frontier economics

ACCELERATING THE DECARBONISATION OF INDUSTRIAL CLUSTERS AND DISPERSED SITES

A report on behalf of the Aldersgate Group

September 2021

CONTENTS

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SHORT SUMMARY FOR POLICYMAKERS

UK manufacturers are significant contributors to the wider economy and, **when correctly implemented, decarbonisation policy can support cost-effective emissions reductions while also helping manufacturers to take advantage of new market opportunities and enhance economic growth.** In particular, decarbonisation policy can support innovation, supply chain growth and job creation in regions across the UK and can enable manufacturers to better compete in markets for low carbon goods and adapt to rising carbon prices.

Through close engagement with businesses in five sectors, we identified a number of policy recommendations for accelerating industrial decarbonisation and supporting the competitiveness of manufacturers in both industrial clusters and dispersed sites in the UK. **While the specific pathways and outcomes will vary, the overall policy needs of dispersed sites and industrial clusters rely on a common set of infrastructure and fuel support and demand-side measures.** The policy framework already exists, and the UK has taken a number of significant steps in the right direction. What is needed is greater certainty, immediate action from policymakers, and policies that provide a pathway to decarbonisation while trying to limit unnecessary distortions between different dispersed sites and industrial clusters. Our overall recommendations to enable this are set out below:

- **Create incentives for electrification by increasing the availability of affordable renewable electricity and shifting the burden of policy and network costs.** High industrial electricity costs have been consistently identified as a barrier to key opportunities for decarbonisation due to the huge amounts of zero carbon electricity that will be required to decarbonise industry. There are several policy options for improving the availability of affordable renewable electricity. As explored in UCL's *Managing Industrial Electricity Prices in an Era of Transition*, these include restoring an efficient investment framework for the cheapest mature renewables, supporting continued growth of interconnection through Ofgem's cap-and-floor revenues system, and establishing a long-term, zero carbon electricity contracts market. An alternative method for creating incentives for electrification would be to shift some of the policy costs from the electricity bills of industrial producers onto industrial gas bills. This shift in costs would need to be accompanied by competitiveness support in the short to medium term for manufacturers currently reliant on gas as a fuel and feedstock that cannot easily or rapidly switch, including in the form of exemptions from these gas costs.
- **Provide certainty of supply and a clear timeline for when low carbon hydrogen, waste biomass, and carbon capture, utilisation, and storage (CCUS) will be available, using Contracts for Difference (CfDs) and government matchmaking.**[1] Producers need confidence that hydrogen and carbon capture infrastructure will be available in order to justify investment. The government should explore adopting CfDs for key alternative fuels and CCUS, directly legislating low carbon hydrogen production and CCUS targets or acting as a "matchmaker" between suppliers and industrial producers. Policymakers should also use the UK Hydrogen Strategy as a starting point to develop standards that define low carbon hydrogen.
- **Use Local Enterprise Partnerships (LEPs) and local authorities (LAs) to design local infrastructure plans in coordination with central government and devolved**

[1] Low carbon hydrogen includes blue and green hydrogen, with green hydrogen to play a larger role in the longer term. Waste biomass will need to be carefully defined to ensure the correct incentives exist to promote sustainable biomass production that complements other environmental commitments.

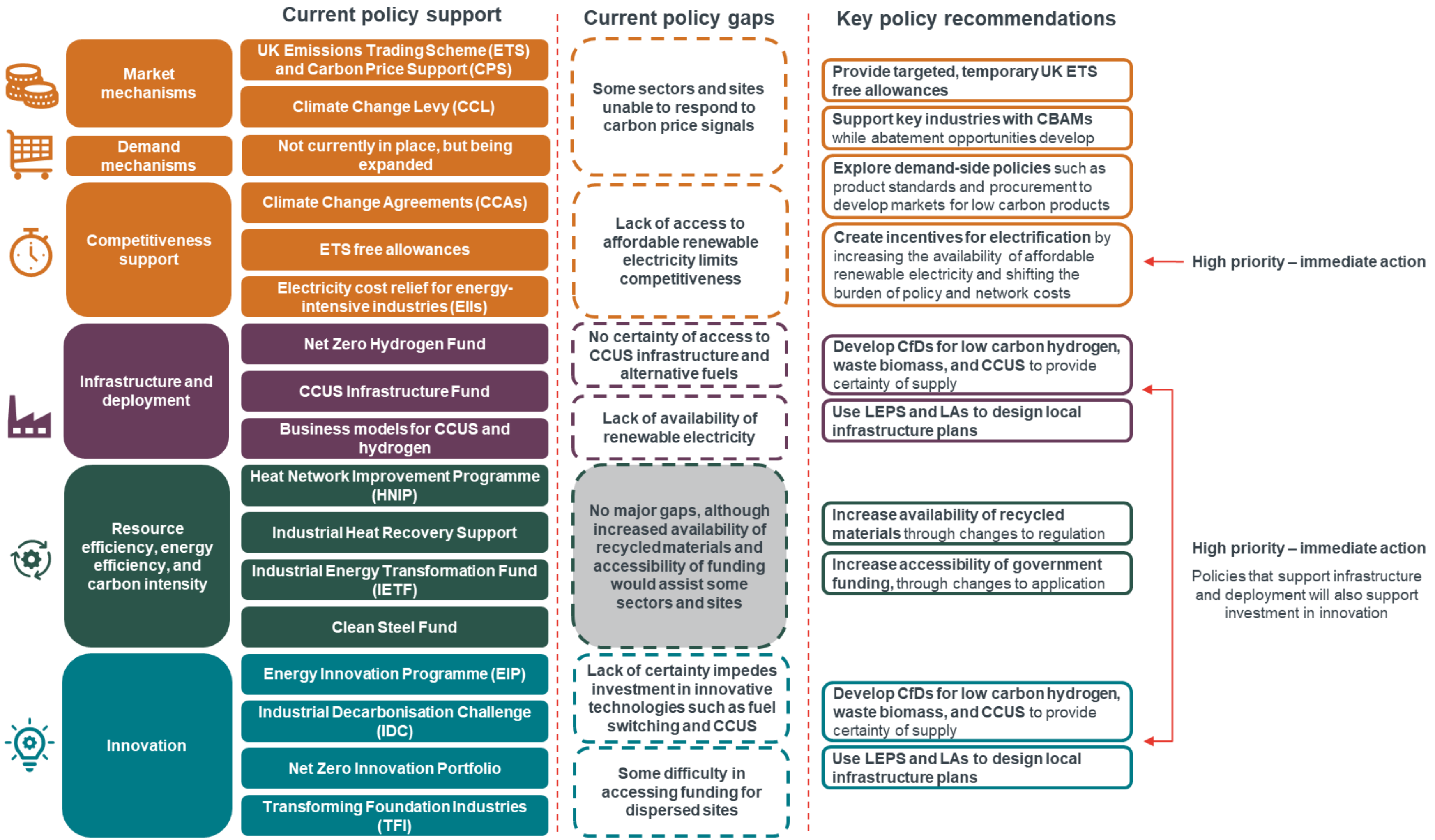
administrations. LEPs and LAs can play a key role in linking infrastructure at dispersed sites to the central infrastructure that will grow out of the industrial clusters. There is also greater scope for collaboration and coordination across government departments and regulatory bodies. These different departments and regulators will need to coordinate both with one another and with actors such as LEPs and LAs to ensure a consistent policy framework that does not generate unnecessary distortions. The existing net zero cross-departmental ministerial group could take a leadership role in overseeing this coordination and reviewing the delivery of local plans. The process for systematic coordination should be formalised by government in a strategy such as the Net Zero Strategy.

- **Provide targeted UK Emissions Trading Scheme (ETS) free allowances on a temporary basis and support from policies such as Carbon Border Adjustment Mechanisms (CBAMs).** In cases where the low carbon policy support, infrastructure, and technology are not in place to enable businesses to respond to carbon price signals, industries at risk of carbon leakage should receive support in the form of free allowances or CBAMs to avoid being put at a competitive disadvantage. This support should be reduced as opportunities for abatement develop and other policy support increases through measures such as CfDs for CCUS and low carbon product standards**.** Policymakers should therefore regularly review the policy support and decarbonisation options available to manufacturers.
- **Increase availability of recycled materials and move to a more circular economy through changes to regulation and increased accessibility of funding.** Some sectors can make further gains in resource efficiency, energy efficiency, and carbon intensity, particularly through greater use of recycled materials – for example, every tonne of recycled glass used in glass production leads to an estimated reduction of 320 KWh in natural gas usage.[2] Changes to building and waste regulations or introducing targets for recyclable material could therefore be of significant benefit to a variety of sectors. To support additional improvements in resource and energy efficiency, the funding application process for policy support should also be simplified, for example by allowing manufacturers to apply for funding on a rolling basis. This is particularly important for programmes such as the Industrial Energy Transformation Fund (IETF).
- **Continue to explore demand-side policies that support the development of markets for resource-efficient and low carbon products.** While demand for low carbon products appears to be limited today, it is developing in some key areas, and initiatives such as the Climate Group's SteelZero are helping to increase demand for low carbon industrial products. Government can support the development of these markets through demand-side measures such as product standards, procurement policies, and information campaigns. Demand-side measures can provide a clear incentive for producers to lower the emissions intensity of production and meet increasing demand for low carbon products. They can also provide a competitive advantage for those producers that are able to differentiate themselves on this dimension, leading to potentially significant market opportunities. International examples of demand-side policy support include The Buy Clean California Act in the USA and the CO_2 Performance Ladder used in the Netherlands.

These recommendations and gaps, as well as the current policy support, are summarised in Figure 1.

[2] Glass Futures, *BEIS Industrial Fuel Switching Phase 2: Alternative Fuel Switching Technologies for the Glass Sector* (2019).

Figure 1 Summary of policy recommendations



Source: Frontier Economics

EXECUTIVE SUMMARY

Industrial clusters and dispersed sites are important hotspots of economic activity, contributing around £170 billion to the economy, accounting for 9% of the UK's gross domestic product, and generating 2.6 million direct jobs across the country.[3] At the same time, both industrial clusters and dispersed sites are sources of carbon emissions, contributing an estimated 37.6 $MtCO_2e$ and 33.6 $MtCO_2e$ respectively in 2018.

Decarbonising these sites is a key part of meeting the UK's ambitious net zero goals and will require significant policy action and investment across the UK. The UK Government has already announced a series of policies to support its net zero ambition. However, if UK industry is to decarbonise at the necessary pace and while maintaining or improving its competitiveness, further action from policymakers is needed to ensure that there is a supportive business environment and that the necessary infrastructure is in place.

Through sector-specific case studies and extensive engagement with industry stakeholders, this report sets out the key policy needs of the UK's industrial clusters and dispersed sites. It goes on to make targeted policy recommendations to help ensure that both types of site, and the heavy industry sector as a whole, are put on a successful path to decarbonisation.

Industrial decarbonisation policies need to support both industrial clusters and dispersed sites and enable these sites to work together to decarbonise. Much of the existing policy debate has focused on industrial clusters, in part because these sites are well suited to the roll-out of decarbonisation infrastructure such as carbon capture, utilisation and storage (CCUS) and hydrogen. They are well placed to be used to trial deployment of low carbon solutions that can then be replicated more broadly. However, given their share of industrial emissions, it is vital that policy also addresses the needs of dispersed sites.

The policy environment must create a business environment that enables and encourages investment. The transition to net zero will be capital intensive. The industrial decarbonisation policy environment is therefore a crucial part of meeting the UK's net zero target. In particular, government can create an overall business environment in which businesses are able to invest and reduce risks, or can bridge funding gaps where private investment may fall short.

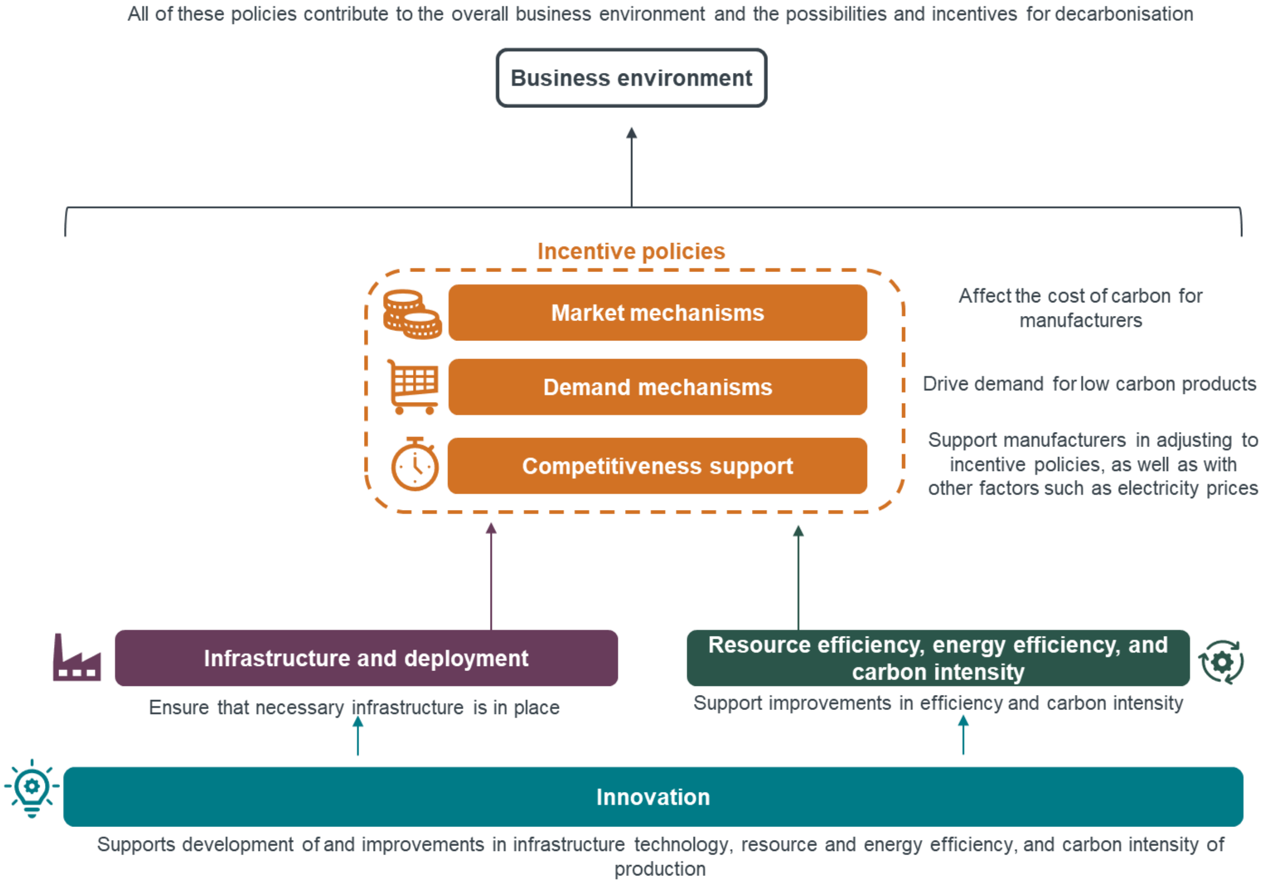
Industrial decarbonisation policy in the UK can broadly be grouped into four overarching categories:

- **innovation policies**;
- **infrastructure and deployment policies**;
- **resource efficiency, energy efficiency, and carbon intensity policies**; and
- **incentive policies**.

These policies support and interact with one another in enabling the decarbonisation of UK industry, as illustrated in Figure 2 below.

[3] *UK Industrial Decarbonisation Strategy* (2021, page 16).

Figure 2 The decarbonisation policy framework in the UK



Source: *Frontier Economics, drawing on frameworks set out by the UK's Industrial Decarbonisation Strategy and Climate Change Committee.*

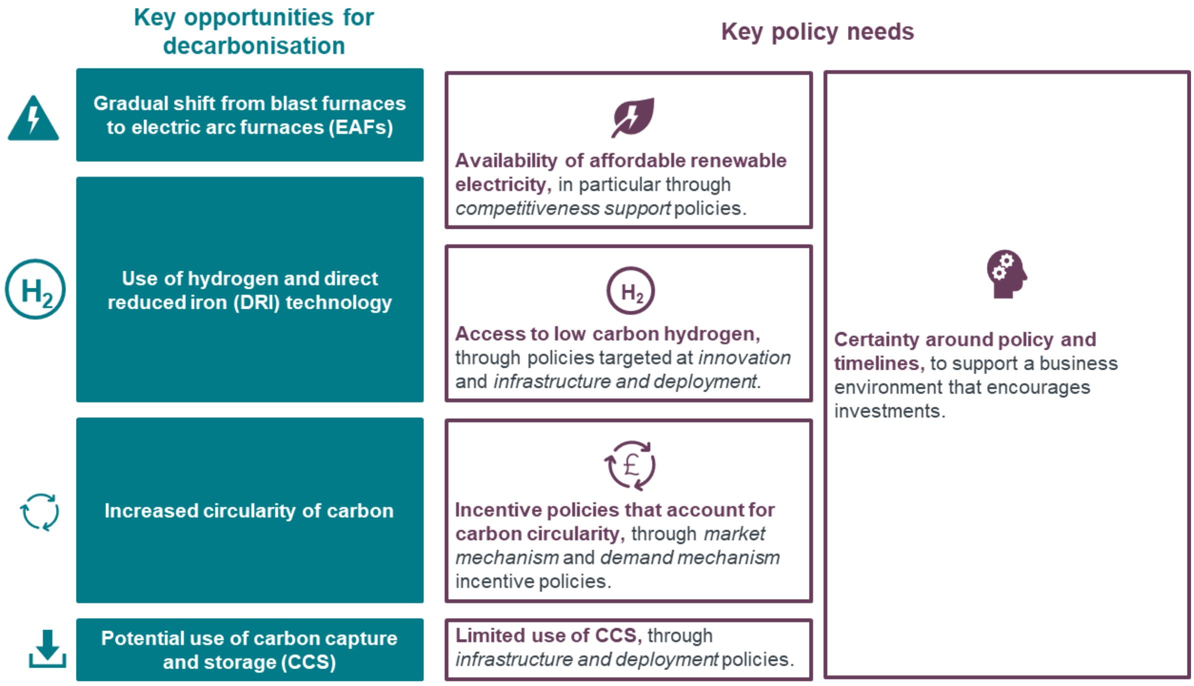
To understand the needs of industrial clusters, we engaged with experts from across the steel sector and chemicals sector. Steel sector stakeholders engaged as part of this study were broadly positive about the direction of the UK Government's existing steel decarbonisation pathway. What is needed for steel manufacturers located in industrial clusters is not a wholly new policy framework but, rather, increased support within the existing framework. In particular, policies should be developed further to support the decarbonisation needs outlined below:

- **Availability of affordable renewable electricity.** This is critical for enabling greater electric arc furnace (EAF) production and for enabling the use of hydrogen-produced direct reduced iron (DRI).
- **Access to low carbon hydrogen.** Low carbon hydrogen enables important decarbonisation opportunities in steel, particularly the use of hydrogen-produced DRI.
- **Certainty around policy and timelines.** Manufacturers need certainty around when key infrastructure will be in place and how prices of production inputs will evolve in order to plan upcoming investments and adapt to a zero carbon world. In general, this requires clear sign-posting by policymakers, but it can also be supported by policies such as Contracts for Difference (CfDs), which provide certainty for when low carbon hydrogen will be available, and by increased coordination across different levels of government.

- **Incentive policies that account for carbon circularity.** This involves ensuring policy is sufficiently flexible to ensure that recycling and re-use are taken up where appropriate and that incentive policies do not inadvertently discourage the use of new and innovative carbon-reducing technologies.

There may also be some scope for limited use of carbon capture and storage (CCS)[4] in supporting steel decarbonisation in the UK, for example for use in the creation of blue hydrogen. The key opportunities and policies for UK steel decarbonisation are summarised in Figure 3 below.

Figure 3 Summary of key opportunities and policies for UK steel decarbonisation



Source: *Frontier Economics*

In the chemicals sector, industry stakeholders expressed that, while the overall policy framework in the UK covers the areas needed to support decarbonisation, more support will be needed to create a business environment conducive to investment. In particular, policymakers will need to accelerate deployment of critical infrastructure such as carbon capture clusters and other decarbonisation technologies. Overall, policy needs to be developed further to support:

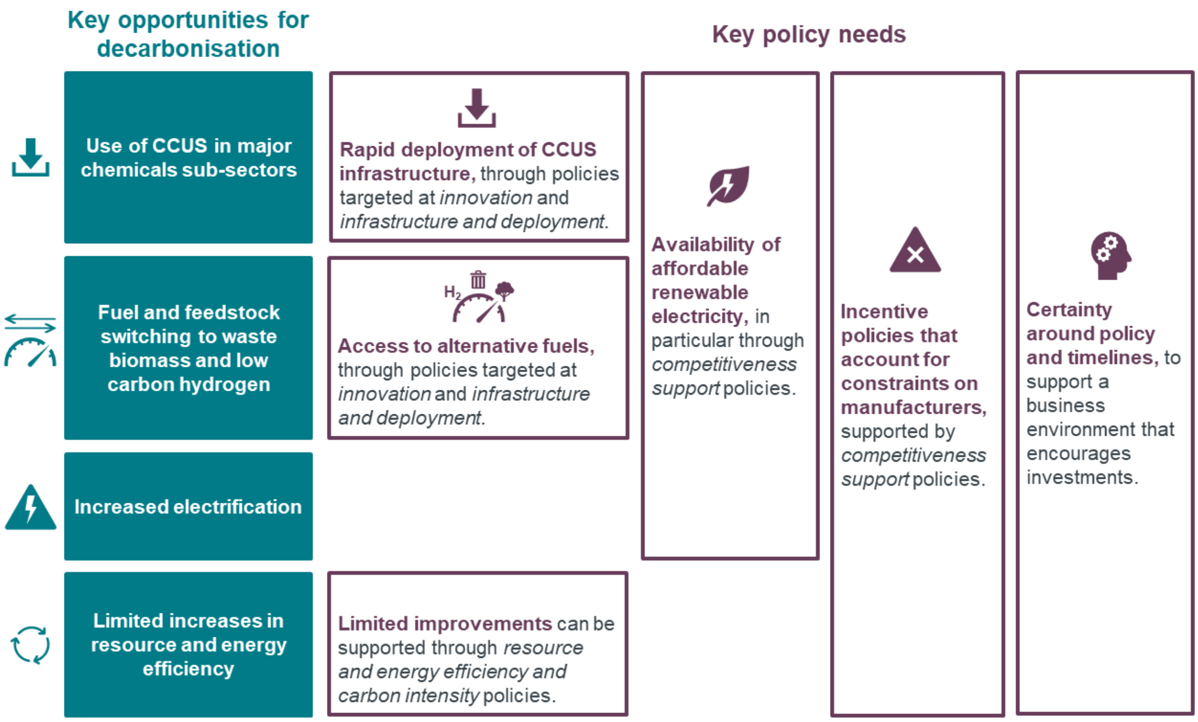
- **The availability of affordable renewable electricity.** Access to large capacities of affordable, low carbon electricity is critical for enabling CCUS, use of low carbon hydrogen as a feedstock and fuel, and increased electrification of production.
- **The rapid deployment and availability of CCUS.** CCUS is a key element in the pathway to net zero for a number of chemicals manufacturers in the UK due to the high purity CO_2 emitted during the production process.

[4] We use the abbreviation CCS, as opposed to CCUS, where stakeholders particularly emphasised the importance of capture and storage requirements as opposed to capture and use.

- **Access to alternative fuels and feedstocks, particularly waste biomass and low carbon hydrogen.** These low carbon fuels can be used as alternatives to fossil fuels, significantly reducing emissions.
- **Certainty around policy and timelines.** As in the steel sector, manufacturers need certainty in order to plan upcoming investments and adapt to a zero carbon world. This can be supported by policies such as CfDs, which provide certainty for when low carbon hydrogen, waste biomass, and CCUS will be available, and by increased coordination across different levels of government.
- **Incentive policies that account for constraints on manufacturers.** Without adequate policy support in areas such as infrastructure deployment and innovation (for example, through CfDs for low carbon hydrogen and CCUS), manufacturers may be unable to respond to incentive policies. Policymakers need to take this into account.

An overview is provided in Figure 4 below.

Figure 4 Summary of key opportunities and policies for UK chemicals decarbonisation



Source: Frontier Economics

To understand the needs of dispersed sites, we engaged experts in the cement, ceramics, and glass sectors. Reactions from stakeholders at dispersed sites to current UK Government policy were mixed. Some highlighted that they broadly found the existing policy framework to be comprehensive, while others identified significant gaps which put their ability to compete with international manufacturers at significant risk. Stakeholders at dispersed sites also indicated that, because of these gaps, the current policy framework does not provide the correct incentives to drive sector-wide decarbonisation.

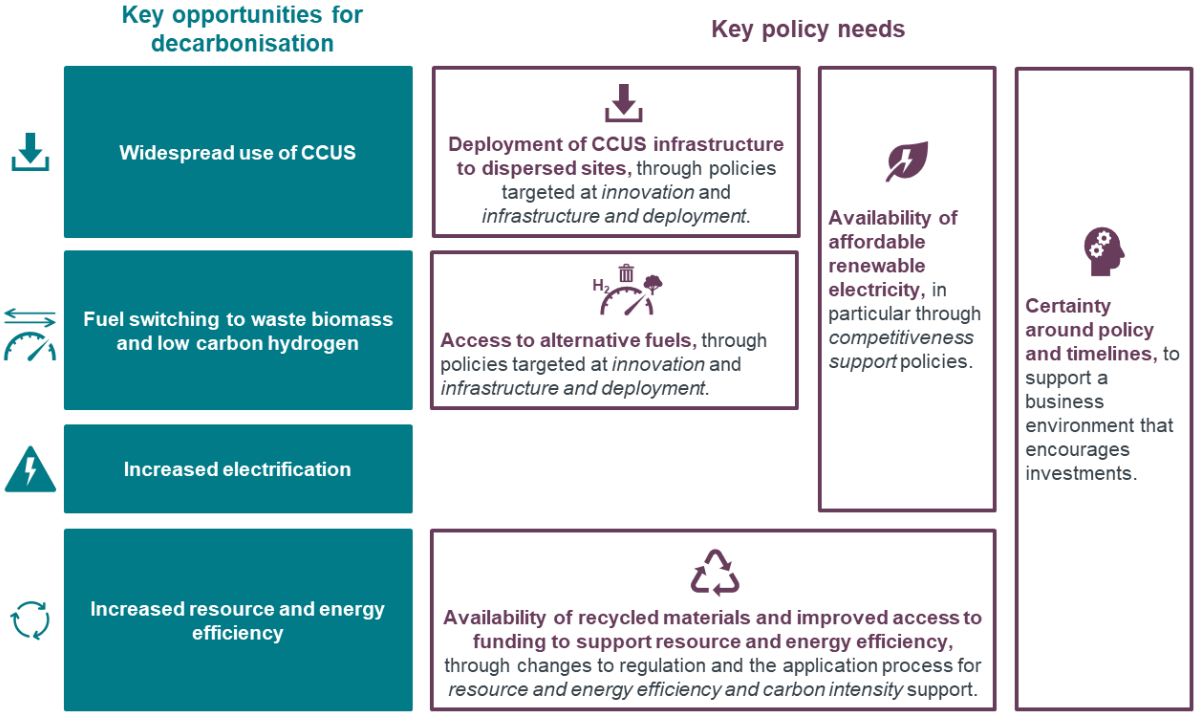
Overall, there are a number of promising pathways to decarbonisation for dispersed sites. However, with the current level of policy support, a number of these options are

not presently viable. To support dispersed sites to decarbonise, policies need to be developed further to support the decarbonisation needs outlined below:

- **Availability of affordable renewable electricity.** Affordable, renewable electricity is important for a number of decarbonisation opportunities at dispersed sites – in particular, it is needed for CCUS, production of low carbon hydrogen, and increased electrification.
- **Deployment of CCUS infrastructure to dispersed sites.** Many dispersed sites will need to use CCUS to decarbonise due to the significant process emissions produced by industries such as cement, ceramics, and glass.
- **Access to alternative fuels, particularly waste biomass and low carbon hydrogen.** The lack of availability of alternative fuels, particularly waste biomass and low carbon hydrogen, is a significant barrier to decarbonisation for producers at dispersed sites.
- **Certainty around policy and timelines.** Manufacturers at dispersed sites need to know whether and when key infrastructure will be in place and how the prices of production inputs will evolve in order to minimise the marginal costs of abatement and avoid stranded assets. In general, this requires clear sign-posting by policymakers, but it can also be supported by policies such as Contracts for Difference (CfDs), which provide certainty for when low carbon hydrogen, waste biomass, and CCUS will be available, and by increased coordination across different levels of government.
- **Availability of recycled materials and improved access to funding to support resource and energy efficiency.** An increased focus on the circularity of carbon could also be a significant benefit to manufacturers. In particular, recycled materials can be used to reduce emissions from production. Policies to support this include changes to building and waste management regulations. The funding application process for support programmes such as the Industrial Energy Transformation Fund (IETF) could also be simplified, for example by allowing manufacturers to apply on a rolling basis.

The key opportunities and policies for decarbonisation of cement, ceramics, and glass at dispersed sites are summarised in Figure 5.

Figure 5 Summary of key opportunities and policies for decarbonisation of cement, ceramics, and glass at dispersed sites



Source: Frontier Economics

Action should be coordinated across different sites and sectors to avoid distortions to domestic production. Major infrastructure will be rolled out gradually, starting with a subset of clusters – the first two carbon capture clusters are targeted for 2025, while the hydrogen network is also intended to be extended gradually to different clusters between now and 2040. This creates a risk that manufacturers for any given sector in one cluster will gain an advantage over manufacturers in another cluster (or in dispersed sites) due to the different availability of key infrastructure and funding. A similar risk exists for substitution between products: glass, steel, and cement all compete to a degree in the construction industry – policies which advantage one at the expense of another may lead to unintended distortions.

While the specific pathways and outcomes will vary, the overall policy needs of dispersed sites and industrial clusters rely on a common set of infrastructure and fuel support and demand-side measures. These different areas of policy action need to be joined up and acted on together and should not be seen as independent interventions. A comprehensive, effectively designed suite of policies is needed to ensure that manufacturers have the necessary support to decarbonise and be competitive in a zero carbon world. In particular, both dispersed sites and industrial clusters need an overall business environment that is conducive to investment.

Policymakers should:

- **create incentives for electrification by increasing the availability of affordable renewable electricity and shifting the burden of policy and network costs;**
- **provide certainty of supply and a clear timeline for when low carbon hydrogen, waste biomass, and CCUS will be available, using CfDs and government matchmaking;**

- **use Local Enterprise Partnerships (LEPs) and local authorities (LAs) to design local infrastructure plans in coordination with central government and devolved administrations;**
- **provide targeted UK Emissions Trading Scheme (ETS) free allowances on a temporary basis and support from policies such as Carbon Border Adjustment Mechanisms (CBAMs);**
- **increase availability of recycled materials and move to a more circular economy through changes to regulation and increased accessibility of funding; and**
- **continue to explore demand-side policies that support the development of markets for resource-efficient and low carbon products.**

These policy recommendations are explored in more detail in **Section 6**.

1 INTRODUCTION

The UK has broad and ambitious decarbonisation goals and is aiming to be a world leader in the fight against climate change. In 2019, the UK passed legislation which committed to bringing all greenhouse gas (GHG) emissions to net zero by 2050, and in 2021 it committed to a 78% reduction by 2035 compared to 1990 levels.[5] The UK has already reduced emissions in recent decades, with overall GHG emissions falling by more than 40% between 1990 and 2019, even as the economy grew by almost 80%.[6] Progress in the industrial sector has been even more extensive, with an overall drop in emissions from industrial processes of 83% between 1990 and 2019.[7] However, with its net territorial emissions standing at over 450 $MtCO_2e$ in 2019, there are significant further reductions to be made if the UK is to reach its net zero ambitions.

UK industrial emissions collectively account for approximately 16% of UK emissions, equal to 72 $MtCO_2e$ in 2018.[8] UK industry includes varied sectors such as iron & steel, chemicals, ceramics, cement, and glass, and can be broadly divided into two categories: clustered sites and dispersed sites. Clustered sites are characterised by shared infrastructure across multiple sectors in close proximity and are typically built up around significant iron & steel, chemicals, or oil & gas refining sites.[9] The Department for Business, Energy and Industrial Strategy (BEIS) includes all sites within 25 km of major industrial clusters and other areas that may be able to access CO_2 transport and storage in its definition of clustered sites. By contrast, dispersed sites do not benefit from the same level of shared infrastructure. While dispersed sites may still include multiple manufacturers located in close proximity, they do not have the same economies of scale as major industrial clusters.

In many cases, clustered and dispersed sites share decarbonisation policy needs, while in other cases they require different types (and different levels) of support. Much of the existing policy debate has focused on clustered sites, in part because these sites are well suited to the roll-out of decarbonisation infrastructure, such as carbon capture, utilisation and storage (CCUS) and hydrogen generation, and can be used to trial deployment of low carbon solutions that can then be replicated more broadly. However, it is important that dispersed sites do not get left behind in the policy discussion. Dispersed sites account for nearly half of the UK's industrial emissions[10] and decarbonisation policy will have to account for their needs if the UK is to achieve its climate goals. Policymakers need to ensure that pathways and timelines exist for connecting these sites to the infrastructure being developed in industrial clusters, and that new low carbon technologies deployed in clusters are also rolled out to dispersed sites where possible. Moreover, many sectors will have sites both in clusters and dispersed sites, and ensuring that policy developments work for industrial sectors as a whole, irrespective of location, is important for avoiding competitive distortions between these sites.

This report seeks to reflect the decarbonisation policy needs of these clustered and dispersed sites. This includes an exploration of the policies required to assist in the transition to net zero while ensuring that UK industry retains or increases its international competitiveness.

[5] https://www.gov.uk/government/news/uk-becomes-first-major-economy-to-pass-net-zero-emissions-law

[6] HM Treasury, *Build Back Better: our plan for growth* (March 2021, page 84).

[7] BEIS, *2019 UK Greenhouse Gas Emissions, Final Figures*. Released February 2021.

[8] *UK Industrial Decarbonisation Strategy* (March 2021, page 16).

[9] See Figure 2 of Annex 3 in the *UK Industrial Decarbonisation Strategy* (March 2021).

[10] *UK Industrial Decarbonisation Strategy* (March 2021, page 17).

- **Section 2** sets out the current policy context and framework supporting industrial decarbonisation.
- **Section 3** summarises evidence, key policy needs, potential impacts on competitiveness, and implications for decarbonisation timelines in the steel sector. This section draws on interviews and discussions with key stakeholders in the steel sector, supported by additional literature review.
- **Section 4** summarises evidence, key policy needs, potential impacts on competitiveness, and implications for decarbonisation timelines in the chemicals sector. This section draws on interviews and discussions with key stakeholders in the chemicals sector, supported by additional literature review.
- **Section 5** summarises evidence, key policy needs, potential impacts on competitiveness, and implications for decarbonisation timelines in dispersed sites, focusing on the cement, ceramics, and glass sectors. This section draws on interviews and discussions with key stakeholders, supported by additional literature review.
- **Section 6** synthesizes this evidence into a set of general policy recommendations to fill current policy gaps.
- **Section 7** concludes.

2 INDUSTRIAL POLICY CONTEXT

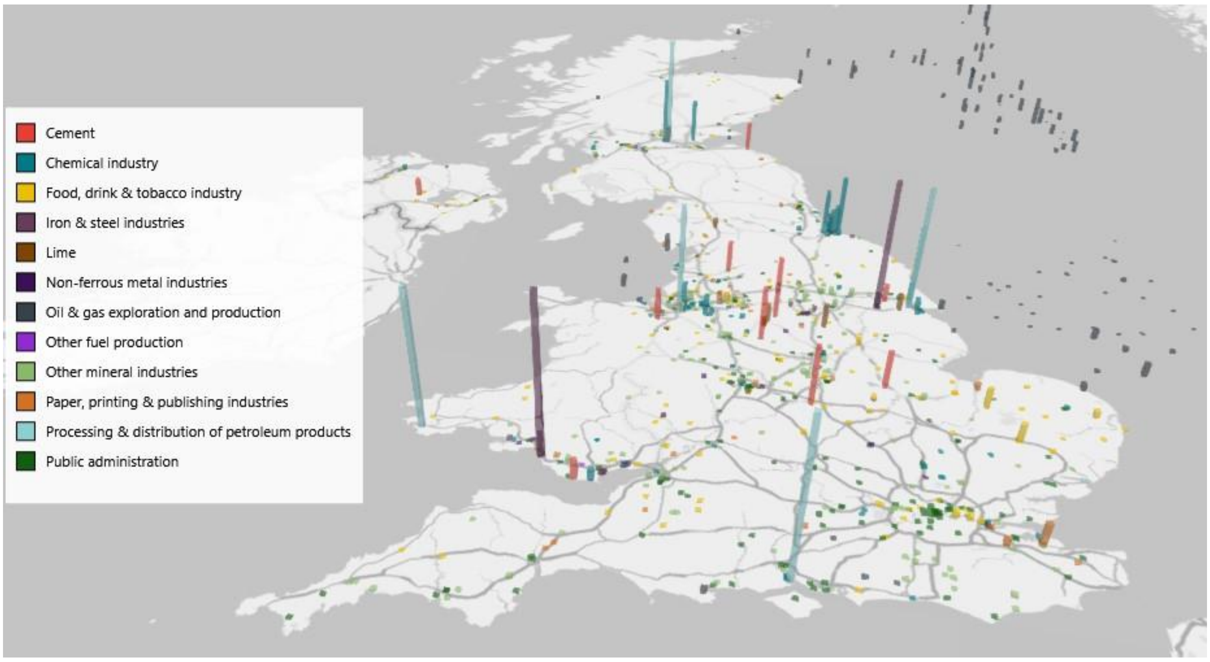
This section sets out the industrial policy context – where industrial clusters and dispersed sites are located, the UK's current industrial decarbonisation policy framework and timeline, and how these policies sit within the wider domestic and international policy context. This context is an important reference point for the decarbonisation opportunities and policy needs explored in subsequent sections.

2.1 Industrial clusters and dispersed sites

There are a range of industrial sites located across the UK, as shown in Figure 6. As well as being major emitters of GHGs, these sites make a substantial contribution to the UK economy. The manufacturing industry accounts for 9% of the UK's gross domestic product (GDP), contributing £170 billion to the overall economy and employing over 2.6 million people.[11] Many of these industrial sites are in relatively deprived regions and are key providers of skilled employment in these locations – for example, the Humber cluster represents nearly a quarter of its region's total gross value added (GVA).[12]

This makes these industries a key factor in the UK's levelling up agenda. One of the UK Government's primary foci is to tackle geographic disparities in access to good jobs across the UK.[13] It is, therefore, critical that decarbonisation policies enhance, rather than hinder, the UK's industrial competitiveness. The economic importance of these sites needs to be accounted for when developing decarbonisation policy.

Figure 6 Location of industry in the UK



Source: NAEI source point data.

Note: Height of bar indicates level of carbon emissions from site.

[11] *UK Industrial Decarbonisation Strategy* (March 2021, page 16).

[12] *UK Industrial Decarbonisation Strategy* (March 2021, page 122). Based on the GVA for Kingston Upon Hull, East Riding of Yorkshire, North East Lincolnshire, and North Lincolnshire local authorities, which the cluster spans.

[13] HM Treasury, *Build Back Better: Our Plan for Growth* (March 2021, page 71).

Industrial sites can be broadly divided into clustered sites (that is, sites located in or near industrial clusters) and dispersed sites. Clustered sites are characterised by shared infrastructure across multiple sectors in close proximity, and are typically built up around significant iron & steel, chemicals, and/or oil & gas refining sites.[14] The UK's Industrial Decarbonisation Strategy's definition of clustered sites includes those sites located within 25 km of the UK's major industrial clusters as well as sites near the Peak District, Londonderry, and Medway, which may be able to access CO_2 transport and storage through pipelines and shipping.[15]

Much of the existing policy debate and framework has focused on the UK's major industrial clusters. Overall, clustered sites in the UK accounted for 37.6 $MtCO_2e$ of emissions in 2018, with nearly a third of this coming from the iron & steel sector.[16] There are six major industrial clusters in the UK, as defined by the UK Government's Industrial Decarbonisation Strategy:[17]

- **Humber cluster.**[18] This site includes the Scunthorpe steelworks, along with notable oil & gas refining and cement production. The Humber cluster emitted approximately 10 $MtCO_2e$ in 2018.[19]
- **Teesside cluster.** The Teesside cluster is a major steel production site and includes a substantial amount of chemicals production. The Teesside cluster emitted approximately 10 $MtCO_2e$ in 2018.
- **South Wales.** This cluster is primarily made up of the Port Talbot steelworks, but also includes some cement and chemicals production. The South Wales cluster emitted approximately 8.9 $MtCO_2e$ in 2018.
- **Grangemouth.** Grangemouth in Scotland is a significant oil & gas refining and chemicals production site. The Grangemouth cluster emitted approximately 5 $MtCO_2e$ in 2018.
- **Merseyside.** Also known as the North West industrial cluster, emissions in Merseyside are primarily driven by oil & gas refining, but also include chemicals and cement production. The Merseyside cluster emitted approximately 5 $MtCO_2e$ in 2018.
- **Southampton.** Production in the Southampton cluster is focused on oil & gas refining, but also includes some chemicals production. The Southampton cluster emitted approximately 3.2 $MtCO_2e$ in 2018.

While a significant proportion of the UK's industrial emissions are driven by these six industrial clusters, nearly 50% of industrial emissions are produced by dispersed sites. This includes emissions from sectors such as cement, ceramics, glass, and food & drink. These dispersed sites are also of significant economic importance – in 2018, the food & drink manufacturing industry contributed approximately £28.8 billion to the UK economy and employed over

[14] See Figure 2 of Annex 3 in the *UK Industrial Decarbonisation Strategy* (2021).

[15] *UK Industrial Decarbonisation Strategy* (2021, page 145).

[16] *UK Industrial Decarbonisation Strategy* (2021, page 17).

[17] *UK Industrial Decarbonisation Strategy* (2021, page 135).

[18] For more information on drivers of emissions in industrial clusters, see ECOFYS, *ICCUS Readiness of UK Industrial Clusters: An Assessment* (January 2017).

[19] Emissions figures for this and other clusters are from the *UK Industrial Decarbonisation Strategy* (2021, page 199). Figures do not include non-ETS emissions in a cluster.

440,000 people, glass added nearly £1.3 billion in GVA, ceramics added a further £1 billion, and the cement sector contributed £274 million in GVA to the UK economy.[20]

These dispersed sites therefore need to be a key part of the policy debate, and their needs should be taken into account alongside the needs of industrial clusters. Neglecting dispersed sites may leave 33.6 $MtCO_2e$ worth of annual emissions without adequate support for a pathway towards decarbonisation[21] and may pose a threat to critical parts of the UK's economy as carbon prices and green markets continue to rise if dispersed sites are unable to react to these market signals. Moreover, industrial decarbonisation policy is not a zero-sum game with respect to clusters and dispersed sites – there is room for policies targeted at clusters and dispersed sites to enhance overall decarbonisation actions, for example by allowing dispersed sites to build on actions taken in clusters and connect to cluster infrastructure.

2.2 Industrial decarbonisation policy today

The transition to net zero will be capital intensive.[22] In 2020, the Climate Change Committee (CCC) put the average annual investment cost of UK industry achieving net zero by 2050 at £1.8 billion between 2020 and 2050, with the annual investment required peaking at £4.1 billion in 2036.[23] Many of these investments may ultimately reduce the marginal cost of industrial production, improve production efficiency, and create the potential for job creation. However, large investments naturally entail risks and these risks can be exacerbated by a lack of certainty about the future path of government policy.[24] The industrial decarbonisation policy environment is therefore a crucial part of meeting the UK's net zero target. In particular, it can create an overall business environment in which businesses are able to invest and reduce risks, or can bridge funding gaps where private investment may fall short. Effective policy can also resolve other market failures such as negative externalities due to under-priced carbon emissions.

Industrial decarbonisation policy in the UK can broadly be grouped into four overarching categories:

- **innovation policies;**
- **infrastructure and deployment policies;**
- **resource efficiency, energy efficiency, and carbon intensity policies;** and
- **incentive policies,** including competitiveness support policies targeted at areas such as electricity prices.

These policies support and interact with one another in enabling decarbonisation of UK industry. Innovation allows for the deployment of new infrastructure and the development of

[20] Based on SIC code level data in the UK's Annual Business Statistics (ABS) for the manufacturing sector.

[21] This is based on the *UK Industrial Decarbonisation Strategy* (2021) definition of clusters and dispersed sites. In this definition, cluster emissions includes emissions from sites within 25 km of the six major industrial clusters, but also includes some emissions from sites located outside of these major industrial clusters (in particular, from sites in the Peak District, near Londonderry, and near Medway). As a result, this figure for dispersed sites should be considered conservative, and may actually understate the proportion of emissions from what could be considered dispersed sites.

[22] HM Treasury, *Net Zero Review Interim Report* (2020).

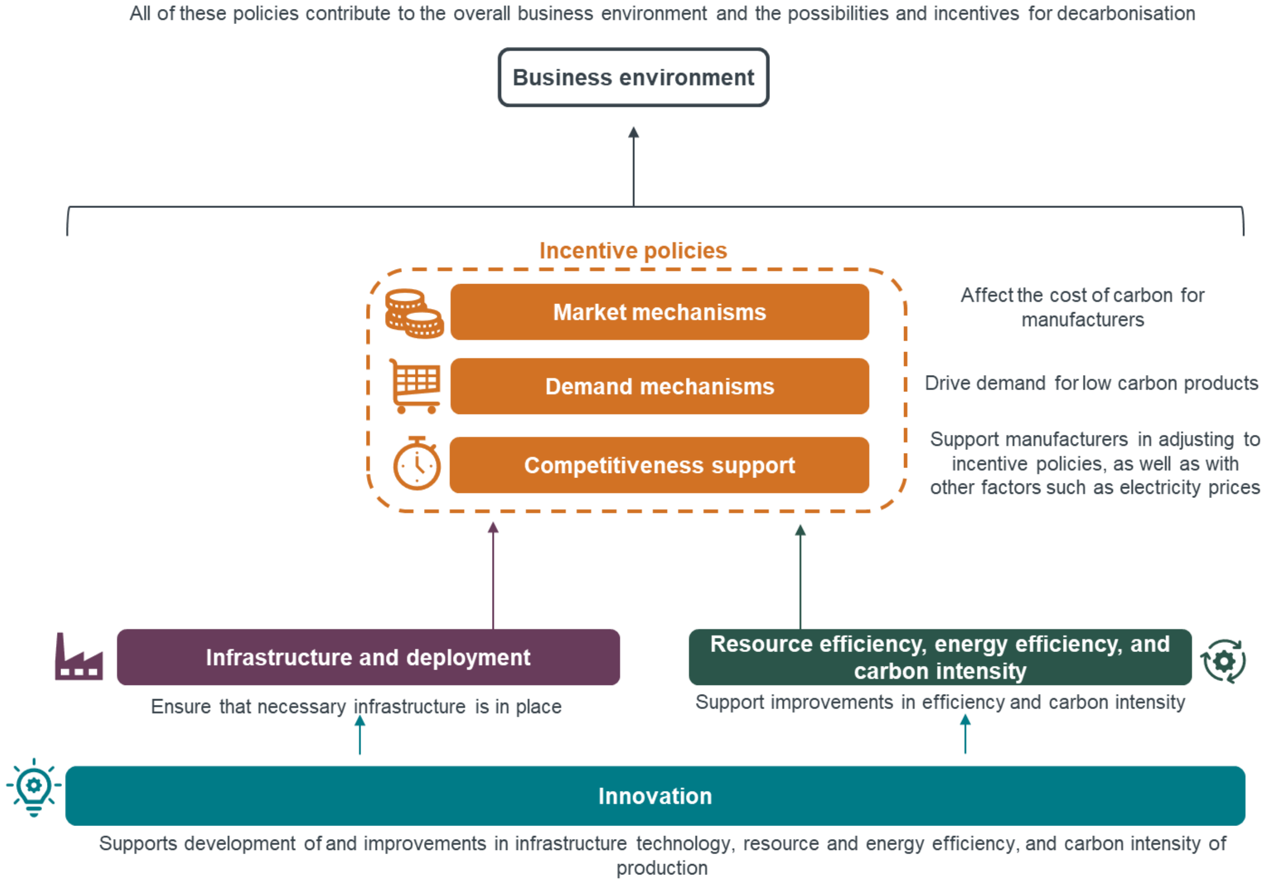
[23] Climate Change Committee (CCC), *Sixth Carbon Budget – Methodology Report* (2020). See supporting data provided alongside the report that sets out the annual additional capital investment spend by sector.

[24] HM Treasury, *Net Zero Review Interim Report* (2020, page 54).

emissions-reducing technologies, and the availability of this infrastructure and improved technology allows manufacturers to respond to signals created by incentive policies. Without adequate infrastructure and cost-effective new technology, signals such as a higher carbon price risk putting manufacturers out of business due to an inability to adjust the emissions intensity of production in response to increasing carbon costs.

If there is adequate support for innovation, infrastructure, and new technology deployment, however, incentives can provide a powerful additional push towards decarbonisation. Together, these policies can be used to create a business environment which enables manufacturers to invest and adapt to a zero carbon world, potentially even gaining a competitive advantage as demand for low carbon products grows. These relationships are summarised in Figure 7, with more detail on these policy types set out in the remainder of this sub-section.

Figure 7 The decarbonisation policy framework in the UK



Source: *Frontier Economics, drawing on frameworks set out by the UK's Industrial Decarbonisation Strategy and Climate Change Committee.*

Incentivising innovation

The foundation of decarbonisation is innovation. Manufacturers need to develop and commercialise new technologies and improve and reduce the costs of existing ones. These are inherently risky investments, and these risks are particularly significant at the early stage of development.[25] The key features of innovation policies are summarised in Figure 8 below.

Figure 8 Innovation policy summary

Innovation

Barriers addressed	Investments in unproven technologies are risky, and involve high upfront costs. Innovation policies **reduce barriers to risky investments** in new technologies by lowering the cost of such investments.
Impacts	Making these risky investments in new technologies **lowers their cost of deployment**, enabling their commercial use and the resulting long term decarbonisation impacts.
Links to other policies	Innovation policies offer critical support to **infrastructure and deployment** and **efficiency and carbon intensity** policies. Without a base of innovation, key infrastructure and technologies may not become commercially viable, and will not be able to be adopted by businesses.

Policy example: the Net Zero Innovation Portfolio

Announced in 2020 as part of the Prime Minister's Ten Point Plan for a Green Industrial Revolution and running until 2025, the Net Zero Innovation Portfolio is a £1 billion fund aimed at accelerating the commercialisation of low carbon technologies, systems and business models in power, buildings and industries.

Source: Frontier Economics

Commercialising and improving emerging technologies, such as CCUS and the use of hydrogen in industrial production, are critical for meeting the UK's net zero goals. Innovation can lead to significant cost reductions in carbon-reducing technologies and make them commercially viable. For example, improvements in offshore wind technology (a key source of green electricity for the UK) are leading to rapid declines in its cost per MWh and improvements in its commercial viability – some estimates have offshore wind prices falling below gas prices by 2023, with the price per MWh falling from £167 in 2017 to £44 by 2023.[26]

Industrial innovation policies in the UK include the Energy Innovation Programme (EIP), the Net Zero Innovation Portfolio and Transforming Foundation Industries (TFI) Challenge. It also includes the Industrial Decarbonisation Challenge (IDC), which is targeted at developing and deploying new technologies such as hydrogen fuel switching at the UK's largest industrial clusters.[27]

International examples of innovation policy include the EU's Innovation Fund, which will provide around €10 billion in support between 2020 and 2030 for the commercial demonstration of innovative low carbon technologies.[28]

Investing in infrastructure and deployment

Once technologies have been developed and demonstrated, they need to be deployed. The UK's Industrial Decarbonisation Strategy is built around the deployment of critical, low-regret

[25] HM Treasury, *Net Zero Review Interim Report* (2020, page 54).

[26] https://www.carbonbrief.org/analysis-record-low-uk-offshore-wind-cheaper-than-existing-gas-plants-by-2023

[27] https://www.ukri.org/our-work/our-main-funds/industrial-strategy-challenge-fund/clean-growth/industrial-decarbonisation-challenge/

[28] https://ec.europa.eu/clima/policies/innovation-fund_en

technologies such as low carbon hydrogen, renewable electricity, and CCUS.[29] The key features of the infrastructure and deployment policies which support this are summarised in Figure 9 below.

Figure 9 Infrastructure and deployment policy summary

Infrastructure and deployment

Barriers addressed	Deployment of key infrastructure like CCUS networks involves **high fixed costs**, and may not be undertaken by the private sector without public support.
Impacts	Policy interventions can ensure that key infrastructure and technologies like CCUS and low carbon hydrogen are available, allowing industry to adjust production to make use of these resources.
Links to other policies	Infrastructure deployment is a key factor in allowing industry to respond to **incentive policies.** Without access to carbon capture or hydrogen, businesses may be unable to respond to an increased carbon price or demand for low carbon products. They are supported by **innovation** policies which enable commercialisation of technology such as CCUS and hydrogen.

Policy example: the CCUS Infrastructure Fund (CIF)

Announced in 2020, the CIF is a £1 billion fund aimed at developing CCUS clusters with transport and storage networks acting as the enabling infrastructure for a variety of capture projects and supporting the development of a new CCUS sector. This is a key part of ensuring CCUS is deployed in at least two clusters by the mid-2020s and four clusters by 2030.

Source: Frontier Economics

Access to key types of decarbonisation infrastructure and technology is crucial for achieving the UK's industrial emissions reduction targets: without this access, manufacturers may be unable to respond to signals such as a higher carbon price. For example, if the only way a manufacturer can make further emissions reductions is through capturing CO_2, but transport and storage networks are not available in their location, a higher carbon price may not incentivise them to reduce the carbon intensity of production. Instead, it would serve only to increase costs and reduce competitiveness, potentially resulting in carbon leakage to other jurisdictions.

Significant investment is needed in infrastructure such as transport networks for captured carbon, low carbon hydrogen production sites, and hydrogen networks. These investments in shared infrastructure entail substantial fixed costs. For example, the required CO_2 transport and storage network which is necessary for carbon capture will involve large initial capital investments, and this infrastructure market may be a natural monopoly in practice due to the economies of scale present.[30] Private companies may be unwilling to make these investments (as the costs could be too large for any one company to make in isolation) or, even if they do so, there may be significant market failures stemming from the creation of a private monopoly.

Infrastructure and deployment policies include the CCUS Infrastructure Fund and the Net Zero Hydrogen Fund (also known as the Low Carbon Hydrogen Production Fund), as well as the industrial clusters mission targeted at developing the world's first net zero cluster.

29 *UK Industrial Decarbonisation Strategy* (March 2021, page 10).

30 HM Treasury, *Net Zero Review Interim Report* (2020, page 93).

Improving resource efficiency, energy efficiency, and carbon intensity

As well as requiring access to infrastructure for carbon capture and low carbon hydrogen, manufacturers need to continue deploying more energy efficient, low carbon production technologies. These policies are largely focused on improving efficiency in existing technologies, rather than deploying new technologies. This improvement in efficiency can be further divided into "resource and energy efficiency" and "carbon intensity", with the former including policies that reduce the energy and resources required for a given output, while the latter include switching to a lower carbon fuel to meet the same energy requirement. The key features of the policies which support this are summarised in Figure 10 below.

Figure 10 Resource efficiency, energy efficiency, and carbon intensity policy summary

Resource efficiency, energy efficiency, and carbon intensity

Barriers addressed	**The cost of investing in more efficient technologies may outweigh the commercial benefit of doing so in the near term**, and investments in emissions reductions may not be made without government support.
Impacts	These investments **directly reduce the carbon intensity of production**, and can also have knock-on effects such as reducing costs and improving efficiency more generally.
Links to other policies	Resource and energy efficiency policies help businesses transform production methods to respond to **incentive policy** signals, and are supported by **innovation** policies which result in more efficient production techniques.

Policy example: the Industrial Energy Transformation Fund

Announced in the 2018 budget, £315 million of funding is available to support the deployment of energy efficiency and other low carbon technologies at energy-intensive businesses. This fund is aimed at those investments which would not happen without government support.

Source: Frontier Economics

These changes can be powerful drivers of emissions reductions: improvements in resource and energy efficiency through means such as greater use of recycled inputs and increased heat recovery can both lower production costs and reduce emissions intensity, while switching from fuels such as natural gas and coal towards waste fuels and electrification of heating can similarly reduce production emissions.

In the UK, efficiency and carbon intensity reduction policies include the Industrial Energy Transformation Fund (IETF), the Heat Network Improvement Programme (HNIP), and the Renewable Heat Incentive, among others.[31]

Creating incentives by influencing the market and demand

Public policy can also be used to send powerful signals to market participants and create incentives to decarbonise through resolving market failures and creating new markets for goods. Incentive policies can be broadly divided into market-based measures and demand-side measures, with competitiveness support policies helping to manage the burden on

[31] For more information on these types of policies, see for example CREDS, *Industrial Decarbonisation Policies for a UK Net Zero Target* (December 2020, page 21).

manufacturers as they respond to the new signals created by these policies. The key features of incentive policies are summarised in Figure 11 below.

Figure 11 Incentive policy summary

Incentives

Barriers addressed

Incentive policies can help overcome **market failures resulting from negative externalities and information asymmetries**, such as excess emissions due to an inefficiently low price of carbon or lack of transparency around emissions for consumers.

Impacts

These policies create signals for manufacturers by raising the price of carbon or driving demand, providing a signal to **invest in lower emissions intensity of production.**

Links to other policies

Incentive policies can be a powerful driver of business decisions, and create the incentive for manufacturers to invest in new production methods and technologies. However, they need to be supported by policies which enable **infrastructure and deployment** and **efficiency and carbon intensity reductions**.

Policy example: the UK ETS

As an emissions trading scheme, the UK ETS operates on a “cap and trade” principle. Overall allowances limit the total amount of GHG that can be emitted by the sectors covered by the scheme (energy-intensive industries, power generation, and aviation), with this cap reducing over time. Participants receive some free allowances and are able to buy and sell allowances, which imposes a price on carbon emissions.

Source: Frontier Economics

Excess carbon emissions are a negative externality, a form of market failure. In the absence of an explicit carbon price, the cost of carbon emissions to manufacturers will be too low, leading to an over-supply of emissions. Implementing a market-based measure such as an emissions trading scheme (ETS) can resolve this market failure and increase the cost of emissions, providing a clear signal to decarbonise. Market-based measures in the UK are the UK ETS, the Carbon Price Support (CPS) mechanism, and the Climate Change Levy (CCL).

Outside of market-based measures, demand-side measures can also create an incentive to decarbonise. Further demand-side measures are planned to be introduced in the UK in the mid-2020s, with demand-side measures including tools such as product standards, green product labels, and public procurement. These serve to create markets for low carbon products, providing an incentive for manufacturers to decarbonise to meet this demand.

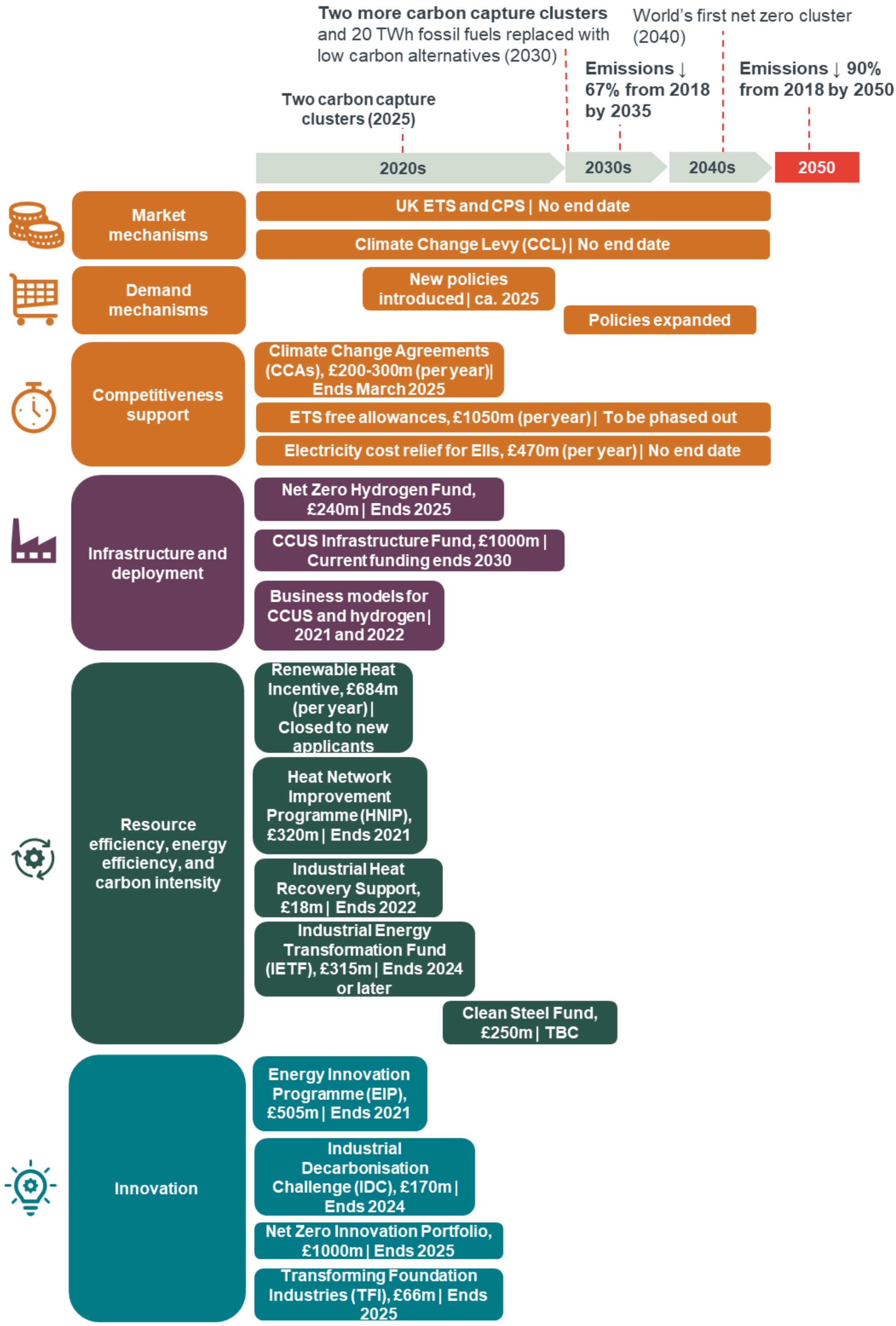
However, businesses need time to adjust to these signals. For example, it takes time to respond to a higher carbon price as businesses need to invest in deploying new assets and technologies. Competitiveness support policies can help to prevent harm to competitiveness as production costs increase relative to international manufacturers who may not face the same carbon costs, and allow adequate profitability in the short run to invest in new assets. This type of policy includes UK ETS free allowances, Climate Change Agreements (CCAs), and electricity cost reliefs for some energy-intensive industries (EIIs).

2.3 Industrial policy and the decarbonisation timeline

The main policies in place are summarised in Figure 12. Overall, billions of pounds of funding is already in place to support industrial decarbonisation in the UK – a significant step in the right direction. Most existing policies targeted at innovation, infrastructure, and improving efficiency and carbon intensity are due to come to an end by 2025, although market-based measures extend beyond that. The most ambitious reduction targets come after the conclusion of most of the currently announced policies, with a targeted drop of 67% in industrial emissions by 2035 and of 90% by 2050.

As a result, to achieve these targets, these policies will likely need to be extended, expanded, or replaced as emissions targets continue to become more restrictive. Manufacturers need to make long-term investments in the coming years in order to decarbonise and replace existing equipment and will require infrastructure such as carbon capture and hydrogen networks to make these investments commercially viable. Expanding existing policies and adapting new ones where necessary will be an important means of enabling these investments and addressing the remaining barriers to decarbonisation.

Figure 12 Policy landscape and timelines



Source: Frontier Economics, based on the UK's Industrial Decarbonisation Strategy (2021).

Note: Monetary values, where indicated, represent approximate cost to government for industrial support. Except where indicated to be annual costs, costs represent the total cost of the programme.

2.4 The wider policy context

Industrial decarbonisation policy is an important part of wider government objectives and policy. Correctly implemented, decarbonisation policy can be a cost-effective way of reducing industrial emissions while also delivering significant economic benefits. In particular, decarbonisation policy can support innovation, supply chain growth, and job creation in regions across the UK and can enhance UK exports by enabling manufacturers to better compete in markets for low carbon goods and adapt to rising carbon prices. This is the core of the UK's Ten Point Plan for a Green Industrial Revolution and a key part of the levelling up agenda.

Decarbonisation policy can support the UK's broader economic objectives

Investments which help UK industry to decarbonise can also be key drivers of growth in jobs in regions that have been harmed by past de-industrialisation. For example, developing 5GW of low carbon hydrogen production capacity could create 8,000 jobs in the UK by 2030 and as many as 100,000 by 2050, particularly in key industrial areas like the North East.[32] Advancing offshore wind could support up to 60,000 jobs by 2030.[33] Investing in CCUS could support around 50,000 jobs by 2030.[34] Overall, a Green Industrial Revolution could support up to 250,000 green jobs in the UK.[35]

More generally, these policies have the potential to significantly enhance the competitiveness of UK industry abroad

As markets for green products develop overseas, being able to serve these markets will be a significant advantage. Industry stakeholders indicated that many of these investments will also improve overall industrial efficiency, reducing the marginal costs of production and improving UK manufacturers' ability to compete abroad. There is also the potential for the UK to become a key exporter of technology and innovation, helping other countries to meet their decarbonisation goals while providing important jobs domestically.

All of this is closely tied to the UK's levelling up agenda, and decarbonisation policy can be used to support this objective. The costs of decarbonisation policies need to be evaluated not just against the emissions reductions which they bring but also against the substantial potential economic benefits they can yield.

Impacts of policies can be enhanced through international cooperation

The UK also has an important role to play on the world stage as a major industrialised country. The UK can use its own net zero ambitions and policies to encourage other nations to adopt ambitious targets and decarbonise themselves. The upcoming United Nations Framework Convention on Climate Change, Conference of the Parties (COP 26) is a major opportunity to do so. Many of these issues will require international collaboration; for example, a carbon border adjustment mechanism (CBAM) is likely to be far more effective (and feasible) with broad international cooperation than it would be for any country acting in isolation.

Overall, industrial decarbonisation in the UK is an important part of the UK's wider goals for a Green Industrial Revolution and the levelling up agenda. The UK is also in a position to encourage other countries to adopt similarly ambitious decarbonisation targets, which would

[32] HM Government, *The Ten Point Plan for a Green Industrial Revolution* (November 2020, page 11).

[33] HM Government, *The Ten Point Plan for a Green Industrial Revolution* (November 2020, page 9).

[34] HM Government, *The Ten Point Plan for a Green Industrial Revolution* (November 2020, page 23).

[35] HM Government, *The Ten Point Plan for a Green Industrial Revolution* (November 2020, page 3).

serve both to increase the likelihood of the world meeting the Paris Agreement's commitments and enhance the effectiveness of the UK's own decarbonisation policies.

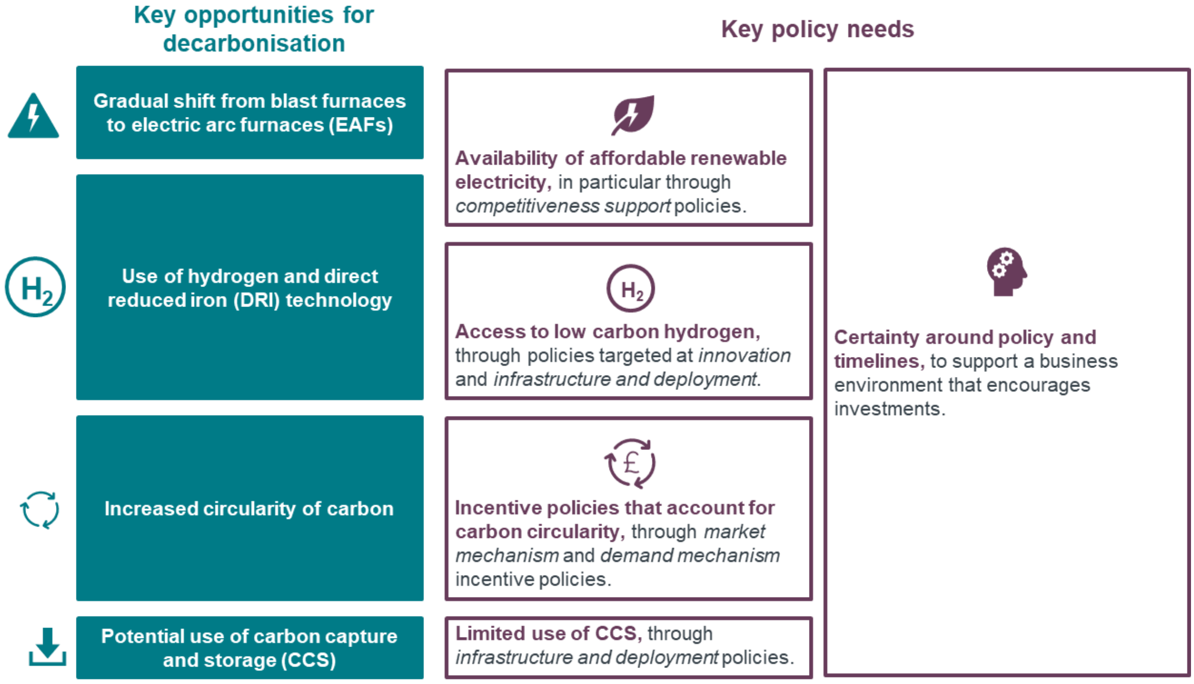
3 DECARBONISATION OF STEEL PRODUCTION IN INDUSTRIAL CLUSTERS

This section explores the opportunities for decarbonisation in the steel sector and the policies needed to achieve this as well as the potential implications for competitiveness and the decarbonisation timeline. It draws on discussions with industry experts and additional literature review.

Some steel production, in particular electric arc furnace (EAF) production, currently occurs at dispersed sites. However, the overwhelming majority of production and emissions are located in industrial clusters, with over 90% of steel sector emissions generated in the South Wales and Humber clusters alone.[36] Overall, steel emissions make up nearly a third of industrial cluster emissions.[37] As a result, the needs of the steel sector are key to informing the needs of clustered sites in general.

Figure 13 below sets out the key opportunities and policy needs of the steel sector. These are explored further in the remainder of the section.

Figure 13 Summary of key opportunities and policies for UK steel decarbonisation



Source: *Frontier Economics*

3.1 Background on industry

The UK steel sector is a relatively small part of overall UK manufacturing but is a significant source of emissions in industrial clusters.

[36] From the Climate Change Committee's (CCC) N-ZIP model.

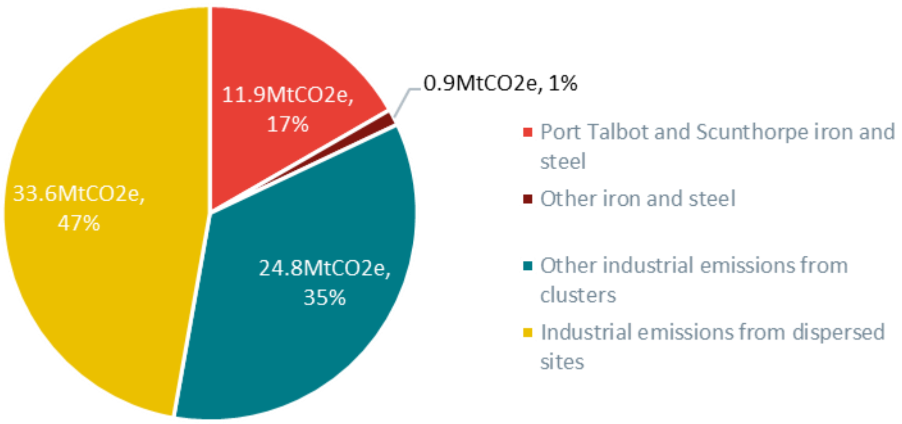
[37] For more information, see the UK's *Industrial Decarbonisation Strategy* (2021). Steel production is largely located in Port Talbot and Scunthorpe, and iron and steel emissions account for 12 $MtCO_2e$ out of total clustered emissions of 37.6 $MtCO_2e$.

In 2019, the UK produced 7.2 million tonnes of crude steel, equal to 0.4% of the world's total steel production and far less than major steel producers like China (which produced 1 billion tonnes) and other European countries such as Germany (which produced 40 million tonnes).[38]

The UK steel industry generated £1.97 billion in economic output in 2020, equal to 1.2% of UK manufacturing output, and supported 33,400 jobs in the UK.[39] However, steel jobs are largely located in a few key areas, with 52% of steel industry employees located in Wales or Yorkshire and Humberside, due to the large steel clusters located there.[40] These jobs also pay well, with the steel salaries in these regions 45% higher than the average salary.[41] This makes the steel industry an important part of the UK's levelling up ambitions. With the right policy context, industrial decarbonisation could also be an opportunity to grow the UK's market share of global steel production and create additional jobs in the UK.

The steel sector accounts for roughly 17% of the UK's overall industrial emissions, with over 90% of steel emissions generated at the Port Talbot and Scunthorpe steel sites in the South Wales and Humber clusters respectively. This is illustrated in Figure 14 below.

Figure 14 UK steel sector emissions relative to total industrial emissions



Source: Frontier Economics, based on CCC N-ZIP model prepared by Element Energy. Derived from 2017 NAEI emissions data.

There are existing and upcoming policies which are helping the steel sector to transition towards net zero. These include:

- efficiency programmes such as the IETF which will provide funding for steel producers to invest in low carbon technologies;
- infrastructure programmes such as the Net Zero Hydrogen Fund, providing capital for low carbon hydrogen investments; and
- the steel sector-specific Clean Steel Fund, which will assist the steel sector with its transition.

Industry stakeholders indicated that the existing policy support framework generally covers their key areas of need. However, more support will be needed to create a business

[38] World Steel Association, *Steel Statistical Yearbook 2020* (2020).

[39] House of Commons Library, *UK Steel Industry: Statistics and Policy* (2021, page 7).

[40] House of Commons Library, *UK Steel Industry: Statistics and Policy* (2021, page 9).

[41] UK Steel, *Key Statistics Guide* (2021).

environment conducive to investment and to enable steel manufacturers to take advantage of key opportunities for decarbonisation.

3.2 Key opportunities for decarbonisation

The steel industry expects that decarbonisation will take place through some combination of the following technologies:

- greater use of hydrogen and direct reduced iron (DRI) technology;
- a gradual transition from blast furnaces to EAFs;
- increased circularity of carbon; and
- carbon capture and storage (CCS).

The overall pathway to decarbonisation is likely to involve improving energy efficiency and reducing emissions at existing blast furnaces in the short term (including through use of DRI and increased circularity of carbon) and a longer-term transition towards EAF and hydrogen DRI production. There is also some scope for support from CCS. These opportunities are linked – CCS, in particular, can play a role in the creation of blue hydrogen for use in the production of hydrogen DRI, and hydrogen DRI can be used in EAF furnaces. There is no single technology that will decarbonise the steel industry, and the opportunities listed are not exhaustive. However, taken together these provide a clear and achievable path to decarbonisation.

Switching to these new technologies and replacing old production equipment can also have significant economic benefits for the steel industry alongside reducing emissions. Past OECD analysis found that the top 5% of steel producers are more than four times more productive than the average steel plant, based on estimates that take into account both labour and capital intensity.[42] Investing in new technologies which reduce carbon intensities can therefore also have a significant positive impact on UK steel's competitiveness.

Opportunity 1: gradual shift from blast furnaces to EAFs

A gradual shift towards EAFs as blast furnaces reach the end of their lifetimes is likely to be a primary means of decarbonisation in steel. Approximately 78% of UK steel output is currently produced using carbon-intensive Basic Oxygen Furnaces (BOFs).[43] EAF production is much less carbon intensive than BOF production,[44] and steel can be produced using EAF technology from scrap metal or DRI. EAF production involves large volumes of electricity, and therefore access to plentiful supplies of low cost, low carbon electricity is an important part of minimising the overall carbon intensity of production and ensuring that EAF is commercially viable. This will also require access to large amounts of scrap metal.

EAF production can also be combined with hydrogen DRI in the long term, reducing the emissions intensity of steel production by approximately 99% compared to current BOF technology.[45]

[42] DSTI Steel Committee, *Research and Development, Innovation and Productivity Growth in the Steel Sector* (March 2016).

[43] World Steel Association, *Steel Statistical Yearbook 2020*.

[44] Toktarava et al., *Pathways for Low carbon Transition of the Steel Industry – A Swedish Case Study*, Energies (2020).

[45] Toktarava et al., *Pathways for Low carbon Transition of the Steel Industry – A Swedish Case Study*, Energies (2020).

Opportunity 2: use of hydrogen and DRI technology

Hydrogen DRI used with EAF will play a critical role in steel decarbonisation in the longer term. This technology is not immediately available for UK production and will require further research and technical adaptation. Several factors need to be in place for this technology to be viable, including availability of low carbon hydrogen, availability of affordable renewable energy (to produce hydrogen and power the DRI process), and reliable access to iron ore.

Despite these current limitations, multiple industry experts highlighted hydrogen DRI as a key opportunity for decarbonisation going forward. For example, many organisations expressed significant interest in government support for a hydrogen-based steelmaking pilot in the UK due to the market opportunities this would create. This is particularly important given that hydrogen-based steelmaking is increasingly moving towards commercialisation internationally:

- The world's first hydrogen-based DRI plant is planned to be operational in China in 2021;[46] and
- Swedish steel producer SSAB's Hybrit programme in Sweden is aiming to have a demonstration plant in place to produce DRI using hydrogen in 2025 and use this to produce fossil-free steel in 2026.[47]

Emissions from hydrogen DRI are anticipated to be low, currently estimated at 0.025 tonnes of CO_2 per tonne of steel produced, compared to 1.6 to 2.2 tonnes of CO_2 per tonne of steel produced by BOFs.[48] Importantly, **DRI is compatible with both BOFs and EAFs, and allows for a gradual transition towards decarbonisation in steel as the sector moves away from blast furnaces.**[49]

Availability of low carbon hydrogen is also important for alternative routes which rely on continued use of blast furnaces. ArcelorMittal's zero carbon pathway includes use of hydrogen in BOFs post 2030,[50] although technical constraints prevent a 100% hydrogen fuel mix being used in blast furnace steel production.[51]

Opportunity 3: increased circularity of carbon

A more circular approach to carbon can also be used to reduce emissions intensity. For example, ArcelorMittal launched a Torero demonstration programme in Belgium in 2018 which converts waste wood into biocoal for use in iron ore reduction in place of fossil fuels.[52] Carbon capture and utilisation (CCU) also represents an opportunity for steel decarbonisation: ArcelorMittal is also pursuing a project jointly with LanzaTech to capture carbon offset products and convert them into chemicals products.

46 MPIUK, *Decarbonisation of the Steel Industry in the UK*.

47 https://www.ssab.com/company/sustainability/sustainable-operations/hybrit-phases

48 Toktarava et al., *Pathways for Low carbon Transition of the Steel Industry – A Swedish Case Study*, Energies (2020).

49 MPIUK, *Decarbonisation of the Steel Industry in the UK*.

50 https://corporate-media.arcelormittal.com/media/yw1gnzfo/climate-action-in-europe.pdf

51 https://bellona.org/news/climate-change/2021-03-hydrogen-in-steel-production-what-is-happening-in-europe-part-one

52 ArcelorMittal, *Climate Action Report 1* (May 2019). Note that, in general, waste wood needs to be tightly define to reduce risks of unintended, adverse environmental impacts from wood which is not waste being used in the production process.

Innovative approaches which take a circular approach to carbon can be meaningful drivers of emissions reductions. These types of innovations can provide intermediate steps in the lead-up to full EAF hydrogen DRI production, and act as powerful emissions reduction methods in their own right.

Opportunity 4: potential use of CCS

Carbon capture and storage (CCS) is also an option for reducing emissions in the steel sector, particularly for capturing the last 10% to 15% of hard-to-abate residual emissions from EAFs. Carbon capture technology can be attached directly to existing technologies. While carbon capture is more complicated for EAF production due to the open nature of the furnaces, it is relatively straightforward to implement at blast furnaces and can be used to reduce emissions for these producers without having to change existing assets. As a result, CCS is likely to be more of an option for older, "legacy" plants and is not a primary focus, according to industry experts. There are also some concerns that CCS may risk locking manufacturers into inefficient technologies due to the incentives it creates.[53]

Although the scope for use of CCS at steel manufacturing plants in the UK may be limited overall, CCS is still important for enabling other opportunities for decarbonisation. For example, CCS is necessary for the creation of blue hydrogen, which can be used to produce DRI and reduce emissions. As a result, even though there may be limited opportunities for direct use of CCS to capture emissions at steel sites in the UK, its availability can still support broader decarbonisation in the steel sector.

3.3 Key policy needs

Steel industry stakeholders engaged as part of this study were broadly positive about the government's existing steel decarbonisation policies. They indicated that there were no major gaps and that existing government policy largely addressed key areas of need but that **what is needed for steel manufacturers located in industrial clusters is increased support within the existing policy framework.** In particular, policy needs to be developed further to support:

- **Availability of affordable renewable electricity.** This can take the form of policies that shift the burden of policy and network costs off of industrial electricity bills.
- **Access to low carbon hydrogen.** This can be supported by policies such as CfDs for low carbon hydrogen.
- **Certainty around policy and timelines.** In general, this requires clear sign-posting by policymakers, but can also be supported by policies such as CfDs and increased coordination across different levels of government.
- **Incentive policies that account for carbon circularity.** This involves ensuring policy is sufficiently technology neutral to ensure recycling and re-use are taken up where appropriate.

[53] MPIUK, *Decarbonisation of the Steel Industry in the UK* (March 2021).

These policies are all part of a broader framework which supports a strong business environment and incentivises investment in the main opportunities for decarbonisation. Given the cost of some of the investments to be made, there is also likely to be a need for some degree of government co-investment or support through policies. However, the key need is a business environment which incentivises efficient investment and decarbonisation. The policy needs explored in this section have been used to inform the overall recommendations in Section 6.

Policies that support availability of affordable renewable electricity

Access to affordable renewable electricity is crucial for the steel industry's decarbonisation pathways, and major steel manufacturers in the UK have identified reducing electricity prices as their highest priority. There are a number of policies which could be used to achieve this; electricity costs for producers can be reduced through competitiveness support projects such as the UK's ongoing electricity relief for EIIs or through implementing measures such as higher renewable levy exemptions or additional network cost reductions.[54] **Alternatively, policy costs related to renewables could be shifted from electricity bills to gas bills in order to increase incentives for electrification,** with a need for interim support for sectors highly reliant on gas to ensure their competitiveness is not negatively impacted over the course of the transition.

The UK is also continuing to invest in increased renewables production to ensure that renewable electricity is available as demand increases. However, short-term support with respect to electricity costs and a long-term commitment to the availability of renewable electricity are critical for the steel sector's decarbonisation goals. Further recommendations for increasing the affordability of renewable electricity in the UK are explored in *Managing Industrial Electricity Prices in an Era of Transition*, a report commissioned from UCL by the Aldersgate Group. Key recommendations include restoring an efficient investment framework for the cheapest mature renewables and establishing a long-term, zero carbon electricity contracts market.

High electricity prices entail higher variable costs of production, limiting the incentive to invest in electrification

The cost of electricity is an ongoing constraint on UK industry; **UK steel producers paid on average £46.60/MWh in 2020/21, nearly double what manufacturers in France (£28.74/MWh) and Germany (£25/MWh) pay**.[55] This is primarily driven by differences in the recovery mechanisms for network and policy costs, with the cost recovery approach taken in Germany and France reducing the cost for large industrial consumers to a much greater degree than the approach taken in the UK.[56] Overall, these higher costs have led UK steel manufacturers to incur substantial additional electricity costs when compared to key competitors. The UK steel sector incurred

[54] UK Steel, *Closing the Gap: How Competitive Electricity Prices Can Build a Sustainable Low Carbon Steel Sector* (February 2021).

[55] UK Steel, *Closing the Gap: How Competitive Electricity Prices Can Build a Sustainable Low Carbon Steel Sector* (February 2021).

[56] See UCL, *Managing Industrial Electricity Prices in an Era of Transition* (2021).

£256 million in additional costs from this electricity price disparity compared to Germany between 2016 and 2021.[57]

Due to the competitiveness of the steel industry, steel producers have difficulty passing these costs on to consumers. This creates a notable disincentive to investing in technologies such as EAF and hydrogen DRI, which require significant electricity capacity, as a high electricity cost would inflate the variable costs of production for these production methods. As a result, even if these technologies are viable at a higher price, an inflated electricity price reduces the incentive to invest and the expected return on this investment.

These high prices constrain margins, reducing capital available to invest

As UK steel manufacturers are constrained in their ability to pass on input costs to consumers, high electricity prices also limit their profitability. This is a significant barrier to investment in new and risky technologies, particularly in those for which it may be difficult to attract third party funding due to their unproven nature. This is compounded by rising carbon costs, which further reduce profitability and the ability to invest for firms that are at the inefficient end of carbon intensity. Lower electricity prices would make UK manufacturers more competitive with their counterparts abroad and allow them to earn a higher margin which may allow for additional capital investments.

Large amounts of renewable electricity are required for critical technologies

EAF and hydrogen DRI both require significant electricity capacity, which may require updates to the electricity grid near industrial sites. Transitioning current blast furnace production to hydrogen DRI with EAF would require more than 20 TWh of electricity, equivalent to 17% of all renewable electricity currently produced in the UK.[58] Other available estimates indicate that electrifying integrated sites or switching to green hydrogen-based steel production would increase electricity demand by more than 300% and 800% respectively.[59] While these technologies can be powered with non-renewable electricity, using non-renewable electricity would lead to additional emissions from electricity generation and limit overall carbon emission reductions.

Overall, if significant renewable electricity capacity is not available, manufacturers could be put in a position where they are unable to adequately respond to signals such as rising carbon prices.

H_2 Policies that support access to low carbon hydrogen

Low carbon hydrogen is critical in the long term for enabling fuel switching and hydrogen DRI in the UK steel sector. While existing support is available through policies such as the Net Zero Hydrogen Fund, this should be further supported through the hydrogen business model to be published in 2022 and levers such as Contracts for Difference (CfDs), which provide certainty surrounding supply.

[57] UK Steel, *Closing the Gap: How Competitive Electricity Prices Can Build a Sustainable Low Carbon Steel Sector* (February 2021).

[58] MPIUK, *Decarbonisation of the Steel Industry in the UK* (March 2021) and Vogl et al., *Assessment of Hydrogen Direct Reduction for Fossil-Free Steelmaking* (2018), Journal of Cleaner Production, 203.

[59] UK Steel, *Closing the Gap: How Competitive Electricity Prices Can Build a Sustainable Low Carbon Steel Sector* (February 2021).

Steel manufacturers need access to hydrogen to enable key decarbonisation opportunities such as hydrogen DRI

Hydrogen DRI is still a nascent technology, and industry stakeholders indicated that more research will be required before it can be commercialised. Existing production sites may also need to relocate to sites with the available infrastructure for hydrogen technology. As a result, manufacturers need confidence that they will have access to hydrogen in order to make potentially risky investments in R&D and/or plant and machinery.

Not every steel site located in an industrial cluster necessarily needs access to hydrogen. One option is for a DRI facility to be built separately in a suitable location near a hydrogen producer (such as in a cluster that features chemicals production), with industry then sharing the costs of developing hydrogen DRI technology. Overall, there are a number of specific forms that policy could take, building upon the UK's existing hydrogen infrastructure policies. However, if the steel sector is to decarbonise and remain competitive in the long term, low carbon hydrogen will be a key input need.

Certainty around policy and timelines

Substantial investment is needed in the UK steel sector in order to decarbonise. Adapting or replacing existing blast furnace facilities will be expensive – industry stakeholders have indicated that approximately £6 billion in investment would be needed to decarbonise the UK steel industry (excluding additional investments such as hydrogen networks). Moreover, this transition needs to start happening in the near future if the UK is to meet its industrial decarbonisation goals. Industry needs time to adapt both in terms of identifying which technologies are most viable given the resources at their disposal and in order to avoid consequences such as sudden shocks to regional employment. Depending on the decarbonisation pathway pursued, employees may need time to retrain or relocate, and timelines need to be built in to enable companies and employees to adapt to these changes.

Steel producers therefore need to know when key infrastructure will be in place, how prices of key inputs such as electricity, hydrogen, and carbon might evolve, and not be faced with unexpected policy shocks. This does not mean that all policies between now and 2040 need to be announced today, or that all funding needs to be made available immediately. However, manufacturers need to have a clear sense of the business environment they will be operating in if they are to make major investments. Without this, they risk making investments in inefficient plant machinery which become stranded assets unsuited for the UK steel sector's future operating environment.

Steel producers need to know when key infrastructure will be available

In particular, steel companies need to know whether (and when) they might have access to key infrastructure such as hydrogen and CCUS networks in order to plan major investments. Hydrogen is an unknown, both in terms of availability and cost, and Britain's Hydrogen Network Plan does not have hydrogen consistently available within clusters until 2040.[60] **This uncertainty effectively increases the expected cost of these investments, as companies that make an investment today need to price**

[60] ENA, *Britain's Hydrogen Network Plan* (December 2020).

in the risk of crucial infrastructure not being available in time. This creates a disincentive to invest in innovative technologies and may skew investment towards less efficient methods. Policies such as CfDs for low carbon hydrogen and CCUS networks could assist with this, as could increased coordination across different levels of government and government departments. In general, a strong policy signal will offer a clear trajectory for investment in infrastructure, which in turn can lead to additional job creation.

Policy needs to avoid price uncertainty

Similarly, steel manufacturers would benefit from a clear expectation of how prices for key inputs like electricity and carbon prices will evolve. This would help them make efficient investments and prioritise technologies which are best suited to their location and needs.

Policy uncertainty creates a risk of UK industry being left behind

The UK is world leading in research but is falling behind in application due to hesitancy in deploying new technologies. Industry stakeholders highlighted the example of steel manufacturing in Sweden, which until recently was behind the UK in terms of technology and production efficiency. However, it has now advanced significantly beyond UK manufacturers due to a more ambitious pace of deployment. **To compete with increasingly innovative manufacturers abroad, the UK needs to move rapidly away from research and towards commercialisation and deployment of new technology in steel.** A more definite policy environment and clear timelines on when critical inputs and infrastructure are available could help accelerate this deployment. It could also increase opportunities for innovative UK companies to translate R&D investments into new export opportunities as markets for low carbon products develop globally.

Policy certainty can create a business environment conducive to investment

There are currently significant difficulties related to financing necessary investments. The steel industry is highly competitive and margins are low, which limits the profits available for investing in new technology and capital.[61] One option to overcome this is greater co-investment from government through programmes such as the Clean Steel Fund. However, a clear timeline for policy and availability of key infrastructure can create an overall business environment which encourages investment. Uncertainty increases risk and reducing this can be a means of unlocking additional private investment by demonstrating more certain future opportunities.

Incentive policies that account for carbon circularity

Policy often lags behind innovation, which can distort incentives and the market. This is understandable – it is difficult to ensure that policy is suited not just for the production methods and technologies in place today but also for those that are yet to be developed. However, creating a flexible policy environment is an important part of

[61] UK Steel highlighted thin margins in steel resulting from intense competition in their *Closing the Gap* report for 2021. Further evidence of low margins is seen in Tata Steel UK's annual report for the year ended 31 March 2020, which showed an operating loss of £213 million on revenues of £2,143 million (excluding restructuring, impairment, and disposal costs).

ensuring that different technologies are treated fairly and that policy keeps pace with innovation.

Flexible incentive policies can make the UK a more attractive place to invest

In particular, an increased focus on life cycle emissions and carbon circularity can encourage decarbonisation and further investment in the UK. Discussions with a major European steel producer highlighted some of the distortions imposed by the EU ETS. This is a result of chemically recycled materials not being included in the definition of waste or being considered at the same level as a biofuel due to these materials not being biogenic in nature. Using this form of waste as fuel does not result in any increase in emissions in the atmosphere; however, under the EU ETS, procurers must surrender permits in order to use it as a fuel, despite it being carbon neutral. A similar complaint has been made by Luossavaara-Kiirunavaara AB (LKAB), which is currently appealing to the European Commission over its decision to reduce LKAB's number of free allowances for using less carbon-intensive iron ore pellets as opposed to sintered ore pellets used by other steel makers.[62] This policy inflexibility creates a disincentive to use an efficient, carbon-reducing technology, which is clearly not the overall goal of an ETS.

If the UK is able to avoid issues such as this by taking carbon circularity into account in incentive policies such as the UK ETS, this can improve its attractiveness as an investment location relative to the EU.

In general, a life cycle approach to carbon can improve competitiveness and decarbonisation

Outside of incentivising investment, encouraging manufacturers to pursue efficient decarbonisation policies, regardless of specific technology, is an important means of decarbonisation. Manufacturers should not be penalised for innovating or taking a broader scope of emissions into account, as this risks distorting investment towards technologies with higher marginal costs of abatement. Ensuring incentive schemes do not disadvantage innovative, carbon-neutral production techniques can help UK steel to reduce emissions in the short to medium term as production gradually transitions towards technologies such as hydrogen DRI.

3.4 Impacts on competitiveness and economic opportunities

Decarbonisation policies can have a positive or negative impact on competitiveness and economic opportunities. They can enable manufacturers to access new markets for low carbon products and improve their productivity. However, they can also create the risk of carbon leakage if domestic carbon costs diverge from those faced by international competitors. Effective policy can minimise the risk of negative impacts, while simultaneously maximising the potential for opportunities such as access to new and growing markets.

[62] https://www.lkab.com/en/news-room/press-releases/lkab-appeals-an-eu-decision-that-harms-the-climate/

Figure 15 Competitive and economic opportunities and risks for the steel sector

Source: Frontier Economics

Demand for low carbon steel is developing in some areas

Demand for low carbon steel products is developing in some markets, particularly in the construction and automotive sectors.[63] This demand appears poised to continue growing in the future, with a number of large steel buyers already signed up to the SteelZero initiative and committed to procuring, specifying, or stocking 100% net zero steel by 2050.[64] However, in general, demand for low carbon steel is limited today, with few requests for Environmental Product Declarations for steel products. Despite their limited state at present, there is the potential for markets for low carbon steel to develop in the future, particularly if the government implements demand-side policies such as mandatory product labels or carbon border adjustments, and manufacturers do expect increasing demand for these products. As these develop, there will be a need for fixed standards or definitions of what is considered “green” or low carbon steel, and for this to be comparable across manufacturers.

Decarbonisation improves productivity

Even without significant demand for low carbon steel, decarbonisation in the steel sector can still yield significant productivity benefits. This is because the right thing to do for decarbonisation is often the right thing to do for efficiency. The most productive steel plants can be more than four times more productive (based on estimates that take account of both labour and capital intensity) than the average steel plant.[65] As a result, replacing older, carbon-intensive production plants can have a significant benefit for the UK steel sector’s productivity and competitiveness abroad, even if new product markets for low carbon goods have not yet emerged. Many of these plants will need to be replaced in the near-to-medium term as they reach the end of their asset lives, and investing in the most futureproof productivity option can have significant long-term benefits for both productivity and decarbonisation.

There may be a risk of carbon leakage if UK policy diverges from carbon prices worldwide without adequate policy support for the sector

Carbon leakage is a major concern highlighted in discussions with steel industry stakeholders. However, existing policies (including carbon pricing and free allowances) appear to mitigate this risk currently, and Frontier analysis indicates the risk of carbon leakage is likely to be low

[63] For example, Mercedes-Benz AG has taken an equity stake in Swedish start-up H” Green Steel and intends to introduce green steel in its vehicle models as early as 2025.

[64] https://www.theclimategroup.org/our-work/press/new-steelzero-initiative-receives-backing-major-businesses-ramping-demand-clean

[65] DSTI Steel Committee, *Research and Development, Innovation and Productivity Growth in the Steel Sector* (March 2016).

unless carbon prices diverge substantially or policies are discontinued.[66] However, it may become a growing risk in the long term if abatement opportunities are unavailable as carbon prices continue to rise.

The UK is a major steel importer and met an average of 61% of its steel demand through imports between 2015 and 2019 although, following the introduction of EU steel safeguard measures in July 2018, imports fell slightly to 51% of demand in 2020.[67] While the UK has been a net importer of steel in recent years, it also exports a substantial amount of steel, with exports representing, on average, nearly half of all UK steel mill deliveries between 2015 and-2019.[68] However, substantial import and export flows are not a sufficient condition for carbon leakage on its own – for carbon leakage to occur, carbon prices must diverge and have a material impact on costs and conduct in responding to this (in the form of abatement opportunities) must be limited.

There appears to be limited risk of this happening in the UK in the short term, despite key competitors in steel such as the USA, Turkey, and China having very low (or zero) carbon prices. This is due to carbon costs being a relatively small part of steel input costs in the UK, even for relatively carbon-intensive BOF production. Frontier estimates suggest that, based on 2019 data, an effective carbon price of £50 per tonne of CO_2 would represent approximately 14% of BOF input costs and 5% of EAF input costs. This means that carbon prices would likely have to diverge substantially from key competitor countries for there to be significant risk of leakage, as competitiveness of the steel sector is not fundamentally determined by carbon tax policy. This is supported by the broader literature on carbon leakage, which finds that, in general, evidence of carbon leakage in steel is low (although much of this literature considers time periods when carbon prices were low).[69]

However, this does not mean that no competitive risks exist, even if carbon pricing alone may not lead to significant leakage in the short term. As carbon prices rise over time, their importance relative to other input costs will grow. Even if there is no divergence between UK carbon prices and carbon prices abroad, if UK steel producers are unable to access the infrastructure and support necessary to reduce emissions, they will face rising costs relative to their competitors as a result of the higher emissions intensity of production. This can lead to investment leakage in the short term as large companies choose to make investments in countries other than the UK, and to carbon leakage in the longer term as UK production becomes less competitive. This would compound the already higher electricity costs faced by UK steel producers, with pass-through of these increased costs difficult in highly competitive commodity markets such as steel.

To mitigate this risk, policymakers can support decarbonisation efforts through policies that support innovation, infrastructure, and deployment, and demand-side policies that support the development of markets for low carbon products. This includes policies such as CfDs for low carbon hydrogen, which provide certainty around the availability of critical infrastructure, and changes to product standards and procurement policy which create demand for low carbon

[66] Based on Frontier estimates, carbon prices would need to increase by ca. £35/tCO_2e in order to increase the cost of BOF production in the UK by 10%, and by ca. £100/tCO_2e to increase the cost of EAF production in the UK by 10%.

[67] From UK Steel, *Key Statistics Guide 2021*. For information on EU steel safeguards (which have now been transitioned to UK specific measures), see https://www.gov.uk/government/news/steel-safeguard-measures-review-draft-recommendation-published.

[68] From UK Steel, *Key Statistics Guide 2021*.

[69] See for example Boutabba and Lardic, *EU Emissions Trading Scheme, competitiveness and carbon leakage: new evidence from cement and steel industries,* Annals of Operations Research, 255 (2017), and Branger et al., *Carbon leakage and competitiveness of cement and steel industries under EU ETS: much ado about nothing*, The Energy Journal, 37 (2017).

products. In the short run, policymakers can also implement shielding policies (including free allocations or CBAMs) which take account of broader emissions such as those from transport, ensure steel manufacturers have opportunities to abate emissions, and limit divergences in factors such as electricity costs between the UK and key competitors. These shielding policies can help manufacturers during the transition to low carbon production, but they should be phased out gradually as additional policies are developed and opportunities for abatement materialise in order to avoid reducing incentives to decarbonise.

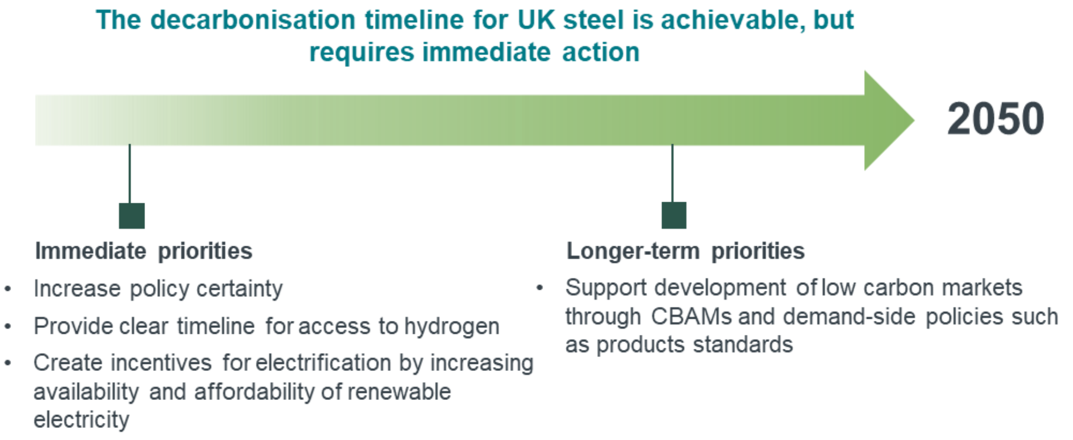
Action should be coordinated across different sites and sectors to avoid distortions to domestic production

Major infrastructure will be rolled out gradually, starting with a subset of clusters – the first two carbon capture clusters are targeted for 2025, while the hydrogen network is also intended to be extended gradually to different clusters between now and 2040.[70] This creates a risk of steel manufacturers in one cluster gaining an advantage over steel manufacturers in another cluster (or in dispersed sites) due to different availability of key infrastructure and funding. A similar risk exists for substitution between products. Glass, steel, and cement all compete to a degree in the construction industry; policies which advantage one at the expense of another may lead to unintended distortions.

3.5 Timelines

In general, industry stakeholders expressed that the decarbonisation timeline for steel is perfectly feasible, with the condition that the required infrastructure is in place and funding is available. In theory, technology could be changed to be largely carbon neutral in a few years' time. This requires key infrastructure, access to the land needed to build new facilities or expand existing ones, and significant investment, but overall the timeline is not challenging if immediate action is taken.

Figure 16 Decarbonisation timeline for the steel sector



Source: Frontier Economics

Policies should be implemented in the near term to enable longer-term decarbonisation

Without immediate action from government, the steel sector may be unable to pursue key decarbonisation opportunities, which leads to both a risk of falling behind key competitors internationally in terms of emissions intensity of production and a risk of making sub-optimal

[70] See ENA, *Britain's Hydrogen Network Plan* (December 2020).

investments that lead to stranded assets. This has already happened with Sweden, which was behind the UK in terms of steel production efficiency until approximately 2018 but has now surpassed the UK in its capabilities. Sweden announced its intention to produce low carbon steel by 2026, which will allow it to serve an emerging market for green steel (Mercedes, for example, has announced its intention to switch to green steel in 2026). Given that the UK Green Steel fund does not start until 2023, this creates a risk of falling further behind.

Delays in investment exacerbated by a lack of policy certainty could have significant competitive consequences as demand for green products grows and policies such as CBAMs are introduced, raising costs for relatively inefficient producers. To avoid this, steel industry stakeholders require clarity regarding government policy and the availability of infrastructure and alternative fuels such as low carbon hydrogen.

If immediate action is not taken to set out a clear policy plan and timeline for decarbonisation, there is a risk that investments will be made in inefficient technologies

Decarbonising UK steel production will require significant investments. Market players currently face uncertainty about which technologies to invest in, which risks significant sunk costs as investments last for decades. This creates both a risk and an opportunity – if policy enables UK steel producers to get the timing right, they can replace old capital with efficient new investments and improve both their productivity and carbon intensity. However, if action is not taken, investment may be made in technologies and infrastructure that turn out to be sub-optimal, limiting industry’s competitiveness going forward.

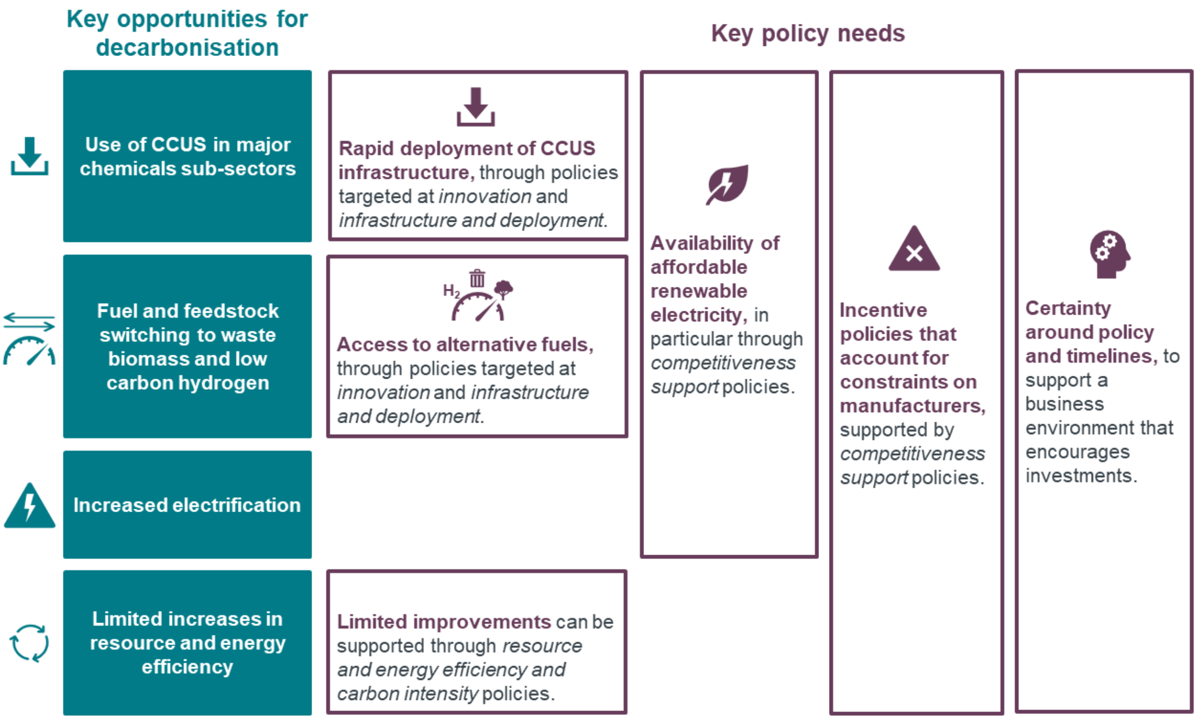
4 DECARBONISATION OF CHEMICALS PRODUCTION IN INDUSTRIAL CLUSTERS

This section explores the opportunities for decarbonisation in the UK chemicals sector and the policies needed to achieve this, as well as the potential implications for economic opportunities and competitiveness and the decarbonisation timeline. It draws on discussions with industry experts and additional literature review. Discussions with industry experts were primarily focused on ammonia production. However, some conclusions are applicable to the wider sector.

Chemicals are produced both at clustered and dispersed sites, but the significant majority of chemicals production and emissions are located in industrial clusters. Overall, chemicals emissions in industrial clusters make up over 20% of industrial cluster emissions.[71] As a result, the needs of the chemicals sector are key to informing the needs of clustered sites in general.

Figure 17 sets out the key opportunities and policy needs of the chemicals sector. These are explored further in the remainder of the section.

Figure 17 Summary of key opportunities and policies for UK chemicals decarbonisation



Source: *Frontier Economics*

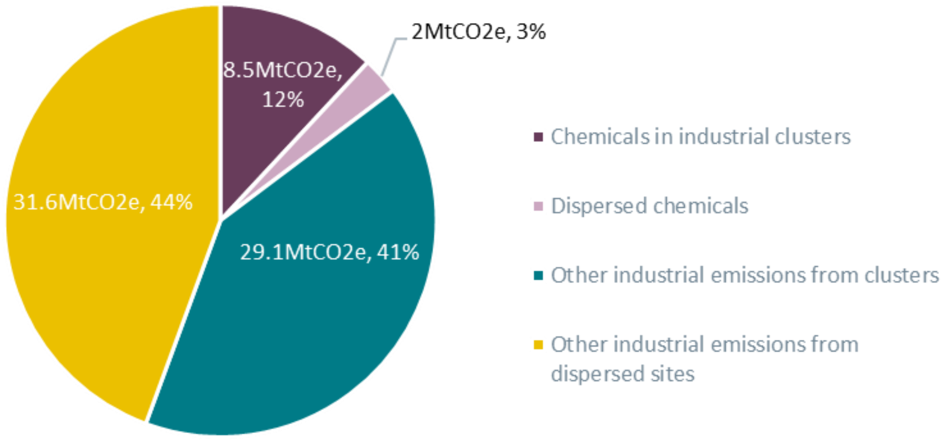
4.1 Background on industry

The UK chemicals sector is a major part of both UK manufacturing and UK industrial emissions. While chemicals manufacturing occurs both in industrial clusters and dispersed sites, the significant majority of chemicals emissions occur in industrial clusters, as illustrated in Figure 18. Chemicals manufacturing in industrial clusters occurs largely at the Teesside,

[71] Based on analysis of Element Energy's N-ZIP model and the UK's *Industrial Decarbonisation Strategy* (2021).

Grangemouth, Humberside, and Merseyside clusters, with chemicals forming the core of the Teesside and Grangemouth clusters.

Figure 18 UK chemicals sector emissions relative to total industrial emissions



Source: *Frontier Economics, based on CCC N-ZIP model prepared by Element Energy. Derived from 2017 NAEI emissions data.*

The chemicals sector is diverse. Chemicals production uses a wide range of production techniques and includes manufacturers operating large-scale continuous plants producing millions of tonnes per year of bulk product as well as small plants producing small batches of speciality chemicals and intermediaries.[72] The range of products from the UK chemicals sector includes ammonia, ethylene, propylene, butadiene, aromatics, and more.[73] Many chemical products are used as intermediaries in a variety of other sectors, including food and drink, energy, automotive, and construction.[74] For example, ammonia is primarily used to produce fertilisers for agriculture, but can also be used in the manufacture of plastics, adhesives, and as a fuel.[75] Ethylene is similarly used to produce a wide range of downstream products, including plastics for use in food and drink packaging, polyester for textile manufacturing, synthetic rubber for use in tyres for the automotive industry, and vinyl for use in PVC pipes and clothing.[76]

The production process differs substantially between different chemical products, with the manufacturing of some products such as ammonia resulting in much higher purity CO_2 emissions than other chemical products. As a result, the precise decarbonisation journey will vary depending on the chemical product – for example, electrification of heat may be a viable decarbonisation opportunity in ethylene production but may hold much less promise in the decarbonisation of ammonia (where CCS is a significantly more important opportunity).[77]

All of this contributes to a highly varied sector which is very important to the UK economy – the UK chemicals sector contributed £10.4 billion in GVA to the UK economy and employed

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72 Griffin et al., *Industrial Energy Use and Carbon Emissions Reduction in the Chemicals Sector: A UK Perspective*, Applied Energy, 227 (2018).

73 Ibid.

74 DNV GL, *Industrial Decarbonisation & Energy Efficiency Roadmaps to 2050: Chemicals* (March 2015, page 11).

75 https://www.ceps.eu/wp-content/uploads/2014/01/Ammonia.pdf

76 https://www.afpm.org/newsroom/blog/ethylene-worlds-most-important-chemical

77 McKinsey, *Decarbonization of Industrial Sectors: The Next Frontier* (June 2018).

109,000 people in 2018, with this rising to £18.3 billion and 155,000 respectively when including pharmaceuticals production.[78]

There are existing and upcoming policies which are helping the chemicals sector to transition towards net zero. These include policies such as the IETF, which provides funding for manufacturers to invest in low carbon technologies, and the CCUS infrastructure fund, which is helping to deploy carbon transport and storage networks in industrial clusters in the UK. While industry stakeholders expressed that the overall policy framework in the UK covers the areas needed to support decarbonisation, they highlighted that more support will be needed to create a business environment conducive to investment and accelerate deployment of critical infrastructure and technologies.

4.2 Key opportunities for decarbonisation

The precise opportunities for decarbonisation will depend heavily on the individual chemical products, with some technologies much better suited to some types of production than others. However, overall decarbonisation in the chemicals sector will take place through some combination of the following technologies:

- CCUS, particularly for production methods that result in high purity CO_2 emissions;
- Fuel and feedstock switching from fossil fuels to waste biomass and low carbon hydrogen;
- Increased electrification, particularly for generating heat and for electrolysis; and
- Further limited increases in resource and energy efficiency.

Overall, while there is no one technology that will decarbonise chemicals production, the overall pathway to decarbonisation is likely to involve improving energy and resource efficiency as well as use of CCUS in the short to medium term, with a longer-term transition towards increased electrification and use of low carbon fuels and feedstocks.

Opportunity 1: use of CCUS in major chemicals sub-sectors

CCUS will play a significant role in the decarbonisation of the chemicals sector. Analysis on deep decarbonisation pathways produced by Element Energy on behalf of the CCC, shows that CCS will likely be the single largest source of emissions abatement for the refining and chemicals industries after reductions in demand for high carbon products.[79] Similarly, a previous decarbonisation roadmap prepared for the UK Government found that CCS could account for over 40% of all emissions reductions in 2050 when compared to 2012 in a maximum technology availability scenario.[80] There is also evidence that CCU can be used to reduce emissions by using captured CO_2 as a feedstock for further production, although this may involve significantly larger electricity capacity requirements than CCS.[81]

However, the chemicals sector is highly heterogeneous, and CCUS will be simpler for some chemical products than others. For example, ammonia production results in high

[78] Based on UK ABS data available from the Office for National Statistics (ONS).

[79] Element Energy on behalf of the CCC, *Deep Decarbonisation Pathways for UK Industry* (2020, page 56).

[80] DNV GL, *Industrial Decarbonisation & Energy Efficiency Roadmaps to 2050: Chemicals* (March 2015, page 59).

[81] Gabrielli et al., *The Role of Carbon Capture and Utilization, Carbon Capture and Storage, and Biomass to Enable a Net-Zero-CO_2 Emissions Chemical Industry*, Industrial & Engineering Chemistry Research, 59 (2020).

purity CO_2 process emissions that can be relatively easily and inexpensively captured and stored, while the cost of capture and storage for ethylene production is expected to be significantly higher.[82] Overall, while CCUS may not be a viable abatement option for all chemicals products, it is still a major opportunity for chemicals decarbonisation.

Opportunity 2: fuel and feedstock switching to waste biomass and low carbon hydrogen

Switching fuel and feedstocks to waste biomass and low carbon hydrogen can also play an important part in the decarbonisation of the chemicals sector. Feedstocks derived from oil or natural gas are central to the production of chemical products such as ethylene and other olefins.[83] Natural gas, coal, and oil are used to produce hydrogen for ammonia synthesis.[84] Natural gas is also used extensively as a source of energy in the chemicals sector to generate steam or for direct heating.[85]

Low carbon hydrogen and waste biomass can be used as alternative feedstocks and sources of fuel, reducing emissions from chemicals production. For example, stakeholders in the chemicals sector indicated that in the longer term there are opportunities for switching to low carbon hydrogen-based fuel in ammonia production. While in the short to medium term, ammonia feedstock in the UK will continue to be natural gas (with the resulting process emissions needing to be abated by CCS), there is the potential to begin using green hydrogen feedstocks produced from electrolysis in the longer term. As a part of exploring this future opportunity, green ammonia plants around the world are trialling production using hydrogen produced by electrolysis.[86] The potential emissions reductions from fuel switching in the chemicals sector could be significant – in Scotland's chemicals sector, it has been estimated that 46% of all emissions reductions in 2045, relative to 2018, may arise from fuel switching.[87]

Opportunity 3: increased electrification

Increased electrification of processes can also play a role in decarbonising the chemicals sector. Electric technologies can be used to replace combined heat and power (CHP), boilers, and dryers used in chemicals production.[88] Electrification can also be used to generate low carbon hydrogen for use as a fuel and feedstock. Electrolysis, in particular, can be used to generate green hydrogen for use in the manufacturing of products such as green ammonia. This in turn can also provide an opportunity for the demonstration of green hydrogen production technologies to encourage investment in other sectors that would benefit from low carbon hydrogen. More generally, electrification can be combined with hydrogen to reduce fuel emissions in the chemicals sector. However, many chemicals processes require high temperatures (and hence high energy inputs).[89] As a result, the price of electricity and

[82] Element Energy on behalf of the CCC, *Deep Decarbonisation Pathways for UK Industry* (2020, page 56).

[83] Griffin et al., *Industrial Energy Use and Carbon Emissions Reduction in the Chemicals Sector: A UK Perspective*, Applied Energy, 227 (2018, page 591).

[84] https://cen.acs.org/environment/green-chemistry/Industrial-ammonia-production-emits-CO2/97/i24

[85] DNV GL, *Industrial Decarbonisation & Energy Efficiency Roadmaps to 2050: Chemicals* (March 2015, page 2).

[86] https://cen.acs.org/environment/green-chemistry/Industrial-ammonia-production-emits-CO2/97/i24

[87] Element Energy, *Deep Decarbonisation Pathways for Scottish Industries: A Study for the Scottish Government* (2020).

[88] Element Energy on behalf of the CCC, *Deep Decarbonisation Pathways for UK Industry* (2020, page 56).

[89] DNV GL, *Industrial Decarbonisation & Energy Efficiency Roadmaps to 2050: Chemicals* (March 2015, page 2).

baseload energy requirements of chemical plants currently pose a significant barrier to electrification.

Despite the current barriers, electrification has the potential to play an important role in decarbonising chemicals production in the future. Element Energy estimated that electric technologies could be the next largest source of emissions reductions after CCS in the UK refining and chemicals sectors in 2050.[90]

Opportunity 4: limited increases in resource and energy efficiency

There is also the potential for further improvements in resource and energy efficiency to reduce emissions intensity in the UK chemicals sector. Griffin et al. (2018) estimated that using the best available technology in lower olefin production could reduce emissions from these products by over 20% (although they highlighted a significant degree of uncertainty around this estimate).[91] New technologies may also lead to greater circularity of carbon for specific products – for example, manufacturers of acrylics are exploring using molecular recycling to improve their ability to recycle acrylics for re-use in the production process.[92]

However, in general, chemicals sector experts indicated that further emissions reductions from improvements in resource and energy efficiency are likely to be limited, as the available improvements have largely been implemented. This is supported by decarbonisation pathway modelling in Scotland which estimated that only 6% of the emissions reductions in the Scottish chemicals sector in 2045, when compared to 2018, would come from further efficiency improvements.[93]

4.3 Key policy needs

The chemicals industry is very diverse and manufacturers of different chemical products will have different decarbonisation roadmaps and face different sets of challenges. However, the sector as a whole needs the deployment of key infrastructure, such as carbon capture clusters, to be accelerated. The chemicals manufacturers located at dispersed sites will also need supporting infrastructure to connect to these clusters. In addition to the rapid deployment of key infrastructure, the chemicals sector requires further policy support to enable investment in decarbonisation and help manufacturers to remain competitive while key decarbonisation opportunities develop. Without this additional support, the current policy environment and timeline could put competitiveness with manufacturers internationally at risk, and could impose carbon costs which manufacturers do not have the necessary support to respond to.

Policy needs to be developed further to support:

- **The availability of affordable renewable electricity**. This can take the form of policies that shift the burden of policy and network costs off of industrial electricity bills.

[90] Element Energy on behalf of the CCC, *Deep Decarbonisation Pathways for UK Industry* (2020, page 56).

[91] Griffin et al., *Industrial Energy Use and Carbon Emissions Reduction in The Chemicals Sector: A UK Perspective*, Applied Energy, 227 (2018, page 596).

[92] https://mcc-methacrylates.com/how-can-molecular-recycling-transform-the-acrylic-industry/

[93] Element Energy, *Deep Decarbonisation Pathways for Scottish Industries: A Study for the Scottish Government* (2020).

- **The rapid deployment and availability of CCUS**. This can be supported through policies such as CfDs for CCUS as well as through clear, commercially viable business models more generally.
- **Access to alternative fuels and feedstocks, particularly waste biomass and low carbon hydrogen.** This can be supported by policies such as CfDs for waste biomass and low carbon hydrogen.
- **Certainty around policy and timelines**. In general, this requires clear sign-posting by policymakers but can also be supported by policies such as CfDs and increased coordination across different levels of government.
- **Incentive policies that account for constraints on manufacturers.** This includes free emissions allowances for manufacturers and sectors that are not currently receiving the necessary support for infrastructure deployment and technology investment. As policy support and opportunities for abatement increase, these free allowances should decline over time.

The key needs explored in this section were used to inform the overall recommendations in Section 6.

Policies that support availability of affordable renewable electricity

As is the case for steel manufacturers, chemicals manufacturers in industrial clusters also need access to large volumes of affordable, renewable electricity in order to unlock key decarbonisation opportunities and remain competitive. This could take the form of changes to electricity pricing which shift some of the policy and network costs off of industrial electricity bills and on to other areas. Further recommendations for increasing the affordability of renewable electricity in the UK are explored in *Managing Industrial Electricity Prices in an Era of Transition*, a report commissioned from UCL by the Aldersgate Group. Key recommendations include restoring an efficient investment framework for the cheapest mature renewables and establishing a long-term, zero carbon electricity contracts market.

High electricity prices entail higher variable costs of production, limiting the incentive to invest in electrification

As noted in Sub-Section 3.3**,** uncompetitive electricity prices are an ongoing constraint on UK industries looking to electrify in general. UK manufacturers are paying more for electricity than competitors in countries such as France and Germany, with analysis by UCL finding that reported UK industrial electricity prices were 44% higher than the EU average in 2019.[94] There are also differences in the recovery mechanism for network and policy costs between the UK and countries such as Germany, France, and Italy which contribute to the higher costs faced by industrial consumers in the UK.[95]

This presents a significant barrier to electrification. Chemicals experts indicated that, while electrification can be an important opportunity for decarbonisation, the cost of increased electrification in the UK is significant. This was identified as an issue for technologies such as electrolysis – while chemicals experts expressed significant interest in using electrolysis to produce hydrogen for use as a fuel and feedstock, this

[94] For more information, see UCL, *Managing Industrial Electricity Prices in an Era of Transition* (2021).

[95] Ibid.

opportunity is not currently being pursued due to the high electricity cost in the UK relative to other countries.

These high prices constrain margins, reducing available capital to invest

UK chemicals manufacturers operate in highly competitive commodity markets, constraining their ability to pass input costs to consumers. High electricity prices limit the profitability of these manufacturers, which poses a barrier to investment in new and risky technologies. The Chemical Industries Association estimated that climate policy costs on electricity were £722 million for the chemicals sector in 2019,[96] a significant cost even for a sector as large as chemicals. This is compounded by additional cost factors such as gas transmission costs and carbon pricing, which further affect UK chemicals manufacturers' competitiveness. As is the case in the steel sector, lower electricity prices would contribute to making UK chemicals manufacturers more competitive and would potentially allow for additional capital investments due to increased profitability.

Large volumes of affordable renewable electricity will unlock a range of decarbonisation opportunities

Large volumes of affordable renewable electricity are necessary for electrification in the chemicals sector due to the high temperatures and energy inputs required for production. Chemicals plants also have a high baseload energy requirement and will require significant capacity of renewables on the grid and flexibility with respect to their energy needs. However, affordable renewable electricity is required for key decarbonisation opportunities beyond increased electrification of production alone. CCS and production of green hydrogen with electrolysis both require significant amounts of renewable electricity, and the current industrial electricity price in the UK poses a significant barrier to these decarbonisation opportunities. This is likely to be a particularly significant barrier for large chemicals manufacturers located in industrial clusters due to the volumes of blue and green hydrogen required for fuel and feedstock switching.

Overall, access to significant affordable renewable electricity would open up a number of routes to decarbonisation for chemicals manufacturers in industrial clusters and would help to improve the ability of UK industry to compete with manufacturers internationally.

Policies that support rapid deployment of CCUS infrastructure

The potential role for CCUS will depend on what individual chemicals manufacturers produce and where they are located. However, CCUS is a major decarbonisation opportunity for some chemicals manufacturers – for example, production of ammonia releases high-pressure, high-concentration CO_2, which can be captured and stored very effectively. Delays in the deployment of key CCUS infrastructure have therefore slowed the decarbonisation journey for these types of producers and limited their ability to respond to carbon price signals.

The current timeline for availability of CCUS at industrial clusters will delay decarbonisation progress

[96] Chemical Industries Association, *Accelerating Britain's Net Zero Economy* (2020, page 6).

The UK Government plans to choose the locations of the first carbon capture projects in 2023.[97] Overall, the current policy timeline only supports there being four carbon capture clusters in the UK by 2030.[98]

The government's intention to establish multiple carbon capture clusters by 2030 is a significant step in the right direction for the UK chemicals sector. However, the current timeline for the establishment of these carbon capture clusters is likely to delay the progress of decarbonisation as manufacturers need to wait and see which clusters are prioritised instead of making investments today. This is a concern for many industries located in clusters. While the exact impact of this will depend on the manufacturer and the product that is manufactured, in general, chemicals experts indicated that delays in the establishment of carbon capture clusters have been a significant barrier. These manufacturers' decarbonisation efforts would benefit significantly from an acceleration of the establishment of carbon capture clusters. Moving beyond feasibility studies and starting to deploy these technologies will enable the government and the private sector to gather evidence on the decarbonisation impact of key technologies and to accelerate progress in general.

Policymakers therefore need to accelerate the deployment of CCUS infrastructure in industrial clusters and provide increased certainty around when and where this infrastructure will be available. **In particular, chemicals experts expressed interest in seeing the locations of carbon capture clusters chosen more quickly, and for four clusters to be brought online by 2025 instead of only two, as currently planned.**

Policies that support access to alternative fuels and feedstocks, particularly waste biomass and low carbon hydrogen

Switching to feedstocks and fuels derived from waste biomass and low carbon hydrogen could be a significant source of emissions reductions in the chemicals sector. As part of this, there is an opportunity for manufacturers of products such as ammonia, which produce their own hydrogen feedstocks, to begin using electrolysis to manufacture green hydrogen in the longer term. However, lack of certainty of supply of these alternative feedstocks and fuels represents a significant barrier. Policies such as CfDs can be used to increase certainty of supply of waste biomass and low carbon hydrogen, alongside existing policies such as the Net Zero Hydrogen Fund.

When designing these policies, it will be important to specify which biomass feedstocks should be used, as some (such as forest biomass) produce higher GHG emissions than coal over Paris-compliant timelines.[99] Where possible, biomass feedstocks should be purely from waste sources. More generally, policymakers such as BEIS should implement robust accounting mechanisms that capture all emissions from the

[97] *UK Industrial Decarbonisation Strategy* (March 2021)

[98] *UK Industrial Decarbonisation Strategy* (March 2021).

[99] See for example Ember, *The Burning Question: Should the UK End Tax Breaks on Burning Wood for Power?* (June 2020). As noted on page 2, burning wood releases more CO_2 per unit of electricity generated than coal. In general forest biomass cannot be assumed to be inherently carbon neutral, with its overall carbon emissions dependent on the CO_2 that is absorbed by forest growth at some point in the future.

production and use of biomass to help ensure low carbon waste biomass is being used.[100]

Lack of certainty of supply of low carbon fuels and feedstocks impedes investment

Uncertainty around availability of waste biomass and low carbon hydrogen is a major barrier to investment in fuel and feedstock switching, particularly given how significant fuel and feedstocks are to the overall cost of chemicals production.[101] Chemicals stakeholders indicated that switching to low carbon hydrogen from the grey hydrogen currently used as a feedstock is likely to be difficult for some manufacturers, as chemicals sites are heavily energy integrated and the volume of hydrogen required for production is significant. Moreover, there is currently a large degree of uncertainty around the availability and pricing of low carbon hydrogen, with a national hydrogen network not planned to be in place until the 2040s.[102] This lack of certainty of supply extends to waste biomass, where uncertainty around sufficient supply has been consistently identified as a major barrier to its adoption as a fuel and feedstock by chemicals manufacturers.[103]

The UK Government is planning to publish business models for hydrogen and a biomass strategy in 2022. The government will need to provide certainty around when these fuels will be available at different industrial clusters, as well as on how pricing and availability of these fuels will evolve and compare to existing fuels. It will also be important to connect different industrial sectors that can share waste, including through policymakers helping to match supply and demand for waste biomass.

Certainty around policy and timelines

The investment required to decarbonise the chemicals sector will be substantial. All pathways to net zero for the chemicals sector require the use of new production techniques that are estimated to cost 20-80% more when compared to current production, with this cost uplift rising to 115% for the final emissions to be cut.[104] Investment in new production techniques needs to be made imminently – large chemical plants can have asset lifetimes of 50 years[105] and, for at least some major chemicals manufacturers in the UK, 2050 is only one investment cycle away.[106] **Delays and uncertainty around infrastructure availability and general uncertainty in the policy environment will put the UK chemicals sector's ability to decarbonise and compete in a net zero world at risk.**

100 BEIS is currently exploring accounting of GHG emissions from biomass use as part of its upcoming biomass strategy – see https://www.gov.uk/government/consultations/role-of-biomass-in-achieving-net-zero-call-for-evidence. There may be scope to collaborate with other government departments, as well as countries internationally, to ensure an effective accounting method is put in place.

101 See, for example, ammonia production costs, where, in general, fuel and feedstock costs represent over half of the overall cost of production (excluding carbon pricing costs). See The Royal Society, *Ammonia: Zero-Carbon Fertiliser, Fuel and Energy Store* (2020, page 17).

102 ENA, *Britain's Hydrogen Network Plan* (December 2020).

103 DNV GL, *Industrial Decarbonisation & Energy Efficiency Roadmaps to 2050: Chemicals* (March 2015, page 73).

104 Material Economics, *Industrial Transformation 2050: Pathways to Net-Zero Emissions from EU Heavy Industry* (2019, page 10).

105 CEFIC/Ecofys, *European Chemistry for Growth – Unlocking a Competitive, Low Carbon and Energy Efficient Future* (2013, page 107).

106 https://committees.parliament.uk/writtenevidence/780/pdf/

Chemicals manufacturers need to know when key infrastructure will be available and how prices of key inputs will evolve

As is the case for the steel sector (explored in more detail in Sub-Section 3.3), chemicals manufacturers also need to know when they will have access to major infrastructure and inputs such as CCUS networks, waste biomass, and low carbon hydrogen. The availability and pricing of all these decarbonisation opportunities is uncertain, introducing risks that increase the effective cost of investment. Policies such as CfDs for low carbon hydrogen, waste biomass, and CCUS networks can assist in reducing this uncertainty and risk and enable businesses to cover operational costs. The same is true for carbon and electricity prices, with uncertainty around these costs limiting the ability and incentive to invest in technologies such as electrolysis.

A lack of policy certainty increases the risk of delays in investment and stranded assets

Chemicals plants are long-lived assets and, while chemicals manufacturers can make incremental improvements, for many manufacturers in the UK there is only one more investment cycle before 2050. Uncertainty increases the risk that manufacturers will invest in sub-optimal technologies which limit their ability to compete in a net zero world. It also increases the risk that manufacturers will delay investment while waiting for greater policy clarity, diminishing their ability to compete internationally as carbon prices rise in the UK and key competitors abroad continue to invest.

However, providing a well-defined timeline for the availability of key inputs and infrastructure through policies such as CfDs and clear business models for low carbon hydrogen, CCUS, and biomass, as well as greater coordination across government in general, can create an overall business environment which encourages investment. Providing this certainty is an important means of unlocking additional private investment.

Incentive policies that account for constraints on manufacturers

As set out in Sub-Section 2.2, decarbonisation policies do not exist in isolation. Different types of policies support one another, with innovation policies, infrastructure and deployment policies, and energy efficiency and carbon intensity policies all helping to ensure that the necessary infrastructure and technologies are available to enable manufacturers to decarbonise. Without this policy support, manufacturers may be unable to respond to the signals provided by incentive policies. It is important for policymakers to take this into account when implementing incentive policies in order to ensure that manufacturers are encouraged to decarbonise without unduly impacting competitiveness.

Some manufacturers are constrained in their ability to respond to carbon price signals

In particular, chemicals experts indicated that in some instances manufacturers are unable to respond to the carbon price signals provided by policies such as the UK ETS. Manufacturers of products such as ammonia are heavily reliant on the availability of CCS in order to decarbonise, due to the volume and purity of CO_2 produced in the manufacturing process. However, as this infrastructure has yet to be deployed in the UK, they are unable to reduce their emissions in response to a rising carbon price.

These constraints on manufacturers' abilities to abate emissions means that a rising carbon price impacts their competitiveness but does not actually provide an effective signal to decarbonise due to the lack of opportunities for abatement.

Policymakers need to ensure that the necessary policy support is in place to allow manufacturers to respond to carbon pricing

As a result, policymakers need to ensure that policies supporting the availability of key infrastructure and technologies are in place in order to enable manufacturers to respond to rising carbon prices and reductions in UK ETS free allowances. **Where this support does not exist, or key technologies and infrastructure are not yet available, manufacturers may need increased competitiveness support in order to ensure that rising carbon prices do not have a significant impact on their competitiveness.** This does not mean only providing support to keep carbon costs equal to those today – if producers are facing high carbon costs which they are already unable to respond to, and these higher carbon costs create a significant risk of carbon leakage, these costs should be alleviated.

4.4 Impacts on competitiveness and economic opportunities

While demand for low carbon chemicals products is currently limited, there is significant potential for this demand to grow in some areas in the future. Low carbon chemicals can also play an important role in reducing emissions in other sectors and assist with the UK's broader decarbonisation efforts. However, the current policy environment in the UK appears to create some significant risk of investment and carbon leakage. Decarbonisation may also lead to further integration of chemicals sites and the need for some manufacturers to relocate, which policymakers should take into account. Overall, effective policy can lead to notable economic opportunities for UK chemicals manufacturers and mitigate the risks of investment and carbon leakage.

Figure 19 Competitive and economic opportunities and risks for the chemicals sector

Source: Frontier Economics

Demand for low carbon chemical products is currently limited, but could develop further in the future

There is not currently a significant market for low carbon chemical products and, in general, chemicals manufacturers do not appear to be able to differentiate themselves based on the carbon content of their products today. However, the demand for low carbon chemicals has the potential to grow significantly as the global economy continues its low carbon transition. Chemicals stakeholders expressed interest in policymakers implementing additional demand-side policies such as product standards to accelerate the development of these low carbon markets. Help to drive the uptake of low carbon products would allow chemicals manufacturers to pass through a portion of the cost of decarbonisation to consumers, improving their incentive and ability to make investments in emissions reductions.

Low carbon chemical products can play an important role in decarbonising other sectors of the UK and global economy

For example, while demand for green ammonia is currently very limited, it has several significant potential future uses. The first is as a fertiliser, with the Department for Environment, Food and Rural Affairs (Defra) currently recommending the use of ammonium nitrate fertilisers as opposed to urea-based fertilisers due to the lower environmental impact of the former.[107] Ammonia also has the potential to be used as a low carbon marine fuel source and to help reduce emissions from marine shipping.[108] Perhaps most importantly for wider decarbonisation efforts, green ammonia can be used as a means of transporting low carbon hydrogen. This is also the case for methanol, another important chemicals product.[109]

As a result, future demand for low carbon chemicals could come from other sectors seeking to decarbonise through the use of alternative fuels such as hydrogen. The spillover effects for low carbon chemicals production could therefore be a significant opportunity. More generally, production of low carbon hydrogen could yield meaningful economic benefits for the UK, with the UK Government estimating that developing low carbon hydrogen could support up to 100,000 jobs by 2050.[110] This growth could be even more significant if the UK becomes a world leader in hydrogen production and export, with estimates that this could create up to 221,000 additional jobs by 2050.[111] The UK chemicals sector is a key part of growing this hydrogen economy.

Carbon leakage, while limited today, is a significant future concern

The UK chemicals sector is significantly exposed to exports and imports, with the UK exporting over £31 billion and importing £30.5 billion in chemical products in 2018.[112] Chemicals sector experts expressed significant concern about carbon leakage, although this leakage is limited today. This is supported by the existing literature on carbon leakage, which has found limited evidence of carbon leakage in the chemicals sector.[113] However, these assessments are largely based upon the assumption of low carbon prices, and this leakage could be much more significant in the future.

Experts in the chemicals sector suggested that investment leakage is already taking place, with large international companies facing choices between investing in the UK or in other jurisdictions where carbon prices and the cost of production are lower. In the shorter term, this creates a risk of UK manufacturers falling behind in the adoption of new technologies, impacting their competitiveness. In the longer term, this create a risk of carbon leakage. The risk of this leakage will vary by product. Vivid Economics estimated that while the risk of carbon

[107] Defra, *Code of Good Agricultural Practice (COGAP) for Reducing Ammonia Emissions* (2018, page 17).

[108] Hansson et al., *The Potential Role of Ammonia as Marine Fuel – Based on Energy Systems Modelling and Multi-Criteria Decision Analysis*, Sustainability, 12 (2020).

[109] https://www.frontiersin.org/articles/10.3389/fmech.2020.00021/full

[110] HM Government, *The Ten Point Plan for a Green Industrial Revolution* (November 2020, page 11).

[111] Element Energy, *Hy-Impact Series Study 1: Hydrogen for Economic Growth* (November 2019, page 6).

[112] Based on publicly available ONS data on UK trade in goods by SIC code classification. The chemicals sector is defined as SIC code 20 – when including pharmaceuticals, this figure is even higher.

[113] See, for example, Bruyn et al., *Will the energy-intensive industry profit from EU ETS under Phase 3? Impacts of EU ETS on profits, competitiveness and innovation* (2010), Oberndorger et al., and *Understanding the competitiveness implications of future phases of the EU ETS on the industrial sectors* (2010).

leakage for chemicals products such as pyridine compounds is low even with a large carbon price differential, a differential of €30 in the EU ETS price with respect to non-EU firms could lead to leakage of ca. 60% for nitrogen fertilisers.[114] This risk of production shifting abroad is compounded by the competitive pressures created by other energy costs faced by chemicals manufacturers, with the Chemicals Industries Association estimating that energy and climate related policy costs amounted to £1.27 billion for the UK chemicals sector in 2019.[115] Chemicals stakeholders also emphasised that key competitors are increasingly located outside of the EU,[116] and a focus from policymakers on EU competitors at the expense of other competitors worldwide enhances the risk of carbon leakage.

To avoid this, policymakers should manage carbon price differentials through mechanisms such as free allocation of UK ETS permits or CBAMs for chemicals sub-sectors at risk of carbon leakage. Policymakers also need to ensure that key infrastructure and policy support is in place to create the necessary abatement opportunities for the chemicals sector. If UK chemicals manufacturers have fewer abatement opportunities than their competitors, there is a risk of investment leakage and production shifting abroad even with no differential in carbon price.

Decarbonisation of the chemicals sector may require further integration of chemicals producers and relocation of manufacturing

Adjusting to a net zero economy may require increased integration of chemicals production in clusters due to the economies of scale related to low carbon technologies such as CCS. Furthermore, while some manufacturers are unable to relocate due to production constraints and the need to be located close to particular markets, others may need to relocate production in order to access the infrastructure and support required for decarbonisation. Policymakers should be aware of these potential impacts when designing policies that affect the chemicals sector. The chemicals sector is a significant employer in the UK, employing over 150,000 people when including pharmaceuticals production.[117] Relocation and integration can have impacts on local employment in the short term as manufacturers adjust production.

4.5 Timelines

With current policy support, chemicals experts indicated that the decarbonisation timeline for the UK chemicals sector will be challenging to meet. However, if policymakers put the necessary additional support in place imminently, accelerate the deployment of key infrastructure such as carbon capture clusters, and follow through on the Ten Point Plan for a Green Industrial Revolution, the chemicals sector can be put on track to achieve its decarbonisation goals.

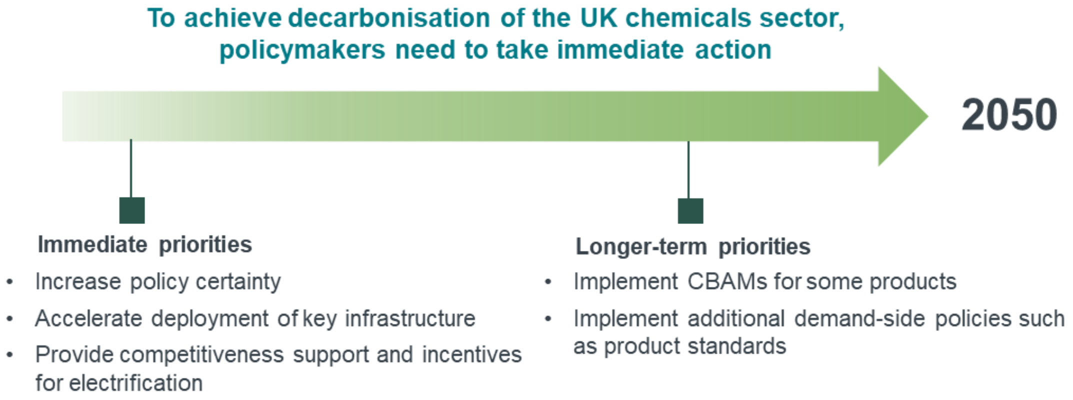
[114] Vivid Economics, *Carbon Leakage Prospects under Phase III of the EU ETS and Beyond* (June 2014).

[115] Chemical Industries Association, *Accelerating Britain's Net Zero Economy* (2020, page 6).

[116] For example, the world's largest producer of ammonia in 2020 was China, followed by the USA and Russia. For more information, see the publicly available statistics published by the US Geological Survey.

[117] Chemicals Industries Association, *Accelerating Britain's Net Zero Economy* (2020, page 3).

Figure 20 Decarbonisation timeline for the chemicals sector



Source: Frontier Economics

Policies should be implemented in the near term to enable longer-term decarbonisation

Immediate action from government is needed to ensure that the necessary abatement opportunities exist for the chemicals sector. This includes accelerating the deployment of CCUS infrastructure and providing certainty of supply of CCUS, low carbon hydrogen, and biomass through policies such as CfDs and clearly articulated business models for both clusters and dispersed sites. In the near term, manufacturers will need additional competitiveness support, such as free allocations, to allow them to remain competitive while these opportunities for abatement materialise. This short-term competitiveness support also includes policies that shift policy and network costs off of industrial electricity prices. In the medium to long term, additional policies such as CBAMs and demand-side policies such as product standards can reduce the risk of carbon leakage and help create markets for low carbon goods to assist manufacturers with decarbonisation.

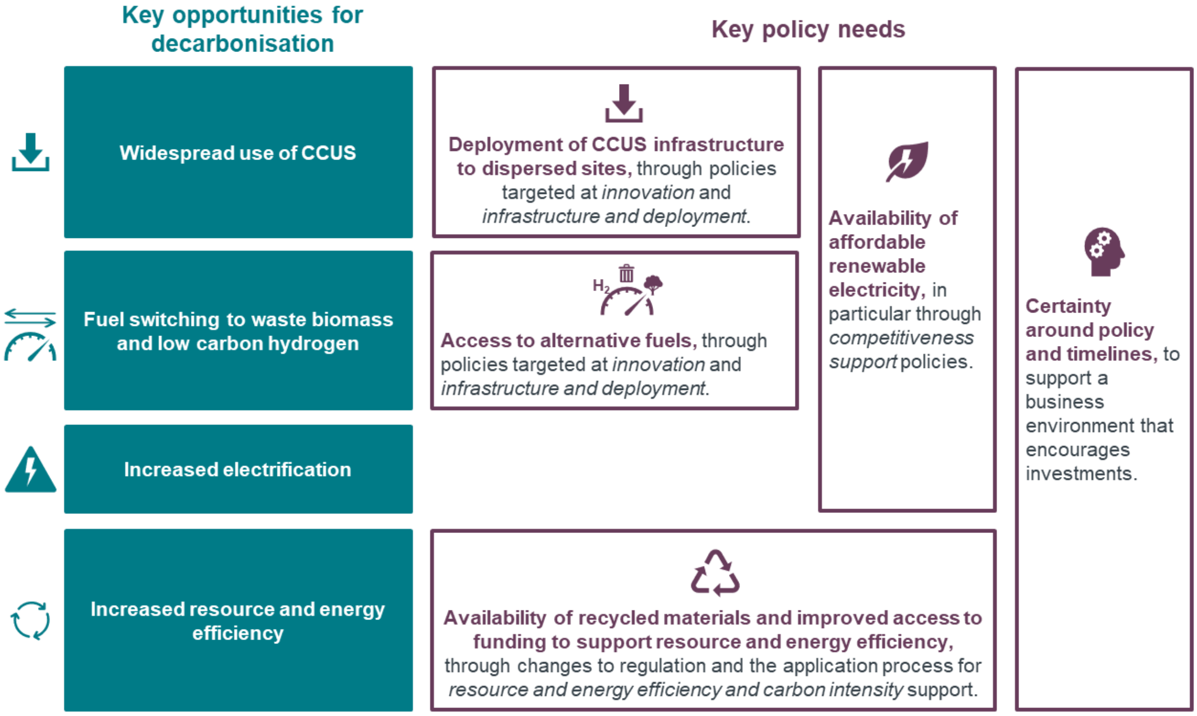
Without this immediate support, there is a significant risk that chemicals manufacturers in the UK will be unable to respond to carbon price signals and decarbonise, leading to loss of competitiveness and carbon leakage. Accelerating the deployment of key infrastructure and supporting manufacturers in adjusting to a zero carbon market can mitigate these risks and put the chemicals sector in a position to decarbonise while remaining competitive.

5 DECARBONISATION OF DISPERSED SITES

This section explores the opportunities for the decarbonisation of dispersed sites and the policies needed to achieve this, as well as the potential implications for UK competitiveness and decarbonisation timelines. It draws on discussions with industry stakeholders and additional literature review. The evidence focuses on three specific sectors: **cement, ceramics, and glass**. While some production in these sectors is located in major industrial clusters (notably for cement and glass), overall these are significant UK industries which largely operate at dispersed sites. As this section is focused on a subset of sectors operating at dispersed sites, the opportunities and policy needs below should not be viewed as exhaustive but, rather, as the key common opportunities for decarbonisation across the sectors studied.

Figure 21 below sets out the key opportunities and policy needs of these sectors and their dispersed sites. These are explored further in the remainder of the section.

Figure 21 Summary of key opportunities and policies for decarbonisation of cement, ceramics, and glass at dispersed sites



Source: Frontier Economics

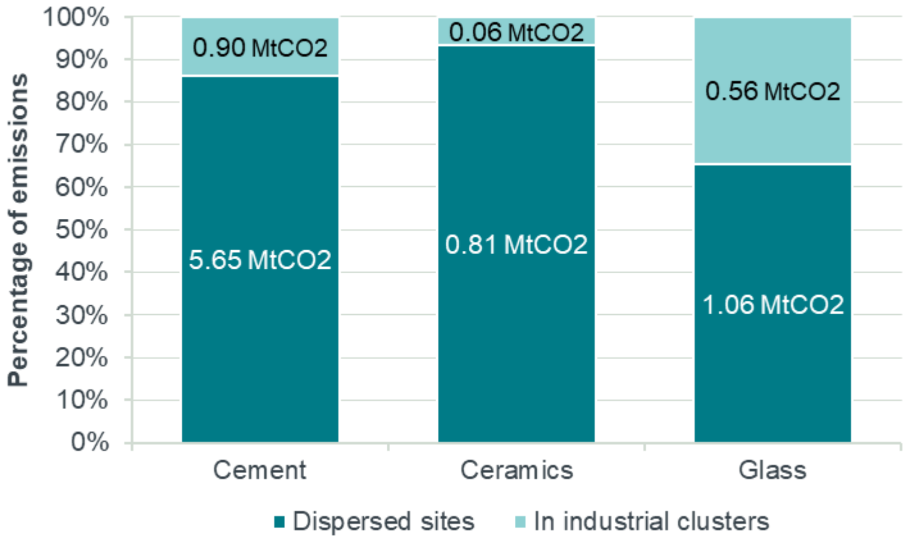
5.1 Background on industry

A wide range of industrial sectors operate at dispersed sites across the UK, producing a wide variety of products using a range of production techniques. While many sectors will have production at both dispersed sites and industrial clusters, there are sectors which are more generally considered "dispersed" due to dispersed sites making up a significant proportion of their production.

Decarbonising dispersed sites is critical for meeting the UK's industrial decarbonisation goals. According to the UK's Industrial Decarbonisation Strategy, an estimated 33.6 $MtCO_2e$ per year are emitted from dispersed sites in the UK, nearly half of the UK's total industrial emissions of 72 $MtCO_2e$.[118] However, this estimate assumes that sites located near Londonderry, Medway, and the Peak District have access to key infrastructure in the form of pipelines or shipping.[119] If analysis is restricted to those sites located more than 25 km away from the existing six major industrial clusters in the UK, the proportion of emissions from dispersed sites is even higher.

The significant majority of cement, ceramics, and glass sites and manufacturing occurs at dispersed sites outside of major industrial clusters, as shown in Figure 22 below. These sectors are also all significant contributors to the UK economy, with cement, ceramics and glass collectively contributing over £2.5 billion in GVA in 2018.[120]

Figure 22 Cement, ceramics, and glass sector emissions



Source: *Frontier analysis, based on Element Energy N-ZIP model. Sites in industrial clusters are defined as those sites within 25 km of one of the six major UK industrial clusters. Emissions data is derived from NAEI 2017 data.*

Industry stakeholders reported mixed reactions to the existing policy support framework, with significant gaps identified for dispersed sites in these sectors. Manufacturers at dispersed sites do receive support for decarbonisation through policies such as the IETF. However, there are fewer policies targeted specifically at dispersed sites than at manufacturers in industrial clusters which are receiving support through initiatives such as carbon capture clusters and the Clean Steel Fund.

More support will be needed to create a business environment conducive to investment and to enable manufacturers at dispersed sites to take advantage of key opportunities for decarbonisation. The policy support required is explored in further detail in Sub-Section 5.3.

5.2 Key opportunities for decarbonisation

The most important technologies highlighted by industry across different sectors and overall decarbonisation pathways are:

- widespread use of CCUS;

[118] *UK Industrial Decarbonisation Strategy* (2021, page 17).

[119] *UK Industrial Decarbonisation Strategy* (2021, page 145).

[120] Based on UK Annual Business Statistics (ABS) data.

- fuel switching to low carbon hydrogen and waste biomass;
- increased electrification; and
- increased resource and energy efficiency.

As is the case in the steel sector, there is no one technology that will decarbonise dispersed sites, and the opportunities listed are not exhaustive. Rather than reflect every possible decarbonisation pathway, the technologies and opportunities set out below are the key opportunities highlighted by industry that could benefit from more policy support.

Opportunity 1: widespread use of CCUS

CCUS is a key part of the decarbonisation pathway for cement, ceramics, and glass. CCUS is by far the largest contributor to carbon reductions in the UK concrete and cement industry's decarbonisation roadmap, estimated to account for a 61% reduction in CO_2 emissions by 2050.[121] The ceramics and glass industries also emphasised the importance of CCUS for their decarbonisation needs, particularly due to the hard-to-decarbonise process emissions released during production.[122] For example, around 25% of emissions from glass production are process emissions which require carbon capture to abate.[123]

Much of the current policy focus has been on CCS, but CCU is also an important opportunity for dispersed sites. CCU can be used in sectors such as ceramics and cement,[124] where it can form materials used in other production processes. This technology generally has the potential to be cost neutral as the materials formed can be used by the manufacturer in production or sold to other businesses. Further research and demonstration of cost neutral decarbonisation technologies such as CCU could therefore have significant benefits.

Opportunity 2: fuel switching to waste biomass and low carbon hydrogen

As is the case for industrial sectors in general, switching from carbon-intensive fuels such as natural gas to lower carbon alternatives is an important means of reducing emissions at dispersed sites. Many of these sites are energy intensive and rely heavily on natural gas today – for example, approximately 85% of the ceramics sector's energy use is natural gas.[125] Fuel usage for heating represents a significant proportion of emissions for sectors located at dispersed sites, with 75% of emissions from the production of flat glass a result of fuel combustion.[126]

Waste biomass and low carbon hydrogen fuel switching are important decarbonisation opportunities. In particular, discussions with cement and ceramics industry stakeholders emphasised the importance of waste biomass to their decarbonisation

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[121] UK Concrete, *UK Concrete and Cement Industry Roadmap to Beyond Net Zero* (2020).

[122] For information on the role of process emissions in ceramics manufacturing, see, for example, Cerame-Unie's *Paving the Way to 2050: The Ceramic Industry Roadmap* (2012).

[123] Glass for Europe, *Flat glass in climate-neutral Europe (2020).*

[124] Skocek et al., *Carbon Capture and Utilization by Mineralization of Cement Pastes Derived from Recycled Concrete*, Scientific Reports, 10 (2020).

[125] British Ceramic Confederation in response to the CCC's Sixth Carbon Budget and Welsh emissions targets – Call for Evidence in 2020.

[126] Glass for Europe, *Flat glass in climate-neutral Europe (2020).*

needs – combining increased use of biomass fuels alongside CCUS could lead to net negative emissions for both cement[127] and ceramics.[128] Switching to biofuel or biogas-based production is also an opportunity in glass manufacturing, yielding similar potential for net negative emissions when combined with CCUS.[129] There is also the potential for industrial symbiosis in the provision and use of waste biomass – for example, CEMEX (a cement manufacturer) and SUEZ (which operates in the waste management sector) have worked together to enable a fuel produced from municipal and commercial waste to replace fossil fuels in the cement manufacturing process.[130]

In addition to waste biomass-based fuels, hydrogen fuel switching is a significant opportunity for decarbonising dispersed sites. Cement can partially switch to hydrogen-based fuel in order to decarbonise, although full hydrogen conversion does not appear to be possible with current technology. In ceramics, hydrogen can be introduced into production with fairly simple retrofitting (although there are some technical challenges that would need to be overcome) and can significantly reduce total emissions. Glass manufacturing can also switch to hydrogen-based fuel without major technical challenges or costs, despite the need for some new capital investments.

Opportunity 3: increased electrification

Electrification of production also represents an opportunity for decarbonisation for some sectors. While there appears to be limited current potential for electrification of cement production in the UK due to the energy required (with CCUS and fuel switching the key opportunities instead),[131] there may be further scope for it in the future and some feasibility studies for electrification of cement production have been undertaken internationally.[132]

There is, however, more significant scope for electrification in ceramics manufacturing and glass. Although these sectors require high temperatures for heating during production and stable electricity connections to avoid interruption of supply, electrification is possible if sufficient affordable renewable electricity is available. However, electricity prices and renewables capacity currently pose a barrier to this, with glass manufacturers indicating that, although electric melting of glass is possible, they are more focused on a hybrid electrification and fuel switching approach given the volume of electricity that would be required for full electrification.

Opportunity 4: increased resource and energy efficiency

Increased recycling of materials in production can help reduce emissions intensity in dispersed sectors. Glass manufacturers have highlighted the importance of recycled

127 Element Energy, *Deep Decarbonisation Pathways for Scottish Industries: A Study for the Scottish Government* (2020).

128 British Ceramic Confederation in response to the CCC's Sixth Carbon Budget and Welsh emissions targets – Call for Evidence in 2020.

129 Glass Futures, *BEIS Industrial Fuel Switching Phase 2: Alternative Fuel Switching Technologies for the Glass Sector* (2019).

130 See The Aldersgate Group, *Zeroing In: Capturing the Opportunities from a UK Net Zero Emission Target* (2019, page 35).

131 See, for example, Element Energy, *Deep Decarbonisation Pathways for Scottish Industries: A Study for the Scottish Government* (2020) – 99% of emissions reductions for Scotland's cement industry are expected to come from fuel switching and CCUS. Electrification of cement kilns in general appears to be difficult, due to the amount of energy required.

132 https://www.iea.org/reports/cement

glass in reducing their carbon emissions. Recycled glass (also known as cullet) can be added back into the furnace as a raw material to help decrease energy consumption and materials usage, with every tonne of cullet used leading to an estimated reduction of 320 KWh of natural gas as well as a further reduction in CO_2 due to reduced use of new raw materials.[133] While recycled glass cannot be used to manufacture all glass products, for many products glass can be re-melted to make new products (e.g. packaging) indefinitely.[134] There is also scope for increased circularity of carbon in ceramics manufacturing – for example, scrap material, such as dust generated from the grinding of clay blocks, can be used in the production of new clay blocks.[135] Use of recycled cement also offers important opportunities,[136] with cement experts indicating that access to decarbonised materials is important for cement in general.

More generally, all sectors indicated that they placed significant emphasis on improving resource and energy efficiency. However, the remaining gains from improved efficiency may be limited in some sectors. For example, UK cement manufacturing is largely at the forefront of existing technology, and further gains from improved energy efficiency are likely to be less important than other opportunities such as use of waste biomass fuel and CCUS.

5.3 Key policy needs

The reactions from stakeholders at dispersed sites towards current government policy were mixed. Stakeholders in the glass sector indicated that they broadly found the existing policy framework in the UK to be comprehensive, although they highlighted a difficulty in accessing existing funding and some infrastructure needs. Reactions from the cement sector were more mixed, with manufacturers highlighting the need for greater guidance and long-term certainty as well as concerns about infrastructure availability at dispersed sites. However, in general, the view put forward by the cement sector was that the UK's emissions reduction targets for the sector are achievable if more support is provided in the near future. Ceramics stakeholders, however, raised major concerns and identified a number of gaps in the policy framework that put their ability to compete with international manufacturers at significant risk.

To support dispersed sites in their ability to decarbonise, policies need to be developed further to support:

- **Availability of affordable renewable electricity.** This can take the form of policies that shift the burden of policy and network costs off of industrial electricity bills.
- **Deployment of CCUS infrastructure to dispersed sites.** In particular, this can be supported through policies such as CfDs for CCUS and increased coordination with Local Enterprise Partnerships (LEPs) and local authorities (LAs). It can also be supported through clear, commercially viable business models more generally.

[133] Glass Futures, *BEIS Industrial Fuel Switching Phase 2: Alternative Fuel Switching Technologies for the Glass Sector* (2019).

[134] https://www.britglass.org.uk/sites/default/files/1709_0001-E1-17_Recycled%20content_0.pdf

[135] http://cerameunie.eu/media/2884/circular-economy-brochure.pdf

[136] For more information on benefits of recycled cement, see Wang et al., *Recycled Cement,* Construction and Building Materials, 190 (2018).

- **Access to alternative fuels, particularly waste biomass and low carbon hydrogen.** This can be supported by policies such as CfDs for waste biomass and low carbon hydrogen.
- **Certainty around policy and timelines**. In general, this requires clear sign-posting by policymakers but can also be supported by policies such as CfDs and increased coordination across different levels of government.
- **Availability of recycled materials and improved access to funding to support resource and energy efficiency.** This can be supported through changes to building and waste regulations and by simplifying the funding application process for support programmes (such as by allowing manufacturers to apply to programmes like the IETF on a rolling basis).

Overall, there are a number of promising pathways to decarbonisation for dispersed sites. However, with the current level of policy support, a number of these options are not currently viable, putting the competitiveness of dispersed sites at risk as carbon prices rise, potentially leading producers to make sub-optimal investments. The key needs explored in this section were used to inform the overall recommendations in Section 6.

Policies that support availability of affordable renewable electricity

Access to affordable renewable electricity is a key route to decarbonisation of dispersed sites, and the cost and availability of renewable electricity was highlighted as a major concern across sectors. Renewable electricity is required for both electrification and CCUS and as an input to hydrogen and is therefore important for multiple decarbonisation opportunities. There are a number of policies which could be used to increase affordability of renewable electricity, including through competitiveness support projects such as the UK’s ongoing electricity relief for EIIs and shifting policy costs related to renewables from electricity bills to gas bills. With respect to availability, existing policies such as CfDs can be used to increase renewables capacity to meet increasing demand. Further recommendations for increasing the affordability of renewable electricity in the UK are explored in the aforementioned policy briefing commissioned by Aldersgate Group from UCL, including restoring an efficient investment framework for the cheapest mature renewables and establishing a long-term, zero carbon electricity contracts market.

High electricity prices entail higher variable costs of production, limiting the incentive to invest in electrification

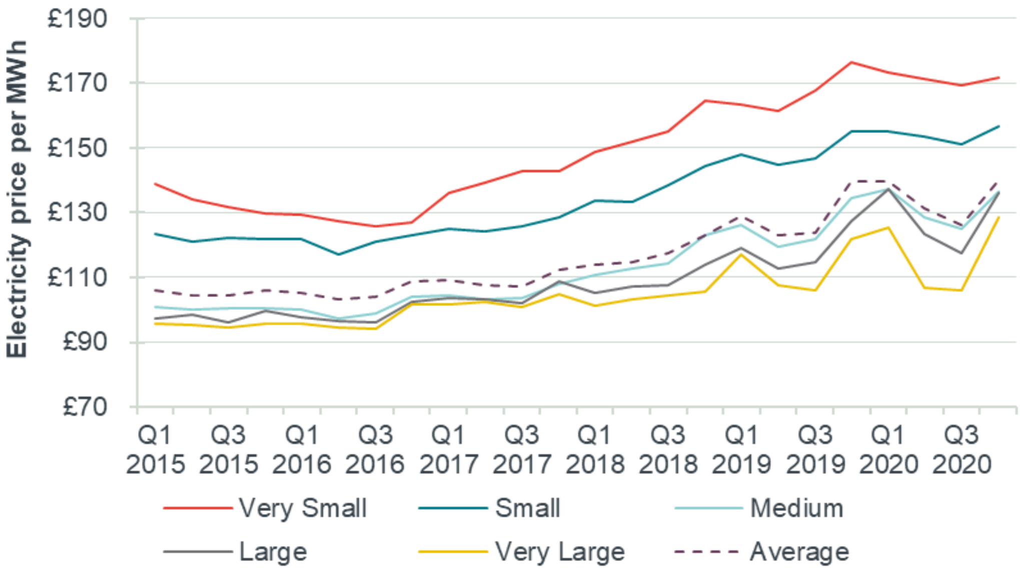
As discussed in Sub-Section 3.3, the cost of electricity is an ongoing constraint on UK industry. On average, BEIS found that industrial electricity prices in the UK in 2019 were the third highest in the IEA overall (out of 27 countries).[137] Analysis by UCL also found that industrial consumers in the UK face higher effective electricity prices than key competitors in countries such as Germany and France, with industry in the UK receiving lower compensation for network and policy costs.[138] **Furthermore, the prices faced by small producers are significantly higher than those faced by large producers, as shown in Figure 23 below**. This is significant for dispersed sites,

[137] See *Industrial Electricity Prices in the IEA*, published 24 September 2020 by BEIS. Comparison figures include tax. Available at https://www.gov.uk/government/statistical-data-sets/international-industrial-energy-prices.

[138] See UCL, *Managing Industrial Electricity Prices in an Era of Transition* (2021).

where many manufacturers operate relatively small sites – for example, 75% of the British Ceramic Confederation's (BCC) members are small and medium-sized enterprises operating single manufacturing sites.[139] The BCC has indicated that on average, the ceramics industry in the UK pays approximately £130 per MWh for electricity, far higher than sectors such as steel.

Figure 23 Electricity prices for non-domestic consumers in the UK by size



Source: *BEIS data on prices of fuels purchased by non-domestic consumers in the UK.*

Note: *Electricity prices include estimate of CCL. Businesses categorised by BEIS as "small/medium" and "extra large" have been omitted from this figure for clarity.*

Due to the competitiveness of these sectors, producers at dispersed sites have difficulty passing these costs on to consumers. This creates a notable disincentive to invest in electrification, despite the potential for increased electrification to accelerate decarbonisation in sectors such as ceramics and glass. Indeed, ceramics stakeholders indicated that electrification is not viable at current prices due to these costs being uncompetitively high relative to major competitors in Europe and abroad.

These high prices constrain margins, reducing available capital to invest

In the absence of an ability to pass on input costs to consumers, high electricity prices also limit manufacturers' profitability. This is a barrier to investment in new capital, particularly for smaller firms which may have less access to capital markets. Ceramics stakeholders indicated that ceramics manufacturers are using their profits to invest in energy efficiency measures and the industry view is that a lack of available profits, due to inflated variable costs, limits the ability of firms to make these investments.

Widely available and affordable renewable electricity will unlock a number of decarbonisation opportunities

Intuitively, **access to affordable renewable electricity is necessary for electrification. Without affordable access to renewable electricity, manufacturers at dispersed sites may not be able to decarbonise through**

[139] British Ceramic Confederation in response to the CCC's Sixth Carbon Budget and Welsh emissions targets – Call for Evidence in 2020.

electrification. For example, the ceramics sector would face a five-fold increase in energy costs through electrification of heat when compared to current gas-fired methods.[140] Given the competitiveness of ceramics and the difficulty in passing these costs on to consumers, this effectively means that further electrification is not commercially viable. This also poses a significant barrier to glass manufacturers, as there is a general concern that it will not be possible to secure the stable and consistent electricity connection required to facilitate 100% electric melting.

The need for access to renewable electricity extends beyond electrification. In particular, CCUS will require a large amount of renewable electricity to be viable. CCS technology is estimated to require 220 KWh of electricity per tonne of CO_2 capture,[141] with UK cement manufacturers estimating that introducing CCUS at their sites could double their electricity demand. **Large amounts of renewable electricity are also required for the production of green hydrogen with electrolysis**. This may require upgrades to the electricity grid near industrial sites.

Overall, access to significant affordable renewable electricity would open up a number of routes to decarbonisation for dispersed sites and improve the competitiveness of UK industry with key international competitors. Lack of access to this important input puts both industrial competitiveness and the ability to decarbonise at risk for dispersed sites in sectors such as cement, ceramics, and glass.

Policies that support deployment of CCUS infrastructure to dispersed sites

Many dispersed sites will need to use CCUS in order to decarbonise due to the significant process emissions produced by industries such as cement, ceramics, and glass. These sites need access to transport and storage networks for captured carbon, as well as support in funding the deployment of carbon capture and utilisation. **All of the different sectors that operate dispersed sites engaged for this report highlighted carbon capture as a key need and referred to lack of infrastructure availability at dispersed sites as a major barrier that policy needs to overcome.** Carbon capture is a substantial step change, which requires more than incremental policy changes.

CCUS will not be cost-effective for every dispersed site in the UK, and the cost of deploying this infrastructure will need to be balanced against the benefits it creates.[142] However, emitters at dispersed sites across the UK without access to this infrastructure will be unable to pursue key decarbonisation pathways.

There is no clear timeline for availability of CCUS at dispersed sites in the UK's Industrial Decarbonisation Plan

The UK Government plans to release a CCUS business model in 2021, with the locations of the first carbon capture projects chosen in 2023.[143] However, it is unclear when (or if) CCUS will be available at dispersed sites, with the current policy timeline

[140] British Ceramic Confederation in response to the CCC's Sixth Carbon Budget and Welsh emissions targets – Call for Evidence in 2020.

[141] ICF, *Industrial Innovation: Pathways to Deep Decarbonisation of Industry. Part 2: Scenario Analysis and Pathways to Deep Decarbonisation* (March 2019).

[142] See, for example, the cost estimates in Element Energy, *CCS Deployment at Dispersed Industrial Sites* (BEIS research paper number 2020/030) (2020).

[143] *UK Industrial Decarbonisation Strategy* (2021)

only supporting that infrastructure at four carbon capture clusters by 2030.[144] While the BEIS research paper on CCS deployment at dispersed industrial sites noted that "Future funding and business models in the UK should include a strategy for [dispersed sites], ensuring viable technology and infrastructure solutions can be made available to them",[145] these funding and business models are still under development.

Without a clear timeline for transport and storage infrastructure at dispersed sites, a significant proportion of dispersed site emissions will have no reductions pathway (particularly for sectors like cement). This means that producers at dispersed sites may be unable to respond to incentive policy signals such as an increased carbon price.

Policymakers therefore need to investigate how best to link dispersed sites to the CCUS infrastructure being developed in clusters. A clear infrastructure plan for connecting these sites to more centralised infrastructure is a key part of providing certainty around the timeline for availability of CCUS.

Deployment of transport and storage networks to dispersed sites faces significant challenges that need to be overcome

There are significant complications to overcome related to transporting captured CO_2 from dispersed sites. Depending on their location, dispersed sites are likely to need pipelines and/or shipping, and the lack of formal costing or planning for this infrastructure presents a significant barrier to decarbonisation. While BEIS has also considered rail and road shipping for carbon captured at dispersed sites, in many cases this is logistically unrealistic given the volume of carbon which needs to be transported.

Furthermore, delays in planning permissions pose a constraint which needs to be overcome. For example, cement sector stakeholders indicated that the sites in the Peak District could benefit from a pipeline from Derbyshire, but in practice it would be very difficult to get planning permission for this. If these processes are not streamlined, they could cause significant delays even if a strong business model is in place for transport and storage infrastructure, as current planning permissions often take years to be approved. The review of the Nationally Significant Infrastructure Projects (NSIP) regime which is currently underway could serve as a basis for looking at planning legislation in relation to other infrastructure such as transport and storage networks for carbon.[146]

CCUS at dispersed sites would benefit from increased policy support for demonstration and deployment

CCUS is a significant opportunity for multiple sectors located at dispersed sites. However, industry stakeholders reported difficulty in accessing this funding, and carbon capture technology is viewed as too costly to pursue at present without support. While funding for CCUS demonstration and deployment is available, very little of this is currently reaching key sectors which operate at dispersed sites.

For example, the BCC indicated that their members in the ceramics sector have only received approximately £200k in CCUS-related funding despite the large number of

[144] *UK Industrial Decarbonisation Strategy* (2021).

[145] Element Energy, *CCS Deployment at Dispersed Industrial Sites* (BEIS research paper number 2020/030) (2020).

[146] See the announcement of the operational review of the NSIP regime available at: https://www.gov.uk/government/publications/nationally-significant-infrastructure-projects-regime-operational-review

ceramics sites across the UK. Stakeholders which operate at dispersed sites also indicated difficulty accessing the funding opportunities available due to the complexity of the application and reporting process. These administrative barriers are likely to be more significant for smaller sites when compared to major industrial clusters.

Policies that support access to alternative fuels, particularly waste biomass and low carbon hydrogen

The lack of availability of alternative fuels, particularly waste biomass and low carbon hydrogen, is a significant barrier to decarbonisation for producers at dispersed sites. Distance from hydrogen clusters and difficulty for smaller producers in accessing funding mechanisms for demonstration and deployment limits ability to invest in this promising technology. Increased funding support related to innovative fuel switching projects and deployment of key technologies for dispersed sites would help overcome these barriers. Policies such as CfDs can be used to increase certainty of supply of alternative fuels, alongside existing policies that are primarily targeted at clusters.

Not all sites and sectors are able to access existing innovation and infrastructure policies funding fuel switching

For some sectors, further research and development will be needed to switch to fuels such as hydrogen. There is existing support for this. For example, MPA received £6.2 million in BEIS funding for fuel switching demonstrations at three sites, including a hydrogen and biomass trial at the Ribblesdale cement works in Lancashire.[147] This is a significant step towards implementing zero carbon fuel for cement works in the UK. However, this funding is not reaching all sectors and sites. Ceramics stakeholders indicated that, despite a desire to trial fuel switching, they are unable to access funding mechanisms to support this.

Lack of certainty of supply of alternative fuels impedes investment

The primary barrier to investment in fuel switching is ultimately uncertainty around availability of fuels. The current hydrogen network plan does not anticipate having a national hydrogen network in place until the 2040s[148] and, in general, there is a large degree of uncertainty surrounding when key alternative fuels will be available. This lack of certainty of supply has been consistently identified as a significant barrier to decarbonisation via fuel switching by industry stakeholders – even if funding support is available to producers, they will ultimately be unable to make the transition if the fuels themselves are not available at dispersed sites. The economic literature also suggests that the impact of uncertainty on investments is larger for small businesses than large businesses, and so dispersed sites are likely to be less able to mitigate this lack of consistent supply when compared to large clustered sites.[149]

The UK Government is planning to publish business models for hydrogen and a bioenergy strategy in 2022. The government will need to provide certainty around when these fuels will be available at different sites across the UK, as well as on how pricing

[147] https://www.hanson.co.uk/en/about-us/news-and-events/fuel-switching-research-project

[148] ENA, *Britain's Hydrogen Network Plan* (December 2020).

[149] See, for example, Ghoshal and Loungani , *The Differential Impact of Uncertainty on Investment in Large and Small Businesses*, The Review of Economics and Statistics, 82 (2000).

for these fuels will evolve and compare to existing fuels. If this certainty is not provided, dispersed sites will be unable to make optimal investments in fuel switching.

Certainty around policy and timelines

More generally, uncertainty around timelines and difficulty accessing funding are barriers for decarbonisation pathways. Significant investments will need to be made at sites across the UK in the near future in order to meet the UK's industrial decarbonisation ambitions. Producers at dispersed sites need to know whether and when key infrastructure will be in place and how prices of production inputs will evolve in order to minimise the marginal costs of abatement and avoid stranded assets.

Long asset lifespans lead to a risk of stranded assets and disincentivise investment

Industrial asset lifespans are long in sectors such as cement, ceramics, and glass. Ceramic kilns typically last approximately 40 years,[150] while the longer-lived assets in glass manufacturing last approximately 20 years.[151] The cost of these investments is often significant,[152] and a lack of policy certainty creates an increased risk that assets invested in today will not be appropriate for the policy environment in the future.

For example, if producers are unsure if adequate biomass or hydrogen will be available in the future, they are less likely to invest in kilns capable of using these low carbon fuels. However, this uncertainty also reduces the incentive to invest in currently available state-of-the-art gas-fired kilns due to the risk of these assets becoming stranded. This makes the UK a substantially less attractive place in which to invest, particularly for large international companies with a number of outside options.

A lack of a well-defined policy for dispersed sites means producers do not know when to invest

Outside of the decision about whether or not to invest, a lack of policy certainty affects investment timings. Producers need to decide whether to invest in decarbonisation technologies which are available today or wait for alternative technologies which are not currently available. A lack of certainty around availability of key technologies and infrastructure creates an increased risk that producers will lock into less optimal technologies, leading to stranded assets in the future and hampering decarbonisation.

Availability of recycled materials and improved access to funding to support resource and energy efficiency

An increased focus on the circularity of carbon from the policy framework could also be a significant benefit to manufacturers in sectors such as cement, ceramics, and glass at dispersed sites. In particular, recycled materials can be used to reduce

[150] British Ceramic Confederation in response to the CCC's Sixth Carbon Budget and Welsh emissions targets – Call for Evidence in 2020.

[151] Glass Futures, *BEIS Industrial Fuel Switching Phase 2: Alternative Fuel Switching Technologies for the Glass Sector* (2019).

[152] For example, the recently announced brand-new factory with capacity to produce ca. 80 million bricks per year invested in by brick business Ibstock will cost £45 million (see https://www.business-live.co.uk/manufacturing/brick-maker-ibstock-announces-new-17855670). In cement, the Dunbar cement plant spent £7 million in 2009-10 ensuring the plant was up to date technologically (https://dunbar.tarmac.com/about-us/). In glass, Saint-Gobain is investing £30 million at its Eggborough facility in East Yorkshire to replace the current furnace (https://www.business-live.co.uk/manufacturing/glass-manufacturer-saint-gobain-invests-20452728).

emissions from production in industries such as glass and cement. Improved access to funding through resource and energy efficiency policies would also support manufacturers in making investments in emissions reductions and improved circularity of carbon.

Policies that increase the availability of recycled material could create new decarbonisation pathways for dispersed sites

The glass industry, in particular, would benefit from greater access to recycled glass for use in production. However, producers are currently constrained by lack of access to recycled glass. Promoting the circularity of construction and demolition waste by introducing targets for recyclable material could therefore be of significant benefit to dispersed manufacturers.[153] The UK Government's Resources and Waste Strategy should also be aligned with the Industrial Decarbonisation Strategy to ensure policies complement one another and maximise the benefits of greater resource efficiency. This could be further supported by demand-side interventions such as procurement policy that provides incentives for increased use of recycled materials and circularity of carbon.

Increased accessibility of funding could also help with the transition to a more circular economy

Manufacturers at dispersed sites identified significant barriers to accessing funding support for improvements in resource efficiency, energy efficiency, and carbon circularity. For example, manufacturers highlighted that the narrow windows for funding applications under the IETF, as well as the need to apply for funding more than a year in advance of when it was needed in some cases, created a significant barrier for businesses. Simplifying the application process and enabling manufacturers to apply for funding on a rolling basis would enable them to better access this support.

5.4 Impacts on competitiveness and economic opportunities

Although demand for low carbon products is currently limited for sectors which operate at dispersed sites, it is developing in specific areas and may become a more significant market opportunity in the future. Low carbon industry can also create highly skilled jobs,[154] and there is scope for the UK to capture a first-mover advantage in green markets to provide new export opportunities. However, the current policy environment in the UK appears to create some significant future risks, particularly in relation to carbon leakage at dispersed sites and distortion of domestic competition. Effective policy that provides certainty for businesses and access to key support and infrastructure can mitigate these risks, help industry access these evolving opportunities, and improve competitiveness more generally.

[153] For more information, see Glass for Europe, *Flat glass in climate-neutral Europe (2020).*

[154] See, for example, the job creation opportunities explored in HM Government, *The Ten Point Plan for a Green Industrial Revolution* (November 2020).

Figure 24 Competitive and economics opportunities and risks for dispersed sites

Source: Frontier Economics

Demand for low carbon products is developing for some sectors but is less advanced in others

The demand for low carbon products varies by sector. Cement and concrete manufacturers are receiving an increasing number of requests for "carbon footprint" assessment of concrete products, as well as carbon performance data for projects. In the glass sector, there is increasing demand for low carbon glass from car manufacturers,[155] but manufacturers are not seeing this same demand materialise for other customers (for example, in the construction sector). In the ceramics sector, demand for low carbon products appears to be limited, with competition still driven primarily by price.

Despite the current situation, this suggests that markets for low carbon products are beginning to develop and may become more significant in the future (particularly as further demand-side decarbonisation policies are introduced). Being able to supply these markets could therefore provide a competitive advantage for UK manufacturers, even where this demand is limited today.

Electricity and carbon costs are constraining international competitiveness and creating risk of increased carbon leakage

Stakeholders in the glass sector indicated that there is limited risk of carbon leakage for the sector, particularly because of the difficulty of transporting key glass products, such as flat glass, internationally. However, risks related to international competitiveness were identified as a primary challenge for cement and ceramics manufacturers. As explored in Sub-Section 5.3, effective industrial electricity prices for manufacturers in the UK are higher than those faced by key competitors abroad, with prices even higher for smaller sites than larger ones. This creates a significant competitive disadvantage for sectors more exposed to international competition, such as ceramics and cement – approximately 20% of bricks and one-quarter of cement are imported in the UK, and ceramics and cement exports are worth ca. £600 million and ca. £100 million respectively each year.[156]

This is compounded by differentials in carbon pricing and cost recovery. There appear to be differences in treatment for key dispersed sites today, with ceramics stakeholders highlighting that manufacturers in countries such as Italy receive substantially more support in terms of carbon cost relief. Due to the emissions intensity of ceramics production, this divergence in price creates a significant risk of carbon leakage. Previous analysis by Vivid Economics found

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[155] See, for example, Mercedes' plan to produce a zero carbon car fleet by 2039: https://www.daimler.com/sustainability/climate/ambition-2039-our-path-to-co2-neutrality.html

[156] Based on publicly available ONS data on UK trade in goods by SIC code classification.

that the ceramics sector was significantly exposed to carbon pricing differentials, with a €30 difference in carbon prices leading to more than a 20% reduction in output of heavy clay ceramics.[157]

The same is true for cement. While there is limited current empirical evidence of carbon leakage,[158] there appear to be significant leakage risks under higher carbon prices. Vivid Economics estimated that a €30 difference in the EU ETS price with respect to non-EU firms would lead to a 100% reduction in cement manufacturing, a higher risk of leakage than any other sector analysed.[159]

There is therefore a risk for some dispersed sites that electricity and carbon price differentials will make production in the UK economically unviable before producers are able to decarbonise, leading to significant carbon leakage. To avoid this, government should manage carbon price differentials through mechanisms such as free allocation of UK ETS permits or a CBAM for sectors at risk of carbon leakage. However, even with no differential in carbon price, UK manufacturers will still be at greater risk of becoming economically unviable if they have fewer abatement opportunities than their competitors. Ensuring availability of key infrastructure and support is important for maintaining the viability of dispersed site manufacturers as the market moves towards zero carbon.

Supporting some clusters or industries more swiftly than others may distort domestic production

Current policies have some significant implications for domestic production. In particular, early-movers, such as the fast-tracked clusters, will pay lower carbon costs than dispersed sites due to greater access to abatement opportunities in the near term, creating distortions where it is not possible for some sites to adapt. Furthermore, manufacturers at dispersed sites indicated that they have difficulty accessing existing government funding, with much of it going to major industrial clusters. This risks creating an increased divergence in competitiveness between those clusters that receive substantial government support and those clusters and dispersed sites that do not. This could result in production increasingly moving towards large industrial clusters in the UK or sites abroad and could lead to increased substitution between products such as cement, ceramics, and steel which compete with one another in the construction market.

This is not necessarily economically inefficient, and some consolidation may be necessary as the overall industrial business model moves towards net zero. However, such substitution would have implications not only for industrial competitiveness but also for broader government objectives such as the levelling up agenda. Government policy should seek to create an equal playing field both within and across sectors where possible to avoid unnecessary distortions and assist all sites in decarbonising. The current policy framework does not achieve this for dispersed sites.

[157] Vivid Economics, *Carbon Leakage Prospects under Phase III of the EU ETS and Beyond* (June 2014).

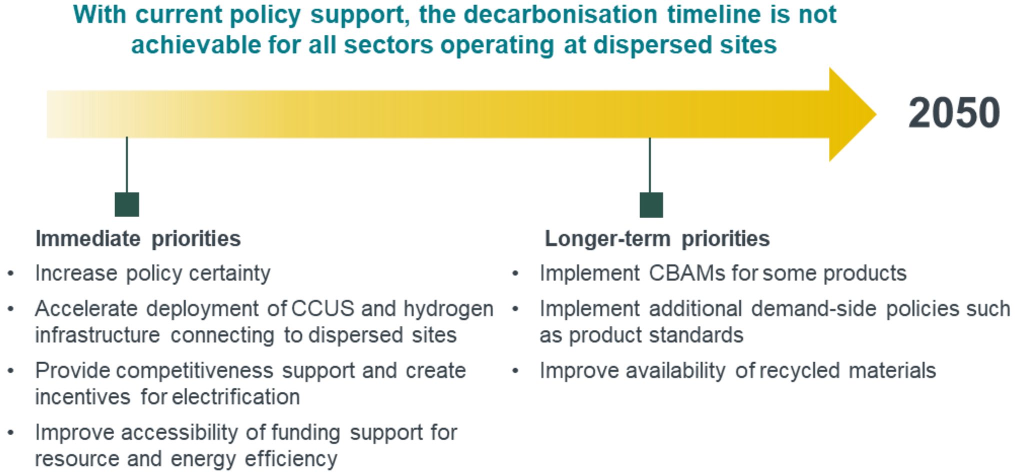
[158] See, for example, Boutabba and Lardic, *EU Emissions Trading Scheme, competitiveness and carbon leakage: new evidence from cement and steel industries,* Annals of Operations Research, 255 (2017), Branger et al., *Carbon leakage and competitiveness of cement and steel industries under EU ETS: much ado about nothing*, The Energy Journal, 37 (2017), and Chan et al., *Firm competitiveness and the European Union emissions trading scheme,* Energy Policy, 63 (2013).

[159] Vivid Economics, *Carbon Leakage Prospects under Phase III of the EU ETS and Beyond* (June 2014).

5.5 Timelines

The UK Government's ambitious goal of a 90% overall reduction in industrial emissions by 2045 compared to 2018 levels is achievable for some sectors operating at dispersed sites with adequate support but is unlikely to be achievable for others. For example, the UK cement and concrete sectors have a clearly articulated roadmap to net zero by 2050, but this roadmap assumes that there will be adequate availability of zero carbon fuels such as hydrogen and biomass and that CCUS networks will be available.[160] None of this is a given for dispersed sites. Even with significant support, some sectors and sites may be unable to decarbonise completely, with glass sector stakeholders indicating that despite their generally positive view of the government policy framework, they do not expect to be able to decarbonise at pace with the UK's net zero goals.

Figure 25 Decarbonisation timeline for dispersed sites



Source: Frontier Economics

Policies should be implemented in the near term to enable longer-term decarbonisation

Without immediate action from government, dispersed sites face a risk of investing in sub-optimal plants and machinery and locking in emissions-intensive processes. Significant investments will need to be made in sectors such as cement, ceramics, and glass in the near future. Without a clear policy timeline and clarity around the availability of key infrastructure, such as carbon transport and storage networks and hydrogen, these investments risk becoming stranded assets. While much of the focus of the UK's industrial decarbonisation policy framework has been on industrial clusters, a lack of attention paid to dispersed sites would leave nearly half of the UK's industrial emissions without support on the path to net zero. Moving too slowly creates the risk of these sites becoming economically unviable before they have a chance to decarbonise.

If key infrastructure and innovation funding is not made available to dispersed sites, government policy needs to take this into account within its incentive policies, as otherwise producers may face carbon costs which they are unable to adequately respond to.

[160] UK Concrete, *UK Concrete and Cement Industry Roadmap to Beyond Net Zero* (2020).

6 OVERALL RECOMMENDATIONS

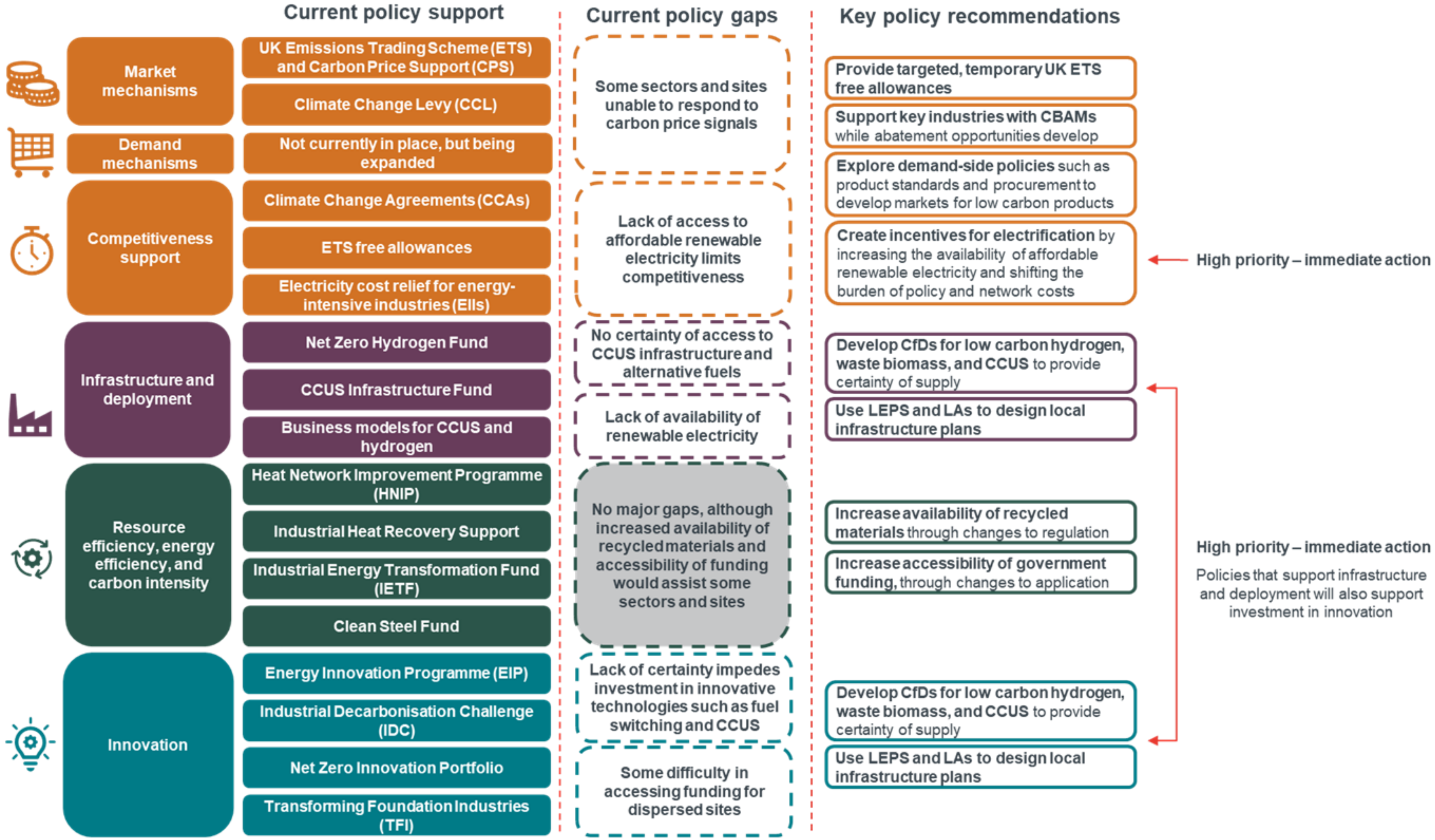
The exact pathways to net zero will vary by sector and site. Some sectors will rely on CCS, while others will make greater gains through electrification and fuel switching. Some smaller sites may focus primarily on energy efficiency and carbon circularity, and others may need to relocate to other UK sites (e.g. closer to relevant infrastructure or inputs) in a zero carbon world.

However, **while the specific pathways and outcomes will vary, the overall policy needs of dispersed sites and industrial clusters rely on a common set of infrastructure and fuel support and demand-side measures**. These different areas of policy action need to be joined up and acted on together and should not be seen as independent interventions. A comprehensive, effectively designed suite of policies is needed to ensure that manufacturers have the necessary support to decarbonise and be competitive in a zero carbon world. In particular, both dispersed sites and industrial clusters need an overall business environment conducive to investment, supported by policies that:

- create incentives for cost-effective, low carbon **electrification**;
- provide access to **low carbon hydrogen, waste biomass, and CCUS** supporting infrastructure;
- create **certainty around policies and timelines**, in particular through increased government coordination;
- provide targeted **competitiveness support** in cases where opportunities for carbon abatement are yet to develop;
- increase **availability of recycled materials** for production and accessibility of funding for resource and energy efficiency improvements; and
- support the development of **markets for resource-efficient and low carbon products** using demand-side levers such as product standards and procurement policies.

In this section, we set out a number of overall policy recommendations to address the needs of both industrial clusters and dispersed sites and fill existing policy gaps. These recommendations and gaps, as well as the current policy support, are summarised in Figure 26 and explored in greater detail below. The policy framework already exists, and the UK has taken a number of significant steps in the right direction. What is needed is greater certainty, and policies that provide a pathway to decarbonisation while trying to limit unnecessary distortions between different dispersed sites and industrial clusters.

Figure 26 Summary of policy recommendations



Source: Frontier Economics

Create incentives for electrification by increasing the availability of affordable renewable electricity and shifting the burden of policy and network costs

High industrial electricity costs were consistently identified as a barrier to key opportunities for decarbonisation – such as electrification, electrolysis, and CCUS – for sectors operating both in industrial clusters and dispersed sites. Policymakers need to create stronger incentives for electrification, which is not currently viewed as viable in many sectors due to the volume and cost of electricity required.

Electricity policy has significantly increased renewable electricity capacity and has brought down the cost of renewable electricity and the wholesale price of electricity. Policymakers should continue to provide a stable investment framework for renewable developers to support the deployment of further renewable electricity capacity. However, policy costs associated with this – such as CfDs, and feed-in tariffs – also put upwards pressure on electrification costs for industrial producers, which disincentivises industrial producers from electrifying. **Policy therefore needs to be more focused on creating a fair cost of electricity for industry while still enabling the energy sector to keep increasing the capacity of and reducing the cost of renewables.**

A number of policy options are available for improving the availability of affordable renewable electricity. As explored in *Managing Industrial Electricity Prices in an Era of Transition,* these include restoring an efficient investment framework for the cheapest mature renewables, supporting continued growth of interconnection through Ofgem's cap-and-floor revenues system, and establishing a long-term, zero carbon electricity contracts market.[161] Policymakers could also increase support through additional electricity cost relief for EIIs.

An alternative method of creating incentives for electrification would be to shift some of the policy costs from the electricity bills of industrial producers onto industrial gas bills.[162] This would decrease the relative price of electricity when compared to natural gas, providing an added incentive for industrial producers to electrify or invest in heating efficiency without increasing the overall financial burden upon them. The same is true of network costs, with a disproportionate burden of these overall costs falling on industrial consumers relative to other countries such as France and Germany.[163] **If these costs are shifted onto industrial gas bills, policymakers will need to carefully consider the competitive impact on industrial producers which are currently reliant on gas for production.** These manufacturers may need additional support in the short to medium term to avoid competitiveness being eroded as they adapt to these cost changes. This could take the form of an exemption from these increased gas costs for manufacturers that cannot easily and quickly switch from gas to electrification, such as the exemption that currently exists in the CCL for feedstock users.[164]

Shifting some of these costs off industrial consumers' electricity bills would provide a stronger incentive to electrify production, without necessarily requiring additional government expenditure.

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[161] See *Managing Industrial Electricity Prices in an Era of Transition* (2021), commissioned from UCL by the Aldersgate Group.

[162] The cost of these policies could also be shifted onto other, non-industrial consumers – however, the distributional and welfare effects of this shift would need to be carefully considered. As these costs must ultimately be paid by someone (either through general taxation or costs for individual manufacturers and other consumers), we have focused on the case where these costs are still paid by industrial consumers but redistributed to create greater incentives for electrification.

[163] See *Managing Industrial Electricity Prices in an Era of Transition* (2021), commissioned from UCL by the Aldersgate Group.

[164] For more information on the exemptions under the CCL, see HMRC's *Excise Notice CCL1/3: Climate Change Levy – Reliefs and Special Treatments for Taxable Commodities*, updated November 2020.

Provide certainty of supply and a clear timeline for when low carbon hydrogen, waste biomass, and CCUS will be available, using CfDs and government matchmaking

Producers in both dispersed sites and industrial clusters need confidence that hydrogen and carbon capture infrastructure will be available to them in order to invest in demonstrating and deploying these technologies. There are existing policies which help support the creation of this infrastructure, including the Net Zero Hydrogen Fund and the CCUS Infrastructure Fund, with detailed business models forthcoming. The UK Hydrogen Strategy also represents an important step towards delivering the evidence-based pathway, compatible with net zero, that is needed in the UK.[165] However, **a significant degree of uncertainty remains.**

To overcome this, the government should explore adopting CfDs for key alternative fuels and CCUS.[166] These long-term contracts would provide clear revenue streams for investors in these technologies and have proven successful in the past at supporting a significant increase in renewable electricity capacity and generation in the UK.[167] This in turn would provide long-term certainty around the availability of low carbon hydrogen, biomass, and CCUS capacity in the future and would support network deployment. There is interest in this type of policy internationally, with the German National Hydrogen Strategy including a pilot "Carbon Contracts for Difference" programme to support the use of electrolysers.[168] Policymakers will need to carefully consider the benchmark price and implementation of these CfDs to ensure they create the desired incentives. Policymakers will also need to develop and establish standards for low carbon hydrogen in the UK as a part of this process.[169]

Alternatively, the UK Government could **act as a "matchmaker" between suppliers of alternative fuels, CCUS infrastructure, and industrial producers** who need access to this infrastructure, helping to develop these markets. Specifically, the government could act as an intermediary to connect sellers and buyers in these developing markets and ensure that there is sufficient capacity to meet demand.[170] However, adopting CfDs for key low carbon fuels and CCUS may be a more effective policy option than the government acting as a matchmaker across multiple sectors. **The government could also complement these policies by directly legislating hydrogen production and CCUS targets** in order to create a clear signal as to the infrastructure which will be available by a given date and provide further certainty of supply.

When supporting the development of these markets, the government should try to ensure that supply of alternative fuels and transport and storage infrastructure slightly exceed expected demand. This will allow for further demonstration and research of CCUS and fuel switching.

Use Local Enterprise Partnerships (LEPs) and local authorities (LAs) to design local infrastructure plans in coordination with central government and devolved administrations

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165 See BEIS, *UK Hydrogen Strategy*, published August 2021.

166 The Government has indicated that it is considering a CfD as part of the CCUS business model in its response on potential business models for CCUS from August 2020. This is encouraging, and the potential for a CfD should continue to be explored for CCUS as well as for key alternative fuels.

167 As set out in BEIS' statistical release on Energy Trends from March 2021, renewables generation reached a record of 134.3 TWh in 2020, up 13.8 TWh over the previous year and outpacing generation from fossil fuels for the first time.

168 The German Federal Government, *The National Hydrogen Strategy* (2020).

169 BEIS is currently operating an open consultation on designing a UK low carbon hydrogen standard, closing 25 October 2021. For more information, see https://www.gov.uk/government/consultations/designing-a-uk-low-carbon-hydrogen-standard.

170 For a private sector example of this type of matching related to emissions reduction, see Board Now, which matches demand and supply of sustainable aviation fuel.

LEPs and LAs can play a key role in linking infrastructure at dispersed sites to the central infrastructure that will grow out of the industrial clusters. The specific needs of individual sectors and sites are complex, and there is no uniform infrastructure deployment plan that will work for every site. This will need to be taken into account by local experts when creating the "spokes" connecting dispersed sites to the "hubs" of infrastructure located at major clusters.

In general, there is greater scope for collaboration and coordination across government departments. Many policy needs will cut across a range of different departments, including BEIS, Defra, and HM Treasury (HMT). Policymakers will need to ensure that they collaborate and build upon one another's work. For example**, the final HMT Net Zero Review should seek to build on and enable the delivery of the BEIS Net Zero Strategy**.

These different departments will need to coordinate both with one another and with actors such as LEPs and LAs to ensure a consistent policy framework that does not generate unnecessary distortions. **There is also a need for careful coordination with devolved governments, particularly with respect to policy mechanisms that are devolved (such as procurement).** The cross-departmental ministerial group could take a leadership role in overseeing this coordination and reviewing the delivery of local plans. The process and role for systematic coordination should be formalised by government in a strategy such as the Net Zero Strategy.

The infrastructure plans designed should be aligned with decarbonisation timelines. This may require acceleration of planning permissions in some cases in order to avoid delays in investments and infrastructure deployment, as these delays can have ripple effects both on competitiveness and decarbonisation. Accelerating planning permissions is already a key goal of the UK's National Infrastructure Strategy,[171] and there is scope for engagement with LEPs and LAs to feature more prominently as a part of this. Engagement with local experts could also ensure buy-in on infrastructure development and that local benefits are maximised.

Provide targeted UK ETS free allowances on a temporary basis and support from policies such as CBAMs

There is currently a risk that some sectors and sites will be unable to respond to the incentives created by market-based mechanisms such as the UK ETS. As set out in Sub-Section 2.2, decarbonisation policies do not exist in isolation. **Different types of policies support one another, with tools such as innovation policies and infrastructure and deployment policies helping to ensure that the necessary infrastructure and technologies are available to enable manufacturers to decarbonise. Without this policy support, manufacturers may be unable to respond to the signals provided by policies such as the UK ETS.** For example, chemicals producers indicated that for some types of chemicals the clear path to decarbonisation is CCUS but, as this infrastructure is unavailable, they are left facing higher carbon costs without any opportunity for abatement. In the absence of opportunities for abatement, there is a risk that increasing carbon costs will result in diminished competitiveness and carbon leakage.

In cases where the necessary policy support and infrastructure are not in place to respond to carbon price signals, industries at risk of carbon leakage should, in the interim, receive support in the form of free allowances or CBAMs to avoid being put at a competitive disadvantage. This does not mean only providing support to keep carbon costs equal to those of today – if producers are facing high carbon costs which they already are unable to respond to, and these

[171] See HM Treasury, *National Infrastructure Strategy – Fairer, Faster, Greener* (November 2020).

higher carbon costs create a significant risk of carbon leakage, these costs should be alleviated. As additional policies are developed and opportunities for abatement materialise, these free allowances can be reduced over time. As part of this process, policymakers should regularly review the policy support and decarbonisation options available to manufacturers in order to determine when free allowances should be reduced.

Further support can also be provided in the form of other shielding policies and broader trade agreements which provide a level playing field in how high and low carbon trade in industrial products is treated.[172] In particular, there may be a role for CBAMs for some products. CBAMs are generally seen as preferable to other forms of shielding because they have, in principle, better environmental and public finance outcomes. They are also increasingly gaining interest internationally, with the EU publishing its proposal for establishing a CBAM in July 2021.[173] However CBAMs are highly complex and currently untested and will need to be implemented carefully.

Increase the availability of recycled materials and move to a more circular economy through changes to regulation and increased accessibility of funding

Some sectors can make further gains in energy efficiency and carbon intensity through greater resource efficiency, including through the use of recycled materials. As explored in detail in the Aldersgate Group's *Closing the Loop* report, **improving resource efficiency across the UK economy could enable the UK to meet its Fourth Carbon Budget and significantly reduce the expected emissions gap to meet the Fifth Carbon Budget**.[174]

Changes to building and waste management regulations or introducing targets for recyclable material could therefore be of significant benefit to a variety of sectors, including glass (which can make use of recycled glass in production) and steel (with EAF production making use of scrap steel). For example, when a building is refurbished, glass is usually crushed and used as aggregates in road construction or sent to a landfill. The process of turning waste flat glass into crushed glass for recycling is also classified as a waste recovery operation and subject to waste management legislation, creating a barrier for the glass industry in re-using this glass in production.[175] Regulatory changes that divert recyclable materials away from destinations like landfills and towards use in industrial production could significantly improve the carbon circularity of manufacturing. **This will require collaboration across multiple government departments – as set out in *Closing the Loop*, resource and waste policy must become a cross-departmental priority.**[176]

Beyond just reducing emissions, increasing the availability of recycled materials could have significant production efficiency benefits for production. Liberty Steel has estimated that steel made from scrap requires approximately a third of the labour input of making it from iron ore, enabling efficiency gains in production and for this labour to potentially be shifted from steel production towards the manufacturing of intermediate steel products.[177]

[172] This includes the steel safeguard measures that were the subject of the Trade Remedies Authority's (TRA) June 2021 review. The UK Government decided to continue the steel tariffs, including on those categories for which the TRA found insufficient evidence to support the continued tariffs. Any future wider review of the trade remedies framework will need to consider how trade remedies should evolve in light of industrial decarbonisation domestically and abroad.

[173] See https://ec.europa.eu/info/sites/default/files/carbon_border_adjustment_mechanism_0.pdf

[174] For more detail, see The Aldersgate Group, *Closing the Loop – Time to Crack on with Resource Efficiency* (July 2021).

[175] UK GBC, *Building Glass into the Circular Economy – How To Guide* (September 2018).

[176] For more detail, see The Aldersgate Group, *Closing the Loop – Time to Crack on with Resource Efficiency* (July 2021).

[177] University of Cambridge for Liberty Steel, *Steel Arising* (2019).

Access to funding through resource and energy efficiency policies should also be simplified. Manufacturers at dispersed sites, in particular, identified significant barriers to accessing this funding. For example, manufacturers highlighted that the narrow windows for funding applications under the IETF, as well as the need to apply for funding more than a year in advance of when it was needed in some cases, created a significant barrier for businesses. Simplifying the application process and enabling manufacturers to apply for funding on a rolling basis would enable them to better access this support and invest in resource and energy efficiency.

Continue to explore demand-side policies that support the development of markets for resource-efficient and low carbon products

While demand for low carbon products appears to be limited today, it is developing in some key areas – for example, the automotive sector is starting to demand increasing amounts of low carbon steel and glass as it moves towards zero carbon production. Initiatives such as the Climate Group's SteelZero are also helping to increase demand for low carbon industrial products.[178]

Government can support the development of these markets through demand-side measures such as product standards, procurement policies, and information campaigns. Examples of these policies have been successfully implemented internationally. **The Buy Clean California Act in the USA** sets out a maximum acceptable level of global warming potential for certain construction materials, driving demand towards low carbon products through a form of product standards.[179] In public procurement, the **CO_2 Performance Ladder used in the Netherlands** rewards suppliers in the procurement process by lowering their tender price (for the purpose of scoring) for making commitments to CO_2 reductions.[180]

The UK Government has already expressed interest in pursuing these types of demand-side policies in its Industrial Decarbonisation Strategy,[181] and should put forward a clear plan for implementing these policies. Exploration and implementation of demand-side policies should be done in coordination with key stakeholders and industry to avoid unintended distortions. These measures can provide a clear incentive for producers to lower the emissions intensity of production and meet increasing demand for low carbon products, and can provide a competitive advantage for those producers that are able to differentiate themselves on this dimension.

[178] See https://www.theclimategroup.org/our-work/press/new-steelzero-initiative-receives-backing-major-businesses-ramping-demand-clean

[179] https://www.dgs.ca.gov/PD/Resources/Page-Content/Procurement-Division-Resources-List-Folder/Buy-Clean-California-Act

[180] https://www.rijkswaterstaat.nl/zakelijk/zakendoen-met-rijkswaterstaat/inkoopbeleid/duurzaam-inkopen/co2-prestatieladder.aspx

[181] See, in particular, chapter 3 of the *UK Industrial Decarbonisation Strategy* (2021).

7 CONCLUSION

Industrial decarbonisation is a key part of the UK Government's broader objectives. UK manufacturers are significant contributors to the wider economy and, **when correctly implemented, decarbonisation policy can support cost-effective emissions reductions while also helping manufacturers to take advantage of new market opportunities and enhance economic growth.** In particular, decarbonisation policy can support innovation, supply chain growth, and job creation in regions across the UK and can enable manufacturers to better compete in markets for low carbon goods and adapt to rising carbon prices.

The overall decarbonisation policy framework in the UK includes a range of different types of policies. These can be categorised into:

- innovation policies;
- infrastructure and deployment policies;
- resource efficiency, energy efficiency, and carbon intensity polices; and
- incentive policies.

These different policies need to work together to support one another, as gaps in one policy type can affect the ability of manufacturers to respond to other policy signals. Innovation allows for the deployment of new infrastructure and the development of emissions-reducing technologies. The availability of this infrastructure and improved technology allows manufacturers to respond to signals created by incentive policies.

Without support to deploy adequate low carbon infrastructure and cost-effective new technologies, signals such as a higher carbon price risk damaging manufacturers' competitiveness due to an inability to adjust the emissions intensity of production in response to increasing carbon costs. However, **if an effective and comprehensive set of innovation, infrastructure, and technology deployment policies is in place, signals such as a higher carbon price can create a business environment which enables manufacturers to efficiently invest in decarbonisation and potentially gain a competitive advantage** internationally as demand for low carbon products grows.

Decarbonisation pathways will vary by sector and product. Steel and chemicals manufacturing are key components of industrial clusters in the UK, and these sectors' decarbonisation pathways are therefore illustrative of the opportunities for emissions reductions at industrial clusters in general. **Decarbonisation of steel manufacturing is likely to involve improving energy efficiency and reducing emissions at existing blast furnaces in the short term (including through the use of DRI and increased circularity of carbon) and a longer-term transition towards EAF and hydrogen DRI production.**

The **chemicals sector** is highly diverse in terms of the products manufactured, and different products will require different pathways to decarbonisation. However, while there is no one technology that will decarbonise chemicals production, **the overall pathway to decarbonisation is likely to involve improving energy and resource efficiency as well as use of CCUS in the short to medium term, with a longer-term transition towards increased electrification and use of low carbon fuels and feedstocks**.

While much of the current policy focus has been on decarbonisation of industrial clusters, **decarbonising dispersed sites is also key to meeting the UK's emissions reduction goals.** Sectors that largely operate at dispersed sites, such as cement, ceramics, and glass, are diverse. Although there is no one technology that will decarbonise all production at dispersed sites, decarbonisation of these sites is likely to rely on widespread use of CCUS, fuel switching to low carbon hydrogen and waste biomass, increased electrification, and further improvements in resource and energy efficiency.

The specific pathways and outcomes will vary. However, dispersed sites and industrial clusters will rely on a common set of policy supports. The policy framework already exists, and the UK has taken a number of significant steps in the right direction. What is needed is greater certainty and immediate action from policymakers. Policymakers should also seek to create an equal playing field, both within and across sectors where possible, to avoid unnecessary distortions and assist all sites in decarbonising. The current policy framework does not achieve this for dispersed sites. Limiting unnecessary distortions will require the deployment of key infrastructure and policy support at dispersed sites to be accelerated in order to help these sites decarbonise alongside industrial clusters.

Overall, policymakers should:

- create incentives for electrification by increasing the availability of affordable renewable electricity and shifting the burden of policy and network costs;
- provide certainty of supply and a clear timeline for when low carbon hydrogen, waste biomass, and CCUS will be available, using CfDs and government matchmaking;
- use LEPs and LAs to design local infrastructure plans in coordination with central government and devolved administrations;
- provide targeted UK ETS free allowances on a temporary basis and support from policies such as CBAMs;
- increase the availability of recycled materials and move to a more circular economy through changes to regulation and increased accessibility of funding; and
- continue to explore demand-side policies that support the development of markets for resource-efficient and low carbon products.

GLOSSARY OF TERMS AND ACRONYMS

Term	Description
BCC	British Ceramic Confederation
BEIS	Department for Business, Energy and Industrial Strategy
Biomass	Some types of biomass (such as forest biomass) produce higher GHG emissions than coal over Paris-compliant timelines. Where possible, biomass feedstocks should be purely from waste sources.
BOF	Blast oxygen furnace
Carbon circularity	Carbon circularity involves designing out waste and additional emissions from the production process. In particular, in a circular process outputs can be re-used in production at the end of their asset life, avoiding some (or all) carbon emissions from production using these recycled materials and reducing net emissions overall.
CBAM	Carbon Border Adjustment Mechanism
CCA	Climate Change Agreement
CCC	Climate Change Committee
CCL	Climate Change Levy
CCS	Carbon capture and storage
CCU	Carbon capture and utilisation
CCUS	Carbon capture, utilisation, and storage.
CfD	Contracts for Difference
CHP	Combined heat and power
CPS	Carbon Price Support
DRI	Direct reduced iron
EAF	Electric arc furnace
EII	Energy-intensive industry
EIP	Energy Innovation Programme
ETS	Emissions Trading Scheme
GDP	Gross domestic product
GHG	Greenhouse gas
GVA	Gross value added
HNIP	Heat Network Improvement Programme
IDC	Industrial Decarbonisation Challenge
IETF	Industrial Energy Transformation Fund
LA	Local authority
LEP	Local Enterprise Partnership
Low carbon hydrogen	Low carbon hydrogen includes blue and green hydrogen, with green hydrogen to play a larger role in the longer term. There is currently a lack of established standards to define low carbon hydrogen, and this standard will need to be carefully considered by policymakers going forward.

Term	Description
Renewable electricity	Electricity produced from renewable energy sources includes the electricity generation from wind, solar, geothermal, some biomass/wastes, and hydro plants (excluding that produced as a result of pumping storage systems). While it can include electricity generated from biomass/wastes such as wood and wood wastes, these sources can result in significant carbon emissions, and renewable electricity as referred to in this report is focused on low carbon renewables.
TFI	Transforming Foundation Industries

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