergency Skills Action Plan.
[82] https://www.gov.wales/net-zero-industry-wales-established-support-decarbonisation-welsh-industry
[83] HM Treasury (2022). Autumn Statement 2022.
[84] Department for Education (2021). Skills for jobs: lifelong learning for opportunity and growth.

the Scottish Government's Just Transition Fund to deliver an Energy Skills Passport to facilitate skills transfer across the offshore energy industry[85].

To kickstart the discussion about specific mechanisms and the policy, legislative and regulatory frameworks needed to support skills development for industrial decarbonisation, IDRIC hosted a Skills Round Table in November 2022, where two major IDRIC research reports on skills and workforce needs for industrial decarbonisation were launched[86].

Policy considerations

Several policy considerations regarding skills have so far been identified in IDRIC's stakeholder consultation:

- Given the scale of the net zero transition needed and the narrow timescales associated, timely action is needed to unlock skills and supply chains now ahead of final investment decisions and to ensure net zero projects are built in time to deliver 2040 ambitions.
- While there is a clear opportunity to transfer skills and upskill from other sectors, like oil and gas, such skills transitions require planning and extensive dialogue among key stakeholders, e.g. with sector skills councils, training providers and employee representatives (e.g. trade unions). However, to enable workers to operate safely and effectively, there will be a need to update skills and knowledge to reflect the different environments, safety implications, scales and applications within the new economy.
- There is an urgent need to co-create and implement competency frameworks based on up-to-date skills needs assessments. Standardised competence assurance can help ensure the transferability of workforce around and between sectors. Ensuring timely and straightforward recognition of skills acquired is crucial to enable experienced workers to quickly meet the emerging needs of the industry.
- Effective coordination is also needed for the education and training provided by schools, colleges, vocational centres and universities alongside the industry- and sector specific training and accreditation.
- Specifically, regarding T-Levels, their development should prioritise the immediate pressures on the green economy, particularly where there are pressing targets, and should evolve to respond to new technologies as the transition unfolds.
- There is a need to increase the variety of potential routes for trainees and sector entrants, such as the schools' pipeline including STEM teaching and projects. Demand for data scientists has grown exponentially in the wider economy, as skill areas such as cybersecurity, machine learning and "big data" are evolving, therefore industry must find ways to attract them.
- There also needs be easy access to contextualised knowledge training (e.g. online, on the job, in partnership with local providers) allowing application of existing skills for those already working in the industry and who may neither qualify for, nor need, lengthy courses such as apprenticeships or T-levels, Higher Nationals, or degree courses. Similarly, apprenticeships should be linked with other types of provision, creating a modular approach that offers skills top-ups, which help to build upon their current qualifications, eliminating the need to undergo a brand-new qualification.
- Stakeholders have also highlighted a lack of an identified central coordinator in addressing industry skills shortages.
- For a comprehensive approach to tackling skills shortages, certain 'push factors' must be addressed. This includes the currently low appetite for industrial career paths among

[85] https://opito.com/media/news/opito-awarded-5-million-through-just-transition-fund-to-deliver-energy-skills-passport

[86] University of Chester & MACE (2022). Enabling Skills for the Industrial Decarbonisation Supply Chain and Energy Institute & CATCH (2022). Hydrogen skills gap study landscape review

many young people, particularly for non-academic routes, but also the drop-off in student numbers in key academic routes such as geology which will be vital for the development of hydrogen and CCS.

- Industry has a role in providing solutions to fill the skills gap, for example through the provision of in-house training programmes that can target specific industry requirements.

4. Supporting effective policy and regulation

As the discussions in the seven priority areas in this report evidence, there is considerable awareness of key barriers for industrial decarbonisation and a will to tackle these. However, with seven years left to reach key emissions reductions goals in 2030 and build the infrastructure foundation needed to achieve Net Zero in 2050, focused action is more important than ever.

How can governments enable and accelerate industrial decarbonisation?

Across the seven policy areas discussed in this report, a number of cross-cutting themes have emerged through which governments can make a key contribution for accelerating industrial decarbonisation:

- Providing clarity and sense of direction, thereby de-risking investment decisions and supporting new markets for emerging technologies and services. Examples discussed in this report include forward-looking financial support schemes for scaling up low carbon technologies and creating a level playing field for decarbonisation routes; strategic infrastructure planning for emerging/expanding CO2, hydrogen and electricity networks; and setting market signals through carbon pricing and demand-side policies.
- Removing specific roadblocks delaying decarbonisation activities in industry. Examples discussed in this report include supporting innovation and dissemination of learning and best practice to ensure a pipeline of solutions for decarbonisation; streamlining planning processes and updating of specific permitting rules and guidance; as well as alignment with European and international standards and regulation where appropriate.
- Coordination and leadership to facilitate joint-up approaches between multiple stakeholders involved in industrial decarbonisation. Examples discussed in this report include the role governments can make in coordinating and supporting the development of strong supply chains and timely investment in net zero skills and workforce, supporting the collaboration among stakeholders (e.g. between clusters through the Industrial Decarbonisation Challenge) as well as supporting public engagement.
- Ensuring a just transition. Distributing costs and benefits equitably across society and building of trust around decarbonisation activities (including through ensuring safety standards, monitoring regimes and certification schemes).

What are the challenges for developing effective and holistic policy and regulation?

In our conversations with policy makers across the UK, several challenges for supporting industrial decarbonisation were identified:

- Pace and uncertainty: industrial decarbonisation requires a portfolio of technological solutions which are still emerging and maturing, while timeframes for decision-making and investment are tight.
- Complexity: there is no silver bullet for achieving industrial decarbonisation, with action needed in multiple areas. These actions require decisions about the right sequencing and combination of interventions, the interdependencies between approaches, as well as careful consideration of the economic, social, behavioural and environmental dimensions of technological change, while dealing with considerable information constraints.
- Distributed responsibilities: policy needed for industrial decarbonisation spans across government departments (e.g. energy, business, planning, environment, skills), requires collaboration between reserved and devolved governments, and coordination with

regulators and local governments, in addition to an awareness of international policy, regulatory and market developments.

How can collaboration and dialogue support effective policy-making?

Collaboration between industry, academia and government can provide support for effective and holistic policy-making. Particular areas where collaboration and dialogue can make a difference have been identified in our conversations with stakeholders:

1. Creating a shared understanding around opportunities and trade-offs of decarbonisation, as well as the practical steps needed for going forward.
2. Providing specific insight and evidence around the technical and non-technical barriers and how to overcome them, the innovation and infrastructure needs, as well as interdependencies and sequences of measures needed. In particular, collaborative efforts can support:
    - Fore-sighting and modelling supply and demand scenarios with real-world project pipelines, working backwards from Net Zero (and beyond) to anticipate key transition points and roadblocks, to identify which actions are needed now.
    - Developing data and accounting frameworks, aggregating information from across clusters and dispersed sites to support decision-making and evaluate best practices.
3. Joint efforts for public engagement and developing trust and support for industrial decarbonisation among the wider public.

Next steps

Throughout 2023, the IDRIC policy team will continue bringing together key actors involved in informing, developing and implementing industrial decarbonisation policy and provide a space for discussion and opportunities for exploring potential collaboration and coordination between government, industry and academia.

The biannual Industrial Decarbonisation Policy Forum will provide a regular touchpoint for engagement on industrial decarbonisation policy, while our upcoming thematic policy roundtables aim to help develop practical tools to assist policymakers across the priority areas defined in this report.

Over the next year, emerging findings from across IDRIC's research portfolio will also contribute further insights on possibilities for scaling up low-carbon technologies, the social, economic and environmental aspects involved, as well as the particular policy and skills-related implications. We will continue to integrate policy-relevant findings into a growing knowledge base for industrial decarbonisation policy.

If you have any comments or feedback, or would like to discuss opportunities for collaboration, please contact the IDRIC Policy Team at policy@idric.org.

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Annex 1 – IDRIC Policy Stakeholder Engagement

The priority areas and policy considerations in this report have been informed by a series of stakeholder engagements with academic partners, industry and cluster representatives and policymakers, in particular:

- Policy and Prioritisation Workshop, January 2022
- First IDRIC Industrial Decarbonisation Policy Forum, March 2022
- IDRIC Partner and Stakeholder Consultation, May 2022
- Feedback round for Draft Policy Synthesis Report, September 2022
- Second IDRIC Industrial Decarbonisation Policy Forum, October 2022

An initial Policy Prioritisation workshop in January 2022 (online, 26 participants), aimed to identify and rank cross-cutting priority areas for industrial decarbonisation policy, collate emerging policy considerations as well as focus areas for further policy research and engagement by IDRIC. Participants included industry representatives involved in cluster roadmaps and deployment projects, the IDRIC Director and Research Co-Directors, as well as IDRIC Academic Cluster Leads.

At the first IDRIC Industrial Decarbonisation Policy Forum in March 2022 (online, 30 participants), we extended the discussion and invited civil servants from BEIS, the Scottish Government and the Welsh Government, as well as representatives from sector trade organisations, to identify ongoing and planned policy activities and opportunities for collaboration and support.

In May 2022, the IDRIC Partner and Stakeholder Consultation invited views from IDRIC partners and stakeholders in industry, academia and government on research needs to inform the design of IDRIC's wave 2 research call. Within this online survey, responses to the question Policy and Regulation highlighted not only research needs in this area but also needs for policy action, and thereby also fed into the discussion in this report.

In September 2022, we invited feedback from all IDRIC academic partners and cluster representatives on a draft of this report (see acknowledgement section).

A revised draft of the report was then presented at the second IDRIC Industrial Decarbonisation Policy Forum in October 2022 (London-hybrid, 30 participants). The Forum brought together academic and industry representatives, as well as representatives from the UK and Devolved Governments, other public bodies, trade associations and NGOs. The discussion focused on remaining gaps and opportunities for collaboration, which informed the final version of this report as well as our upcoming event programme for 2023.

Contributions

The following individuals and organisations participated in these workshop discussions and/or provided feedback informing the insights in this report:

IDRIC Director, Research Co-Directors and Academic Cluster Leads

- Mercedes Maroto-Valer, Heriot-Wat University
- Anna Korre, Imperial College London
- Marcelle McManus, University of Bath
- Benjamin Sovacool, University of Sussex
- Maxine Akhurst, British Geological Survey
- Lindsay-Marie Armstrong, University of Southampton
- Joseph Howe, University of Chester
- Jon Maddy, University of South Wales,

- Jonathan Radcliffe, University of Birmingham

IDRIC academic and research partners from Energy Institute, the University of Chester, the University of Leeds, the University of Manchester, the University of Southampton, and the University of Sussex, (see also Acknowledgement section).

Industry and Cluster organisations: Camirus Limited, Catch UK, CR Plus, Hull & East Yorkshire LEP, Humber Industrial Cluster Plan/BeaconTech, NECCUS, NEPIC, Net Zero Industry Wales, Peel NRE, Progressive Energy, Scottish Enterprise, SGN, Storegga, and Tees Valley Combined Authority.

Government and funding bodies: BEIS, Scottish Government, Welsh Government, UKRI/Industrial Decarbonisation Challenge, EPSRC

Trade bodies, public sector organisations and NGOs: Bellona, CCSA, Committee on Climate Change, ECITB, Energy-intensive Users Group, Hydrogen UK, National Infrastructure Commission, Scottish Carbon Capture and Storage, Scottish Hydrogen and Fuel Cell Association, UK Steel/Make UK.

In addition, numerous bilateral conversations with stakeholders across industry, academia and policy have added valuable insights which supported the development of this report.

While this report has been informed by extensive stakeholder feedback, the content does not necessarily represent the views of all individual members and partner organisations of IDRIC. The responsibility for the content of this report, including for any errors, lies with the editorial team.

Annex 2 – Reserved and devolved powers

Table 1 shows those areas of policy relevant to climate change mitigation which are in the powers of the devolved administrations as well as recent legislative changes that have had implications for the UK's devolution settlements.

1. Powers of the devolved administrations of direct relevance for industrial decarbonisation[87]

Key:
• Devolved/transferred
x Reserved
with potential for carbon reduction

Policy area	Devolved Nation		
	Scotland	Wales	Northern Ireland
Agriculture, fisheries, forestry and rural development			
Funding for the exercise by the Forestry Commissioners of their functions	•	•	•
Rural development	•	•	•
Agri-environment schemes	•	•	•
Economic and fiscal policy			
Fiscal, economic and monetary policy, including the issue and circulation of money, taxes and excise duties, government borrowing and lending, control over United Kingdom public expenditure, the exchange rate and the Bank of England	x •[a.]	x	x
Financial markets, including listing and public offers of securities and investments, transfer of securities and insider dealing	x	x	x
Economic development	•	•	•
Regeneration	•	•	•
Supporting low carbon innovation, through support and demonstration of new and emerging energy technologies for research	•	•	•
Energy			
Generation, transmission, distribution and supply of electricity	x	x	x
Security of energy supply	x	x	•
Renewables Obligation (regional)	•	x	•
Support to essential energy infrastructure	•	•	•
Oil and gas, including the ownership of, exploration for and exploitation of deposits of oil and natural gas, offshore installations and pipelines	x	x	x
Coal, including its ownership and exploitation, deep and opencast coal mining and coal mining subsidence	x	x	x
Nuclear energy and nuclear installations, including nuclear safety, security and safeguards, and liability for nuclear occurrences	x	x	x
Energy end-use			
Fuel poverty	•	•	•
Domestic energy efficiency support	•	•	•
Public sector energy efficiency	•	•	•
Promoting business energy efficiency	•	•	•
Trade and industry [b.]	•	•	•
Import and export control	x	x	x

[87] Adapted from Climate Change Committee (2015). Meeting Carbon Budgets - Progress in reducing the UK's emissions 2015 Report to Parliament, Technical Annex 7: Devolved Administrations

Product standards, safety and liability	x	x	x
Telecommunications and wireless telegraphy, including internet services	x	x	x
Designation of assisted areas	x	x	x
Protection of trading and economic interests	x	x	x
Inward investment	•	•	•
Promotion of trade, exports and tourism	•	•	•
Business advice and support	•	•	•
Research Councils	x	x	x
Training and skills	•	•	•
Transport			
Road transport	x	x	x
Highways and trunk roads (construction and maintenance)	•	•	•
Bus policy	•	•	•
Bus service provision (via local authorities)	•	•	•
Freight transport strategy	•	•	•
Freight transport grants	•	•	•
Rail transport, provision and regulation of railway services	•	x	•
Funding of rail services provided under franchise agreements	•	•	•
Improvement or development of railway services	•	x	•
Financing of core rail infrastructure	•	x	•
Financing of additional rail enhancements	•	•	•
Rail safety	x	x	•
Marine transport, including navigational rights and freedoms	x	x	x
Regulation and safety of shipping	x	x	x
Financial assistance in respect of shipping services carrying passengers between certain destinations and the region	•	•	•
Air transport	x	x	X
Regulation of air transport	x	x	x
Funding of route development	•	•	•
Cycling routes	•	•	•
Transport of radioactive material	x	x	x
Environment	•	•	•
Climate change policy	•	•	•
Waste policy	•	•	•
Water policy	•	•	•
Air quality	•	•	•
Pollution control	•	•	•
Marine pollution			
To 12 nautical mile limit	•	•	•
To 200 nautical mile limit	x	x	x
Pesticide control	•	•	•
Flood prevention and coastal protection	•	•	•
Marine, terrestrial and freshwater biodiversity	•	•	•
Countryside / nature conservation	•	•	•
Miscellaneous			
Sustainable development	•	•	•
Equal opportunities	x	x	x
Local government and housing			
Building standards	•	•	•
Appeals regarding building regulations	•	•	•
Building rating policies	•	•	•
Funding and management of local government	•	•	•
Housing policy	•	•	•
Renovation of low-grade housing	•	•	•

Planning / consents			
Planning policy	•	•	•
Local planning authority guidance	•	•	•
Planning disputes and appeals	•	•	•
Nationally significant infrastructure	•	x	•
Land use planning system	•	•	•
Planning applications from major electricity generators up to 50MW	•	•	•
Planning applications from major electricity generators over 50MW (including offshore up to 12 nautical mile limit)	•	x	•
Offshore wind and water energy developments over 1MW	•	x	•

United Kingdom Internal Market Act 2020 [88]

The United Kingdom Internal Market Act 2020 as introduced following the UK's exit from the European Union, intended to manage potential regulatory divergence and prevent emergence of trade barriers within the UK as a consequence of leaving the EU single market framework. While the Act does not change the power of devolved legislatures to regulate goods and services within their borders, it means that such regulation may not be enforceable on goods and services entering from other parts of the UK. This places practical limits on the ability of devolved governments to raise standards on certain goods and services, as they then risk being undercut by those imported from elsewhere in the UK. The Act established common framework agreements, through which the four governments intend to manage divergence.[89]

Note:
[a] Can vary the basic rate of income tax by 3p in the £.
[b] Some aspects of company regulation are devolved to Northern Ireland

[88] United Kingdom Internal Market Act 2020.
[89] Institute for Government (2021). The United Kingdom Internal Market Act 2020.

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