UNIVERSITY OF CAMBRIDGE
INSTITUTE FOR SUSTAINABILITY LEADERSHIP

Policy Briefing

Market driven decarbonisation:

The role of demand-led innovation in supporting emission reductions in foundation industries

The University of Cambridge Institute for Sustainability Leadership

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Executive summary

Foundation industries, such as iron and steel, cement, glass and basic chemicals, account for around 15 per cent of the UK's greenhouse gas emissions.[1] Decarbonisation of these industries is a necessary to enable other sectors to reduce their embedded emissions and transition to climate neutrality. However, current policies, such as the UK's Emissions Trading System, have been insufficient to drive deep decarbonisation in these industries, which require long-term investment and new technologies.[2,3] This briefing outlines a set of research findings demonstrating how policy can enable demand-led innovation to accelerate the pace of climate action and help secure economic and competitive benefits by developing leadership in this area.

Demand-led innovation is innovation incentivised by a visible gap in the market for a product or a service that consumers or buyers want access to and for which they would be willing to pay. Clear demand signals from downstream companies assure manufacturers that they can generate financial returns by designing a new product or service and bringing it to the market. Certainty over demand reduces the risk of investment in research and development (R&D) of new products and services, improving the economic feasibility of innovation and commercialisation of new products and production processes. Actions by the UK Government can support demand-led innovation in UK industry in such a way as to accelerate climate action and decarbonisation.

A range of UK policies, including the 2021 Industrial Decarbonisation Strategy[4] have set ambitious targets for reducing emissions in these industries and acknowledged the need for policies that create demand for low carbon materials in order to incentivise investment in structural changes that enable deep emission cuts. However, the UK government has not yet taken sufficient steps to provide the private sector with the appropriate incentives. With 2050 being only one industrial investment cycle away, further action is becoming urgent.

This briefing summarises the findings from a collaborative research project delivered by CISL, drawing on insights from partners in industry, academia and wider civil society. The project focuses on how demand-led innovation can support industrial decarbonisation and what government and business action would facilitate this.

The research identified four key decarbonisation pathways to achieve net zero aligned emissions reductions in UK foundation industry value chains:

- Electrification
- Circular economy solutions
- Novel technologies
- Innovative products, processes and practices

These four pathways are not mutually exclusive: considering the urgency with which industrial GHG emissions need to be aligned with the UK's climate targets, all available levers will need to be deployed. Although novel technologies and technological innovation are hugely important, technological solutions alone are insufficient to decarbonise heavy industry. The viability of every single decarbonisation pathway depends on both sufficient customer demand for low carbon products across the value chains and also contextual conditions that enable effective supply-side responses to demand signals. To date, basic materials producers have faced insufficient consumer demand for products made with climate-neutral or circular materials.

Decarbonisation of the foundation industries is challenging because of high heat requirements, process emissions that cannot be eliminated through fuel switching, and contextual factors that reduce the incentives for low carbon innovation. The research that informed this briefing identifies five cross-cutting challenges to innovation and upscaling of low carbon innovation in foundation industries. These are:

- the high capital cost of production technologies;
- a supply-demand catch-22 undermining scope to depart from established approaches;
- lack of standardised data collection and reporting on embodied carbon emissions;
- exposure to trade; and

- lack of familiarity or engagement with new materials, novel products, and new technologies among downstream users in foundation industries and value chains.

Developing the necessary technologies to decarbonise the production of basic materials presents an enormous opportunity for the UK industry. Large economies such as the US and the EU have acknowledged the huge economic benefits and competitive advantage that early investment in low carbon innovation and adoption can deliver. These are reflected in the US Inflation Reduction Act (IRA) and the EU's Green Deal Industrial Plan (GDIP)[5] and Net-Zero Industry Act,[6] which seek to support the scaling up of the manufacturing of clean technologies in these jurisdictions.

Although there are actions that businesses can take and have taken, as illustrated by case studies in the full research report,[7] considerable policy intervention and innovation are needed to support the emergence and growth of this demand, and to establish contextual conditions that encourage an effective supply-side response across value chains. **Without decisive and urgent action by the government and by UK industries, the UK economy stands to miss out on the benefits that will accrue to companies that are among the first to develop cost-effective ways to produce materials and products with lower embodied carbon content.**

Drawing on existing literature and discussions with our industry partners, the research identified three urgently needed actions that the UK government could undertake to support demand-led innovation in UK industry in pursuit of the UK's climate targets. These include:

1) Designing and implementing **policies to create demand for low carbon products and materials.**
2) Designing and implementing **policies that support contextual conditions to encourage innovation or support the scaling up demand for innovative technologies and approaches** by businesses across the foundation industry value chains.
3) Establishing **international collaboration to accelerate demand for low carbon materials and products globally.**

In addition to government action, non-governmental organisations and non-departmental government bodies facilitate these processes by bringing companies together, facilitating dialogue and information sharing, and encouraging higher ambition. Grants and loans to support knowledge generation and collaboration between academic institutions and the private sector to address specific challenges can facilitate the emergence of new insights, best practices and innovative solutions.

The key results from the research discussed in this report are summarised in Table 1 (below).

Table 1: Summary of the challenges and solutions for foundation industry decarbonisation

Key decarbonisation pathways			
Electrification	Circularity	Novel technologies	Innovative products, processes and practices

Cross-cutting challenges				
High capital cost of new production technologies	Supply–demand catch-22	Lack of standardised data collection and reporting on embodied carbon emissions	Exposure to trade	Lack of familiarity or engagement with new materials or production technologies among downstream users
All of these challenges reduce the relative appeal of low carbon materials and products, thus reducing demand for sustainably mined feedstocks, low carbon fuels and low carbon production technologies in foundation industries.				

	Key actions the UK government could undertake		
Type of policy intervention	**Policies to create demand and support the scaling up of demand**	**Policies to establish supportive contextual conditions for effective supply-side response**	**International collaboration**
Regulatory reforms	Mandatory product standards on embodied emissions and recycled material content Regulation mandating lifecycle carbon assessments Regulatory processes that are responsive to innovation Ban on sales of products from intensive processes	Electricity market reform Cap on industrial energy prices or increased indirect cost compensation for energy-intensive industries using 'clean' fuels / power Mandatory embodied carbon data collection and disclosure Regulatory sandboxes	International collaboration to develop and implement embodied carbon emissions accounting and reporting rules Support for cross-national private sector initiatives Internationally collaborative 'Carbon Border Adjustment Mechanism' or 'climate clubs'
Financial support and fiscal incentives	Tax deductions / exemptions for users who commit to buying 'low carbon' Fiscal incentives for downstream companies to invest in new product designs to improve recyclability	Carbon tax or Emissions Trading System (ETS) Capital subsidies, grants, fiscal incentives and subsidised loans for investment in emerging or experimental technologies, new business models or recycling Tax exemptions for certain low carbon investment	
Risk sharing and risk mitigation mechanisms	Government-backed insurance schemes for new products, recycling businesses and recycled products and materials	Incentives for insurance providers to create new products for low carbon markets Carbon Contracts for Difference (CfD) for foundation industry materials Government-backed insurance schemes for new products, recycling businesses and recycled products and materials	
Public sector investment	Revision of public sector procurement rules Allocation of government contracts to first movers Net zero aligned requirements for government contractor	Public sector infrastructure investment Grants and low-cost loans for the private sector for transformational technologies Government funding to support convening activities and funding programmes by non-departmental government bodies	

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1. Introduction

Materials produced by foundation industries are vital to the UK economy, supporting local economies and producing materials for essential infrastructure and downstream manufacturing industries. However, these industrial operations account for nearly 15 per cent of the UK's annual CO_2 emissions.[1] Their decarbonisation is essential to avoid carbon leakage and import dependency as the UK economy transforms to achieve its climate neutrality target by 2050.[8]

Demand-led innovation is innovation incentivised by a visible gap in the market for a product or a service that consumers or buyers want access to and for which they would be willing to pay. Clear demand signals from downstream companies assure manufacturers that they can generate financial returns by designing a new product or service and bringing it to the market. Certainty over demand reduces the risk of investment in research and development (R&D) of new products and services, improving the economic feasibility of innovation and commercialisation of new products and production processes.

In foundation industry value chains, market demand (or market pull) for low carbon materials and products is currently not high enough to incentivise substantial investment in new low carbon innovation, or to scale up the demand for existing low carbon technologies. However, with more than 90 per cent of global GDP being covered by net zero targets,[9] the markets for clean technologies and products are expected to grow rapidly in the coming decades, creating new employment opportunities and generating economic growth.[10]

Countries are beginning to recognise the enormous economic benefits and competitive advantage that early investment in low carbon innovation and adoption can deliver. In this context, companies' ability to adapt to the new competitive sustainability paradigm will determine their survival and ability to thrive in the global markets. As the modelling results discussed in Section 3.3 show, the decarbonisation of industries can help reduce emissions while also boosting industrial competitiveness and driving economic growth. Moreover, companies implementing large-scale decarbonisation measures can recoup the initial higher cost by becoming market leaders.

However, decarbonisation of the foundation industries is challenging because of high heat requirements, process emissions that cannot be eliminated through fuel switching, the capital-intensive nature of the production assets, the high risk profile of experimental technologies, and exposure to global trade. Contextual factors, such as product standards, availability of scrap and the pricing and availability of electricity and other low carbon alternatives to fossil fuels (such as green hydrogen) also present barriers to change. These contextual factors reduce the incentives for companies in foundation industries to invest in low carbon innovation or scale up innovative technologies or approaches.

In the UK, the absence of a clear policy framework for how long-term industrial emission reduction targets will be met creates uncertainty over how fast future market demand for low carbon materials and products will grow. This uncertainty increases the risk of investment in innovation, experimental low carbon technologies, and new low carbon technologies that are available but require high capital investment or incur higher operating costs. Although the 2021 Net Zero Strategy,[11] the Industrial Decarbonisation Strategy,[12] and the 2023 Powering up Britain energy security plan[13] set sectoral and economy-wide emissions reduction targets – and indicate which types of technologies could be deployed to achieve them – they fail to address the crucial question of how the process of technology adoption will unfold in practice.

To understand the role of foundation industries in this process, consideration needs to be given to where they sit in the end-to-end value chain (see Section 3.1). Demand for low carbon materials produced by foundation industries is key to delivering the targets and technology adoption rates assumed in various decarbonisation strategy documents. By responding to demand from consumers and companies further down the value chain (such as automotive manufacturers, property developers and their component suppliers) for materials with low embodied carbon content, foundation industries also create the demand for sustainably mined and transported raw materials, clean energy such as green hydrogen and renewable electricity, and technologies such as electric arc furnaces and carbon capture and storage solutions.

This policy briefing draws on a more detailed Technical Report[7] and sector-specific deep dives,[14,15,16] which a team of researchers produced in collaboration with industry representatives from energy companies, foundation industries and downstream value chains. The key objective of the research project was to explore how demand-led innovation could support industrial decarbonisation and what kind of government and business action could facilitate this. The research project investigated how actions by policymakers, consumers and businesses across foundation industry value chains could better support the creation of the market demand that is needed to incentivise low carbon innovation and faster adoption of existing low carbon technologies in the UK, some of which are not yet available at commercial scale.

The research identified four key decarbonisation pathways to achieve net zero aligned emissions reductions in the UK foundation industry value chains: Electrification; Circular economy solutions; Novel technologies; and Innovative products, processes and practices.

These pathways are not mutually exclusive: considering the urgency with which industrial emissions need to be aligned with the UK's climate targets, all available levers will need to be deployed. Although novel technologies and technological innovation are hugely important, technological solutions alone are not sufficient to achieve the decarbonisation of heavy industry. In each decarbonisation pathway, there is a need for varying degrees of policy innovation, process innovation, technology innovation, product innovation and business model innovation.

The researchers also identified five interrelated challenges that cut across all foundation industries, presenting barriers to decarbonisation through innovation and scaling up of innovation, as follows:

- high capital cost of production technologies
- a supply-demand catch-22
- lack of standardised data collection and reporting on embodied carbon emissions
- exposure to trade
- a lack of familiarity or engagement with new materials among downstream users.

These challenges reduce companies' ability to make significant investments in low carbon technologies, making them essential issues for government policy to address. These challenges are discussed in reference to the different decarbonisation pathways (Section 4) and policy interventions (Section 5) that could address them.

Although a robust long-term business case for clean production investments depends on market-based demand for products made from the efficient use of climate neutral materials,[17] a certain degree of government intervention is needed to enable, support and facilitate business engagement in foundation industry decarbonisation.

To test the central thesis of the analysis regarding the role of demand in driving investment in decarbonisation, the researchers partnered with Cambridge Econometrics to carry out a pilot-style modelling exercise focussing on the non-metallic minerals (ie cement, glass and ceramics) sector using the multisectoral E3ME model. The modelling results showed that economies could obtain substantial employment and competitiveness gains, and achieve emissions reductions, by investing in policies that incentivise industrial decarbonisation by creating demand for materials and products with lower embodied carbon content. These results, alongside the qualitative research results and business case studies, have influenced the recommendations for how government action could help support demand-led innovation and faster adoption of innovative solutions (Section 5).

2. Background

Interventions and incentives to create and scale up demand for low carbon materials are important to align economic objectives of industrial growth and competitiveness, innovation and technology adoption with the net zero emission goal. Virtuous cycles, whereby lower production costs are reflected in lower sale prices, thus accelerating the quality and adoption rate of new technology, can support the scaling up of innovation.

2.1 Industrial competitiveness and net zero

With more than 90 per cent of global GDP[18] being covered by net zero targets, the markets for clean technologies and products are expected to proliferate. According to one study, the value of 'green industries' is expected to exceed US$10trln[10] by 2050. In this context, industrial companies' ability to adapt to the new competitive sustainability paradigm will determine their survival and ability to thrive in changing global markets.[19,20] Companies that are among the first to develop cost-effective ways to produce materials and products with lower embodied carbon content will benefit from being able to avoid the cost of a rapidly increasing carbon price, as well as from gaining a larger market share and from selling their intellectual property to others.

Increasingly, countries are beginning to recognise the enormous economic benefits and competitive advantage that early investment in low carbon innovation and adoption can deliver. As acknowledged in the UK's Net Zero Strategy,[21] and Chris Skidmore's independent net zero review,[22] developing the necessary technologies to decarbonise basic materials production presents an enormous, but currently largely untapped, opportunity for the UK industry. A similar understanding in the US has informed the design of the 2022 US Inflation Reduction Act (IRA),[23] provoking the EU to announce plans[24] to offer tax breaks and simplify permitting processes for new clean technology production sites, eventually culminating in the publication of its Green Deal Industrial Plan (GDIP)[5] and Net-Zero Industry Act,[6] intended to scale up the manufacturing of clean technologies in the EU.

Relaxing the EU state aid rules would enable the UK government to offer more direct support to businesses.[i] However, the UK's 2021 Net Zero Strategy,[12] the 2021 Industrial Decarbonisation Strategy[12] and the 2023 'green day' announcements[25] have been widely criticised for failing to map out a credible pathway to net zero[26] and presenting a missed opportunity[27] to urgently accelerate decarbonisation and the transition to a more sustainable economy in the UK.[28,29,30] Most notably, these strategies and plans do not provide comparable incentives or certainty over the future direction of travel for companies' UK operations, compared to those included in the US IRA and the EU's GDIP and Net Zero Industry Act, raising concerns that UK companies will not be able "compete on a level playing field".[31]I

Yet, due to long investment cycles, the investment in innovation and scaling up of new technologies and production processes in foundation industries must take place now to ensure that low carbon materials will be available in sufficient quantities when the production using the incumbent technologies becomes increasingly unsustainable. Private sector companies cannot deliver this transition alone: government policy is key to ensuring that decarbonisation presents an economically viable pathway and protecting the UK economy against carbon leakage and industrial decline.

2.2 Innovation and the technology learning curve

Innovation involves a complex (non-linear) chain of phases involving different actors, barriers and policy influences. Having a good concept and proving that it *could* work in practice is only the start of a long journey. Even if a new concept or technology is successfully demonstrated to have potential, this does not necessarily lead to successful commercialisation of the product. The transition from the early 'technology push' stages of the process (basic

[i] The EU-UK Trade Agreement obliges the UK to follow the EU rules for state aid (subsidies for business) and competition if it wishes to enjoy tariff-free access to the European markets following Brexit.

research, applied research and development, and demonstration – ie Technology Readiness Levels,[32] TRL 1-5) to the 'market pull stages' (commercialisation and beyond) is a notoriously difficult gap to bridge.

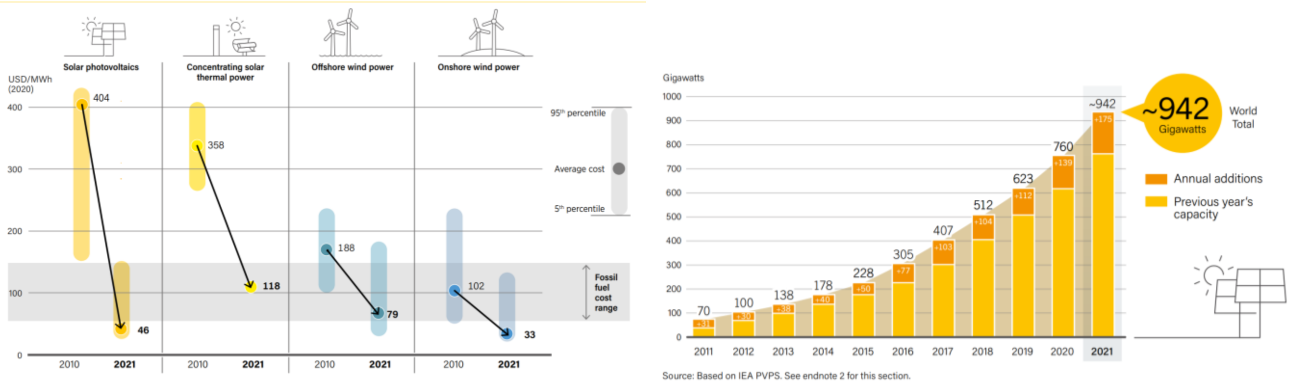
In foundation industry value chains, commercialisation and market diffusion of low carbon innovation depend on downstream companies' willingness to purchase these materials. Reinforcing feedback loops through demand growth and technology learning is key to accelerating the innovation and adoption of low carbon production technologies and approaches in the foundation industry.

Currently, incumbent (carbon intensive) production technologies are more readily available and cheaper to purchase (and, in some instances, to operate). As a result, lower carbon products and materials incur a so-called 'market premium' (ie a higher sale price than more carbon-intensive equivalents), which companies further down the value chain must be willing to pay to enable producers further up the value chain to make a viable business case for investing in low carbon production processes and material inputs. Unless downstream companies are both willing and able to do this in large numbers, additional support is needed to address specific challenges and opportunities in the development of low carbon supply chains that companies may struggle to address or consider too risky to tackle.[33]

However, higher adoption rates of new technologies would reduce their per-unit production costs over time, leading to cost parity with incumbent technologies or even lower costs altogether (Grubb et. al., 2014; see also modelling study in Section 3.3 of this report). This so-called technology learning process, whereby the cost of per unit production declines as production volumes grow, leads into a virtuous cycle whereby the lower production costs are reflected in lower sale prices, thus accelerating the quality and adoption rate of new technology.[34]

The technology learning process can be illustrated by the solar PV industry over the past 10-15 years. As globally installed capacity has grown, the levelized cost of solar PV technology has substantially decreased. This is shown in Figure 1, where the left panel shows levelized cost changes between 2010 and 2021, and the right panel the capacity additions between 2011 and 2021.

Figure 1: Technology learning process illustrated[35]



Source: Renewables 2022 Global Status Report (pages 154 and 126)

A similar process of technology learning could accelerate both the demand and supply of low carbon steel, cement and glass (as well as other foundation industry materials), enabling new, low carbon solutions to capture a growing share of the market and economies of scale to develop. Over time, this would push down the cost of all low carbon material inputs and production technologies across the value chains, from mining to product disassembly, material decontamination and adoption of more circular solutions. The modelling exercise in Section 3.3 of this briefing illustrates how this process could result in multiple benefits in the cement, glass and ceramics industries in the UK.

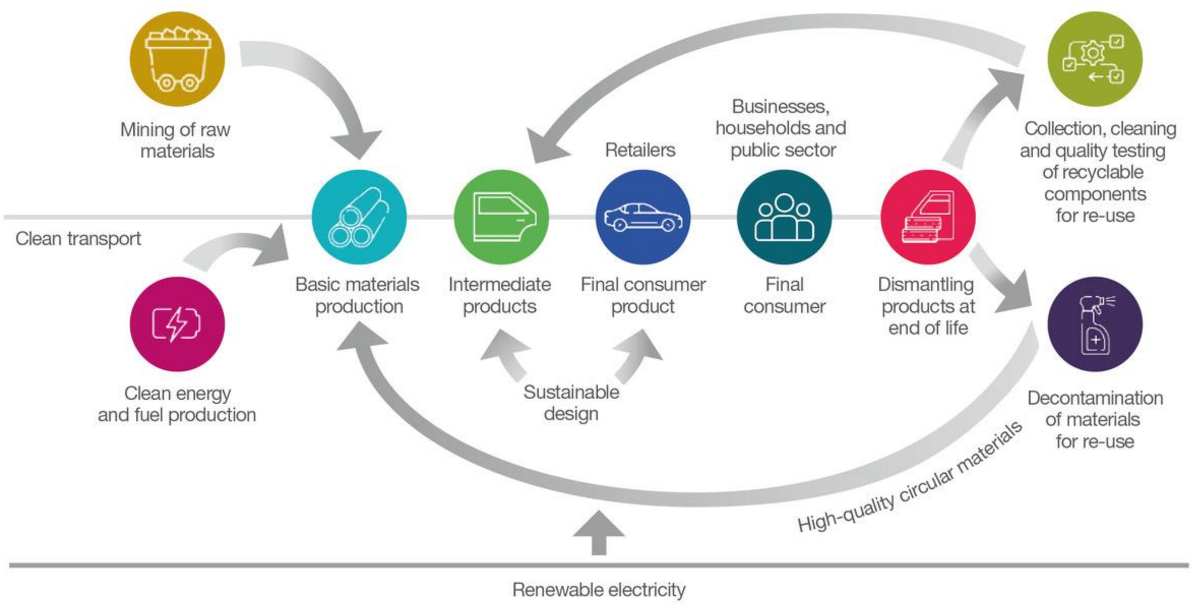
3. Decarbonisation of the whole value chain: how demand can help?

Focusing on all stages and stakeholders of the value chain is important for decarbonisation. The end-to-end value chain approach developed by the research team in collaboration with industry partners illustrates how demand can play a key role in promoting circularity and driving innovation within the production and consumption processes, highlighting the crucial role of demand in incentivising and enabling innovation. Five key barriers to low carbon innovation and its upscaling apply across the different decarbonisation pathways and industry value chains.

3.1 The end-to-end value chain approach

In collaboration with industry partners, the research team developed an 'end-to-end value chain approach' to identify how demand drives decarbonisation across value chains, focusing specifically on the value chains for iron, steel, cement and glass. This approach is illustrated in Figure 2. In this end-to-end value chain approach, each company along the value chain has two functions: they are a consumer of upstream products and materials and a producer of downstream operations. This also applies to individuals, households or government agencies that are typically referred to as 'end users': in a more circular model, these so-called end users are proactive agents all along the value chain that provide scrap for circular primary production and recyclable components for manufacturing, thus playing an essential role in enabling decarbonisation.

Figure 2: End-to-end value chain for low carbon foundation industry



One of the fundamental reasons for focusing on the entire value chain is **scope 3 emissions**. These emissions do not emerge from a company's operations (like scope 1) or electricity, steam, heat or cooling (scope 2), but are generated within the upstream and downstream value chain. For many companies, especially those that use large quantities of energy intensive materials, scope 3 emissions can be much larger than scope 1 and 2. However, scope 3 emissions are generally more difficult to mitigate because they are determined by other operators in the value chain. For example, a car manufacturer can reduce their scope 1 and 2 emissions by electrifying their operations and purchasing renewable electricity. Still, their scope 3 emissions come from the embedded CO_2 in the material inputs that go into each car (upstream scope 3) and the use of the cars they manufacture (downstream scope 3). To mitigate these emissions, a car manufacturer would need upstream producers to produce components and materials with low embodied CO_2 emissions and downstream users to use low carbon fuels (such as renewable electricity) to power their cars.

Each company in the value chain must address their scope 1 and 2 emissions to enable downstream companies to estimate their upstream scope 3 emissions and take steps to reduce them. However, controlling scope 1 and 2 emissions is difficult for certain companies at the early stages of the value chain, including mining, energy and fuel production, and foundation industries. As a result, addressing upstream scope 3 emissions is currently impossible for many companies, including foundation industries, unless they meet their energy demand from low carbon sources, run their own (sustainable) mining operations and can control how raw materials are transported to the production facilities (See Case Study 1: Rolls Royce – The decarbonisation journey of Rolls-Royce facilities and supply chain in the Technical Report).

3.2 The role of demand

The end-to-end value chain approach depicted in Figure 2 illustrates the crucial role that demand plays in enabling material producers and manufacturers to accrue economic benefits from switching to low carbon production. Because all companies along a value chain are connected to upstream and downstream companies, actions are needed along the entire value chain to generate enough demand for a widespread transition to the decarbonisation of industry, value chains, and business models.[17]

Demand signals need to flow upstream, from the final consumer product, through the intermediate product manufacturers, to the basic materials producers, mining of raw materials and clean energy and fuel production (as illustrated in the end-to-end value chain graph in the previous section).[17] Currently, the challenge to foundation industry decarbonisation is that, in current markets, the demand for low carbon materials and products with low embodied carbon content is undeveloped and, in some cases, absent entirely. In this context, progressive businesses are largely left to their own devices to take voluntary action, for example, by setting up cross-sectoral low carbon buyers coalitions, such as SteelZero and Concrete Zero (featured in the Technical Report). However, the financial viability of voluntary progressive business action is determined by contextual conditions.

The idea of low carbon buyers' coalitions is endorsed in the UK's 2021 Industrial Decarbonisation Strategy,[36] which states that "We [the government] want to help private companies combine their purchasing power by facilitating the formation of voluntary buyers' alliances". These coalitions can have an even greater impact on an international scale if material consumers from several countries join in. Such large cross-national efforts to consolidate demand could radically change the investment landscape for low carbon material producers, improving investors' confidence in decarbonisation, and thus ease access to low-cost finance for foundation industries to invest in low-cost production and its upscaling.

3.3 Macro-econometric benefits of demand-led innovation

To investigate the central thesis of the research, CISL commissioned Cambridge Econometrics to undertake a modelling exercise to examine the impacts of demand-led innovation on the UK economy, specifically in the non-metallic mineral products sector. The exercise compared the effects of supply-led and demand-led innovation scenarios using the E3ME macroeconomic model[ii]. The results show that initial increased downstream demand for low carbon goods can drive the upscaling of low carbon technologies, leading to quicker cost decreases and positive economic and employment impacts in the decarbonised sectors and other parts of the economy. The accelerated adoption of low carbon technologies in industries can provide a double dividend of reducing emissions, boosting

[ii] The E3ME model's post-Keynesian approach, which considers the economy as a demand-led system with unused capacities and endogenous money supply, provides the theoretical underpinnings for the analysis.

competitiveness, and driving economic growth. Measures that give an initial guaranteed market for low carbon products, including regulatory reforms, financial support, product standards and labelling schemes, could all play an important role in realising such an outcome (See section 7 of the Technical Report for more detail on the modelling and the results).

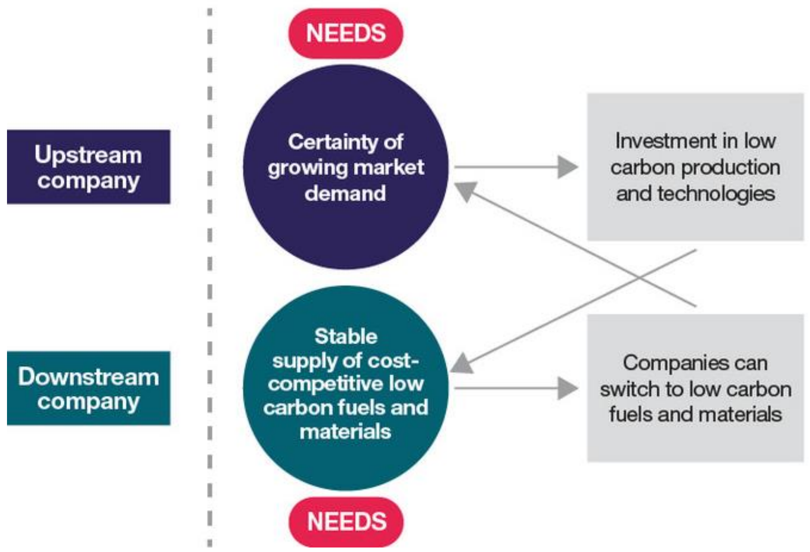
3.4 Challenges to low carbon innovation and upscaling

As mentioned in the introduction, the research identified five cross-cutting challenges to innovation and upscaling of low carbon innovation in foundation industries. These include:

High capital cost of production technologies. Long product lifespan means that decisions over modifications, retrofits or entirely different types of technology to facilitate fuel-switching to green hydrogen, electrification, or CCUS are usually made when the existing assets reach the end of their lifespan and need extensive maintenance or replacement. Replacing a production asset before such time could be prohibitively expensive unless the operating costs of new technologies decline substantially below the operational costs of the installed technologies. This means that companies will need to make decisions to make their assets compatible with decarbonisation pathways before some of the novel technologies that are being developed, such as green hydrogen or CCUS, are available at a commercial scale and before a critical mass of the market is willing to pay a premium for materials with lower embodied carbon content.

Supply-demand catch-22. This refers to a situation whereby an upstream company does not have a large enough market demand to upscale the production of low carbon materials or the technologies to produce them, and downstream companies can only risk investing in alternative technologies once they have a stable supply of upstream products. The supply-demand catch-22 can emerge between foundation industries and downstream or upstream companies. Between foundation industries and upstream companies, the supply-demand Catch-22 can reduce the pressure to improve the sustainability of mining operations or the viability of upscaling clean energy production, such as green hydrogen. Moreover, uncertainties among foundation industries over the future availability and quality of scrap material can also prevent shifting to more circular production models in the glass and steel industries. The supply–demand catch-22 is illustrated in a graphical format in Figure 3 (below).

Figure 3: Graphical illustration of supply–demand catch-22



Lack of standardised data collection and reporting on embodied carbon emissions. Lack of transparency and clear benchmarks – including the absence of shared embodied carbon accounting and reporting standards – can make it difficult or even impossible for potential low carbon material purchasers to compare different 'low carbon' alternatives and compromises their ability to market their own products as 'demonstrably' low carbon. This causes severe challenges for companies that have signed up to the Science-based Targets initiative's (SBTi) net zero standard,[37] committing to reduce their emissions by at least 90 per cent across all scopes (including scope 3) by 2040. However, due to a lack of high-quality, comparable data on embedded emissions in upstream basic materials and intermediate products, companies that use large amounts of basic materials find it extremely difficult to estimate (and control) their scope 3 emissions.

Exposure to trade. This becomes a problem primarily if cheaper imports are available alongside domestically produced materials. Most of the major foundation industry material consumers, such as automotive manufacturers, need to compete against imported products in the domestic market. These market dynamics constrain the material users' ability to pay the 'green premium' for lower-carbon materials and to pass these costs on to their consumers.

Lack of familiarity or engagement with new materials among downstream users in the foundation industries and value chains are interlinked. This can lead to concerns over their performance and, thus, reluctance to choose them over familiar alternatives. Lack of familiarity with new technologies can also increase the cost of debt finance or make products more difficult to insure.

These challenges reduce foundation industry's ability to make major investments in low carbon technologies, making them fundamentally important issues for government policy to address. Creating demand and certainty of demand growth in the future for low carbon materials is key to incentivising increased use of circular materials, low carbon fuels and investing in innovation. A case in point is the possibility of using different material inputs such as replacing some of cement's clinker content with Supplementary Cementing Materials (SCMs) among foundation industries. In the next section, we illustrate how these barriers to innovation and its upscaling play out with different industrial decarbonisation pathways.

4. Decarbonisation pathways: where and why demand is needed?

The research identified four key pathways for decarbonisation along the foundation industry value chains, and the contextual conditions that would enable progress under each pathway. Each of these pathways presents several opportunities for business and the economy, but there are also challenges to their delivery. None of these pathways is sufficient alone to deliver the UK's industrial decarbonisation targets, meaning that all possible levers will need to be deployed. Where relevant, this section includes reference to business case studies that are included in the full research report, showcasing business actions and experiences.

Table 2: Summary of the key decarbonisation pathways for UK foundation industry

Key decarbonisation pathways			
Electrification	**Circularity**	**Novel technologies**	**Innovative products, processes and practices**
New types of Power Purchase Agreementsfor energy-intensive users	Material substitution and efficiency (to enable users to pay more for low carbon materials) New product designs to improve disassembly and decontamination of components	Ability of foundation industries to deploy green hydrogen or Carbon capture, utilisation and storage (cost considerations) Guarantees over future returns for companies investing in Carbon capture, utilisation and storage	Innovation in material inputs (eg new feedstocks to reduce process emissions) Business-to-business collaboration to deliver incremental reductions down the value chain Challenge-focused public-private collaboration mechanisms and platforms (similar to European Battery Alliance but for steel, cement, glass and other foundation industry materials)
Enabling contextual conditions			
Stable, reliable, abundant renewable power supply Fair price on electricity (electricity cost must be lower than the cost of using fossil fuels)	Improved public awareness of the importance of recycling Improved recycling infrastructure Emergence of markets for high-quality scrap materials to improve the financial viability of new business operations in recycling and reuse	Risk mitigation mechanisms to protect producers of green hydrogen Regulatory reforms to improve the profitability of green hydrogen production Infrastructure to safely transport green hydrogen or captured carbon Public awareness and acceptance of novel technologies	Ability to acquire legally mandated certification and insurance for novel technologies and materials and products using innovative approaches or technologies Explicit guidelines for how to share credit for emissions savings through Business-to-business collaboration
Demand for materials and products with lower embodied carbon content than current market average in the UK			

4.1 Electrification

Direct electrification makes it possible for renewable electricity to replace fossil fuels in many energy-intensive operations, in theory providing near-zero emission energy at a very low marginal cost. Electrification has already been proven to be a technologically viable pathway to decarbonisation in specific sectors, such as the steel industry and many other downstream manufacturing sectors. However, the dominant fully electric technology in the steel industry (the Electric Arc Furnace, or EAF) requires scrap (ie recycled steel) as the material input, linking the feasibility of electrification in the steel sector closely to the improvements in recycling practices, infrastructure and regulation described below in reference to the circular economy practices.[iii]

The research identified three significant challenges to electrification in foundation industries where government intervention could support the transition from fossil fuels to electricity. These include:

- **Impact of industrial electrification on electricity demand.** To meet this demand, the UK would need to invest in considerable upgrades to its power generation capacity and transmission and distribution infrastructure.
- **The current pricing structure in the UK energy market does not reward consumers for making cleaner choices.** There is a pressing need for electricity market reform that decouples the cost of cheap, clean, renewable power from the volatile and high gas prices would enable energy intensive-industries to benefit financially from committing to using clean energy to power their processes.[38] New approaches to energy pricing, such as the Green Power Pool,[39] would allow energy-intensive industries to harness the benefits of the expansion of cheap renewable energy, improving the financial viability of clean production processes. It would also reduce the need for major financial interventions from government to alleviate the impact of soaring electricity costs on the competitiveness and economic viability of low carbon foundation industry operations, such as electrified steel-making. As such, cheap, reliable, and abundant supply of renewable electricity would also support the growth of circular practices in foundation industries (see Case study 2: Liberty Steel and High Value Manufacturing Catapult – The UK's scrap steel opportunity in the Technical report)
- **Electrification of existing plants will require considerable capital investment** in new facilities compatible with more circular, electrified production methodologies. For example, Tata Steel estimates that it would cost roughly £3bn to convert just one of their coke-fuelled blast furnace (BF-BOF) into an electric arc furnace (EAF) (see the Steel sector deep dive for more detail on different production technologies). Considering this, the plan announced by the UK Government in early 2023 to subsidise the conversion of one of Tata Steel's and one of British Steels' blast furnaces by £300m each may not be sufficient, covering only around 10 per cent of the costs.[40]

4.2 Circularity

Circular economy solutions allow materials and products to be kept in use for longer, reducing emissions and environmental damage from energy-and material-intensive production and extraction processes.[41,42,43] To facilitate the emergence and growth of circular approaches in the UK, intermediate and final product manufacturers must develop innovative designs that reduce material contamination and make the disassembly and recycling of the different materials and components more feasible and cost-effective.[44] Using scrap to produce materials such as steel, glass, and aluminium must also be feasible for foundation industries. There must be a sufficient scrap supply and high enough demand for materials and products with high recycled content. Considering the scale and urgency of the challenge, policy interventions may be required to address UK low carbon products and materials being outcompeted by imported materials and products that are cheaper but more carbon intensive.

As mentioned above, one of the main barriers to greater circularity in foundation industry value chains is the lack of sufficient quantities of high-quality recycled materials. Although greater use of cullet (recycled glass) offers a technologically feasible decarbonisation pathway to glass manufacturers, the UK has yet to realise its full potential. In 2019, 71 per cent of container glass on the market was recycled (1,824 kt), with 29 per cent being lost to landfill (750

[iii] As discussed in the Sectoral deep dive: Steel, another technology called direct reduction (DRI) in combination with an EAF could be utilised to reduce dependency on scrap steel in EAF production. However, this route would involve importing sponge iron as hot briquetted iron from countries where this can be manufactured. The DRI-EAF route is currently not being used in the UK but has recently grown in popularity in other jurisdictions.

kt). Only 36 per cent of the recycled container glass returned to glass manufacturing (925 kt), with the rest being down-cycled as aggregate in construction (475 kt), recycled in other remelt applications (132 kt), or exported (292 kt). The balance between recycled glass supply and new glass demand in the UK results in an average recycled content rate in new glass products of 38 per cent (Zero Waste Europe Report)[45] (see Case Study 3: Waste container glass in the Technical Report).

Similarly, to improve the retention and utilisation of scrap steel in the UK, there needs to be a sizeable domestic market for recycled steel and an improvement in circular practices across the supply chain. Improving the quality of secondary material flows will be critical: scrap steel is 100 per cent recyclable but inherent material losses (1 tonne of scrap steel yields about 0.91 tonnes of new crude steel) and inadequate recycling practices reduce the actual recycled rate of end-of-life scrap to ~85 per cent.[46] Moreover, the vast majority of this is exported to countries with a market for lower quality scrap than UK manufacturers would need (See Case Study 2: Liberty Steel and High Value Manufacturing Catapult – The UK's scrap steel opportunity in the Technical Report).

The 'pent-up demand' in the steel sector provides a good example of a supply-demand catch-22 situation: because there is limited market demand for materials with low embodied carbon emissions that can be achieved via the use of scrap, only a few foundation industry manufacturers are actively seeking better access to scrap. As a result, business models around material decontamination and recycling have yet to emerge to produce high-quality scrap in large quantities for the UK foundation industries.

To address the challenge of pent-up demand, new business operations need to emerge, possibly (at least initially) with government support through start-up grants and low-cost loans, to collect, clean and quality test recyclable components for re-use and decontaminate materials for recycling. Collaborative arrangements involving two businesses across a value chain can result in emission reductions. For example, a collaboration between the Schaeffler Aerospace Division and Rolls Royce resulted in significant reductions in CO_2 emissions through the Maintenance, Repair, and Overhaul (MRO) of engine bearings. As this case study shows (See Case study 4: Rolls-Royce / Schaeffler – Refurbishment and recycling of steel components in the aerospace industry in the Technical Report), the refurbishment of a bearing can save up to 81 per cent of CO_2 compared to the manufacturing of a new bearing, comparable to the emissions of an average refrigerator over 2.5 years; however, the refurbishment and recycling of used bearings require cooperation between the producer of the bearings and either the Original Equipment Manufacturer (OEM) or the end customer, or both.

Importantly, new business models around recycling can only emerge if the collection of recyclable materials is improved and domestic markets for scrap develop to make these new business operations financially viable. Technological innovation is also needed to improve the recyclability of foundation industry materials. In addition to materials such as steel and aluminium, the need for innovative recycling technologies also applies to rare earth elements (REEs), which are entering the product life cycle in rapidly increasing quantities as the push for electrification in automotives, aerospace, machinery, and other sectors accelerates. Currently, the UK has a limited REE processing industry, and the recycling rate for REE and high value materials used in electric motors is less than 3 per cent. To address this challenge, the Warwick Manufacturing Group (WMG) Centre High Value Manufacturing Catapult (HVMC) are working on a project to extract, recycle and reuse REE permanent magnets from electric motors to help improve a domestic supply chain network. However, none of these approaches are yet commercially viable or suitable for industrial use and will require government support and intervention to become market ready (see Case study 5: High Value Manufacturing Catapult – Recycling of rare-earth elements in electric motors in the Technical Report).

4.3 Novel technologies

The industrial decarbonisation challenge cannot be solved solely through electrification and circular solutions. By 2050, there will still be a need for some 'virgin' material manufacturing to meet the growing demand caused by population growth and increasing wealth globally. To achieve net zero, UK's Industrial Decarbonisation Strategy[36] relies heavily on the deployment of novel technologies, particularly Carbon Capture, Usage and Storage (CCUS) and hydrogen. Because these technologies are not yet available at a commercial scale, it is difficult to estimate how they will grow and can be integrated into the existing systems, their cost, infrastructure needs for safe deployment, and public acceptance.

According to the strategy, CCUS technology is expected to mitigate CO_2 emissions by 8 million tonnes per year by 2050. However, CCUS is still in the development stage and not yet ready for deployment. The economic and technical viability of the technology remains uncertain, and it may be complicated if the manufacturing plants have multiple emissions points. Yet, because foundation industry production assets are capital-intensive and have long lifecycles of 30 to 40 years, all new and renovated plants must be ready to fit CCUS when it becomes commercially available, especially in the cement industry, where fuel-switching could not remove substantial process emissions. This means that companies may need to spend considerable capital to make their assets CCUS ready without any guarantee that the technology will ever be available or affordable.

The key innovation areas needed to make CCUS economically viable include technological solutions to reduce costs, ways to capture carbon emissions from multiple emission sources at a plant, and secure transportation and storage of the captured carbon. Any measures that can cut emissions through efficiency improvements or innovation in terms of material use and process emissions, such as new circular economy technologies that improve the recyclability of materials, will help to reduce the amount of CCUS that is needed (see the Cement sector deep dive for further detail on cement industry decarbonisation pathways in the Technical Report).

Alongside CCUS, the use of renewable energy sources is a crucial step in the decarbonisation of energy-intensive industry value chains.[47] Green Hydrogen, produced using 100 per cent renewable electricity, can significantly contribute towards the government's decarbonisation goals, particularly in sectors that are hard to electrify, such as heavy industry and heavy goods vehicles. It is currently being piloted in the steel industry[48] in Sweden).

Although the UK's Hydrogen Strategy[49] sets an ambitious target of 10 GW of low carbon hydrogen production capacity (subject to affordability and value for money, with at least half from electrolytic hydrogen) in the country by 2030 (up from the current 0.7GW of predominantly carbon intensive hydrogen), green hydrogen is currently not produced in the UK at commercial scale, making the abatement potential and sustainability of this route the subject of significant debate.[50] In the absence of green hydrogen, companies that switch from natural gas to hydrogen will increase rather than decrease their emissions while incurring higher costs due to the inefficiencies of converting methane to hydrogen. The availability and affordability of green hydrogen are also being questioned because the UK's existing gas grid is largely unsuitable for transporting hydrogen.[51] For green hydrogen to take off as a viable pathway for industrial decarbonisation, further investment and technological innovation are needed to ensure that the hydrogen transport network is leak-proof, fit for purpose, and extensive enough to service the industries that most need to have access to green hydrogen.

At present, the viability of green hydrogen projects is also hindered by the supply-demand catch-22 and regulatory and policy barriers, which need to be addressed for the hydrogen sector to realise its potential. Without a readily available and abundant supply of green hydrogen, it will be risky for energy-intensive companies to upgrade their furnaces to operate with hydrogen. To address this challenge, innovation is needed to design new types of Power Purchase Agreements (PPAs) specifically for hydrogen use in energy-intensive processes. There may also be a need for a government-backed insurance scheme that protects foundation industries if production processes are disrupted due to insufficient supply.

The key regulatory and policy barriers to hydrogen production include network access costs, policy costs, the regulatory framework around metering, and lack of compensation for system balancing for green hydrogen producers (Case study 12: Scottish Power – Regulatory and policy challenges for green hydrogen in the Technical Report). In addition to these regulatory barriers, the subsidies available for hydrogen producers currently cover less than half of the investment costs.[52] This means that large-scale investment in green hydrogen (needed to instigate fuel-switching further down the value chain) remains risky for the energy companies, especially while hydrogen transport infrastructure is underdeveloped and energy-intensive industries do not have production facilities designed to run on hydrogen. Government funding mechanisms, such as Contracts for Difference (CfD) type approaches, have been proposed to address these challenges for low carbon hydrogen production.[52] The UK Government's recent certification scheme to verify the sustainability of low carbon hydrogen[53] may also help to build transparency and confidence across the sector.

Novel digital technologies, such as blockchain and Artificial Intelligence (AI), could be deployed to support various decarbonisation pathways, including electrification, circularity, the use of CCUS and the deployment of green hydrogen. These technologies could allow companies to accurately calculate the embodied carbon content of their products and securely share the data across value chains, potentially increasing demand for low carbon materials and products. Access to high quality, verifiable, reliable, and comparable data on the embodied carbon content of different materials is a necessary precondition for policies such as mandatory embodied carbon standards for products and instruments, such as Digital product Passports (DPPs), to be implemented. Access to high quality embodied carbon content data is also needed by companies to calculate their scope 3 emissions and to take measures to reduce them in line with any future regulations or requirements, as well as to promote their products as 'low carbon'. Such data will also be useful to support the expansion and efficiency of existing (voluntary) business initiatives such as the Science Based Target Initiative (SBTi), Steel Zero and ConcreteZero (both case studies are available in the Technical Report).

4.4 Innovative products, processes and practices

The final one of our four key decarbonisation pathways is innovative products, processes and practices. This refers to a range of actions that can help reduce (but not eliminate) emissions from any foundation industry or their downstream value chain. These solutions typically emerge when the opportunities to revamp the existing technologies used to manufacture the basic material are constrained by the factors set out in the previous three pathways. However, changes in some operational functions are more feasible in the short term.

Innovative processes, practices and products can help reduce demand for 'virgin' materials by enabling material or even large components to be reused multiple times (a practice often categorised as a 'circular solution'). In addition, new product designs can improve material efficiency, making use of advanced steel grades to enable components and applications to be designed with a reduced volume of material. Tata Steel UK has been using this approach successfully with its automotive customers where 'light-weighting' of vehicles has been a focus for many years. Now the company is working with industry partners to bring a new design approach to building systems in the construction sector. Tata Steel's SEISMIC project,[54] which was set up in 2020 to develop a platform-based construction approach, enables standardised building components to be used in construction at scale and off-site across unrelated projects. For example, a component designed in the same way can be used for a school, a hospital, or a prison. This approach could reduce CO_2 emissions from the steel used in the construction sector and make the construction of new buildings faster. However, these benefits can only be realised with high uptake from the construction industry (see Case study 8: Tata Steel – Innovation in construction products in the Technical Report for more detail).

Another example of how process reformulation has cut transport-related emissions in major downstream industries is provided by Encirc's 360 solution,[55] which enables emissions reductions from shipping beverages that are sold in glass bottles. Encirc's improved supply chain management involves transporting liquid in bulk from producers around the world to Encirc's UK site. The beverages are bottled using a closed-loop system in containers manufactured using industry-leading technology and experience. The bottles are then stored in a warehouse, where artificial intelligence (AI) and automation enables them to be packaged in bespoke, consolidated loads (ie mixed pallets), which can be shipped directly to retailers (see Case study 7: Encirc's 360 service – Inviting partners to join the journey to a greener supply chain in the Technical Report).

However, this category also encompasses non-technological innovative solutions, such as changes in material inputs, that reduce emissions from material manufacturing without necessitating substantial changes to the production technologies. A demonstrative example of this included Ecocem's "ternary cement", which is made of a blend that has a clinker content of 20 – 25 per cent (compared to the current EU and UK industry standard of around 77 per cent), combined with SCMs (eg slag, FA, Clays, accounting for 25- 35 per cent of the content) and fillers (40 – 55 per cent of the content). Because of the high share of clinker in cement's total emissions (see Cement sector deep dive for further details), reduced use of clinker in the ternary cement can reduce CO_2 emissions by up to 70 per cent, generating financial savings through the avoidance of costly CO_2 credits. It will also reduce thermal energy demand by around 75 per cent and water demand in concrete manufacturing by approximately 50 per cent, in addition to reducing the future demand for CCUS.

Ternary cement has been proven to work efficiently with concrete and achieve the workability and performance standards required and can be produced with minor changes to existing production plants by increasing the use of cementitious/filler technologies already widely used in the cement sector. As a result, transitioning a plant to produce ternary cement instead of traditional cement is more immediate, cheaper, less disruptive and less energy intensive than the deployment of CCUS technology. However, its uptake can be hindered by prevailing standards for cement and concrete.

Aside from the examples mentioned above, new business models, such as service-based business models (whereby consumers pay for the right to use rather than to own products), could also fall into this category.

5. Supporting demand-led innovation: What policies can help and how?

Policy measures can be used to mitigate the cross-sectoral challenges to low carbon innovation and the upscaling of innovative solutions in foundation industry value chains. Based on analysis of the decarbonisation pathways as well as case studies submitted by the industry partners, the research identified three kinds of government actions that are needed: i) actions that create direct demand for low carbon products/materials; ii) actions that establish contextual conditions to support innovation and iii) actions that support international collaboration to secure demand for low carbon materials and products.

5.1 How policies can incentivise low carbon innovation and upscaling

Policies can play a crucial role in driving the development and adoption of new, low carbon technologies by creating demand for new products, thus reducing the risk of losses to companies that invest in their development and production. Considering that we are now only one industrial investment cycle away from 2050, by when the UK foundation industry should have reduced their emissions by at least 90 per cent, new policies to create markets for low carbon basic materials are badly needed to incentivise innovation and to remove barriers to scaling up of new, innovative solutions that are currently being piloted. To be effective, these policies will need to address all stages of the industrial production value chain,[17] including incentivising innovation and facilitating market diffusion through to increased demand in the downstream sectors, such as property development and automotive manufacturing. This includes removing barriers to deploying new low carbon materials and products by downstream industries.

The UK's 2021 Industrial Decarbonisation Strategy[36] contains plans for several calls for evidence and sets out preferred options for some funding mechanisms. It also sets out a number of measures to improve resource efficiency, including (a) exploring low carbon product standards and labelling which will consider embodied carbon, as well as broader environmental impacts and (b) a £30 million UKRI Circular Economy Research Programme aimed at working with industry to develop new approaches to resource efficiency.[56] However, it does not provide specific policy frameworks with explicit technology-led roadmaps[57] for how the long-term targets will translate into strong market demand that make the innovation and uptake of low carbon solutions in the foundation industries economically viable.

So far, demand-side policies to incentivise decarbonisation in the UK have been very limited, with the Emissions Trading System (ETS) being the sole policy mechanism applied to directly reduce industrial emissions. Yet, due to contextual conditions and the design of the ETS, it has been largely unsuccessful in incentivising the development and scaling up of new technologies and low carbon alternatives to material inputs. This lack of incentives to design and adopt low carbon technologies (instead of simply improving the efficiency, thus reducing the per unit emissions from current production facilities) has slowed down decarbonisation. This has been the case especially in sectors that face greater outside competition and have continued to receive free allowances, such as most foundation industries. Moreover, volatile carbon price, political uncertainty, and how the allocation of free allowances was determined discouraged companies that rely on capital-intensive means of production from drafting long-term decarbonisation plans and making significant and risky structural investments needed for deep decarbonisation.[2]

Drawing on existing literature and our discussions with our industry partners, the research identified several actions that the UK Government could urgently undertake. These include:

1) Designing and implementing **policies to create demand for low carbon products and materials.**
2) Designing and implementing **policies that support contextual conditions to encourage innovation or support the scaling up demand for innovative technologies and approaches** by businesses across the foundation industry value chains.

3) Establishing **international collaboration to accelerate demand for low carbon materials and products globally.**

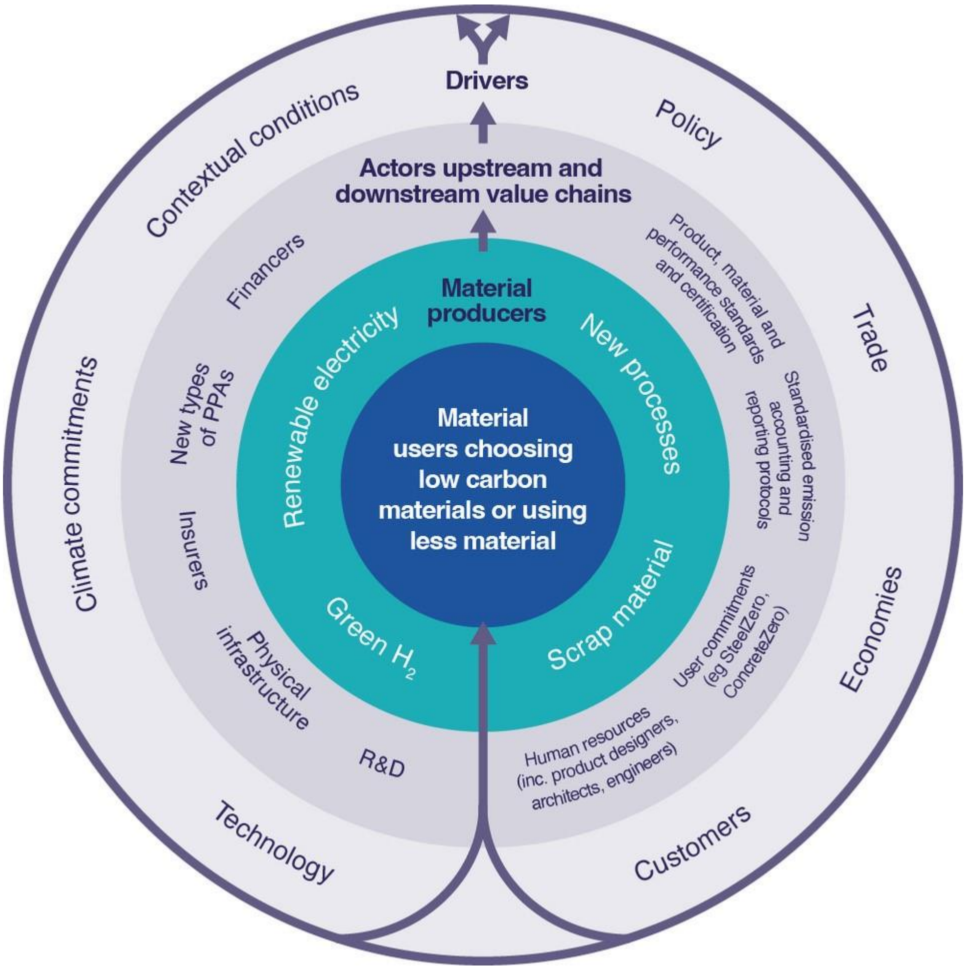
These broad actions and policy objectives can be addressed through a set of policy measures, falling into four main categories as shown in Table 3. Some most important and/or more novel policy measures are discussed in more detail below the table.

Table 3: Policy measures to support the development of demand for low carbon materials and create enabling conditions for an effective supply side response[58]

	Key actions the UK government could undertake		
Type of policy intervention	**Policies to create demand and support the scaling up of demand**	**Policies to establish supportive contextual conditions for effective supply-side response**	**International collaboration**
Regulatory reforms	Mandatory product standards on embodied carbon content (across value chains) or recycled material content (Aldersgate Group, 2022), supported by clear emissions accounting protocols and standards Regulation mandating (and creating a framework) for whole life-cycle carbon assessments for material-intensive products (Cannon et al., 2020) Regulatory processes that make it easier and faster to update product and material standards in response to the emergence of new, innovative, solutions Ban on sales of products from emission-intensive processes (Gerres et al., 2021)	Electricity market reform such as green power pools (Grubb et al., 2022) Cap on industrial electricity prices or increased indirect cost compensation for companies that use electricity or green hydrogen to provide long-term certainty that using cleaner energy (ie renewable electricity or green hydrogen) will always be more cost-effective than using fossil fuels Mandatory embodied carbon data collection and disclosure (McKinsey & Co, 2020b) Regulatory sandboxes to test new ideas / materials (German Federal Ministry for Economic Affairs and Climate Change, 2019)	Collaborate with trade partners and other major economies to develop and implement a shared embodied carbon emissions accounting and reporting rules for basic materials and intermediate products, such as the Clean Energy Ministerial Industrial Deep Decarbonisation Initiative (United Nations Industrial Development Organisation, 2023) Support initiatives that are led by the private sector and non-governmental organisations, such as the Carbon Call initiative (The Carbon Call, 2023) Collaborate with major trade partners to implement policies, such as the Carbon Border Adjustment Mechanism (CBAM) or 'climate clubs' (Financial Times, 2023; Markkanen 2021; OMFIF, 2023)
Financial support and fiscal incentives	Tax deductions / exemptions for user companies who commit to buying 'low carbon' (for incrementally growing share of material demand, assuming available supply) Fiscal incentives for companies further down the value chain (ie foundation industry material users) to invest in new product designs to make products more recyclable	Carbon tax or Emissions Trading System (ETS) Capital subsidies, grants and subsidised loans that cover a considerable share of the capital cost of investing in newly emerging experimental technologies as soon as they reach the market, but incur a considerable cost premium Tax exemptions for certain investments (eg deployment of transformational technology) Tax deductions or exemptions if revenue is recycled for certain purposes, such as R&D or investment in low carbon production technology Fiscal incentives to support investment in innovative solutions, including experimental new technologies and new business models Fiscal incentives for companies expanding their operations to cover recycling during the early stages of the transition to a more circular economy (including quality testing operations for recycled and reusable materials, components and products)	
Risk sharing and risk mitigation mechanisms	Government-backed insurance schemes for new products, recycling businesses, and recycled products and materials	Incentives for insurance providers to create new products for low carbon markets (eg providers and users of experimental / novel technologies) Carbon Contracts for Difference (CfD) for foundation industry materials (Chiappinelli & Neuhoff, 2020) Government-backed insurance schemes for new products, recycling businesses, and recycled products and materials	
Public sector investment	Revision of public sector procurement rules (embodied carbon limits and recycled content requirements) (Grubb et al., 2020) Allocation of government contracts to first movers (OECD, 2016) Operations that receive government subsidies could be subject to minimum requirements on low carbon material use / maximum levels of embodied emissions	Public sector infrastructure investment (eg waste management and recycling, electricity grids, hydrogen supply and distribution) Grants and low-cost loans for the private sector for transformational technologies Allocation of government funding to support convening activities and funding programmes by non-departmental government bodies to support knowledge generation and collaboration between academic institutions and the private sector to facilitate the emergence of new insights, best practices and innovative solutions	

The interrelationship between policies, contextual factors, decarbonisation pathways and companies across the foundation industry value chains is illustrated in Figure 4 below. This figure depicts how demand, driven and enabled by complex factors, could flow across the ecosystem to enable companies across the foundation industry value chains to decarbonise their operations, resulting in low carbon materials and products.

Figure 4: Demand-driven ecosystem to facilitate decarbonisation in foundation industry value chains



Regulatory reforms

Regulation can play a significant role in driving demand for low carbon materials and products, as well as impacting the ability of the supply to respond to demand-side signals.

Although many of the policy measures mentioned in Table 3 are well known and widely used, some ideas are novel or have not yet been applied in foundation industry decarbonisation. For example, regulatory sandboxes[59] could provide a real-life environment for the testing of innovative technologies, products, services or approaches that are not compliant with the existing legal and regulatory frameworks. To date, this approach has been used predominantly in the finance industry.[60] However, regulatory sandboxes could potentially be used to create the opportunity for companies in manufacturing sectors to test products that have been made using new technologies or novel production practices, to assess their suitability and fitness for purpose in real-life conditions and for policymakers to identify if regulatory changes should be made to enable these products to access the market. Regulatory sandboxes could also be used to explore the regulatory and legislative frameworks that need to be created to support data collection and sharing on embodied carbon emissions.

Product standards can mandate a minimum level of environmental performance and incentivise producers to adopt low carbon technologies and production methods, leading to innovation and overall sustainability improvements. They can also nudge consumers towards more sustainable products and disincentivise the sale of more carbon intensive carbon-products, thus stimulating investment and innovation in low carbon materials by creating confidence about future demand. To be effective, these standards would need to be well-designed, mandatory, and tightened over time. By implementing mandatory product standards, the UK Government could ensure that industry is competing on a level playing field and that companies pushing further on reducing emissions are not put at a competitive disadvantage.[61]

However, to avoid hindering innovation, emissions intensity standards should be technology neutral and focus on performance instead of using certain technologies or specific material inputs.[17] It is also important for product standards to be influenced more by the performance of products than the material inputs or the use of specific types of production technology. Updating and revising these standards should be responsive to the emergence of new, innovative solutions. For example, the current standards for cement and concrete are based on incumbent technologies that are emission-intensive by design. However, performance-based standards would be more neutral, incentivising innovation and making it more feasible for downstream companies (such as the construction industry) to switch to new low carbon alternatives.

Some countries are already moving in the direction of using primarily performance-based standards. For example, the PerfDuB project in France aims to establish a methodology to ensure the durability of concrete and to create an operational and practical performance-based approach that can be adopted by all stakeholders in the construction industry. This will involve defining the 'absolute' and 'comparative' methods for justifying durability through gathering input and feedback from all stakeholders to identify and address gaps in the current framework. The goal is to create an operational and practical performance-based approach that can be adopted by all stakeholders in the construction industry.[62][63] The results of the PerfDuB project have been incorporated into the new concrete standard published at the end of 2022, creating opportunities for the use of innovative formulations within the new standard.

Labelling schemes can be implemented independently or alongside product standards and other policy measures. These schemes can support decarbonisation by providing clear information about the carbon emissions of products, incentivising sustainable production, empowering consumers to make informed choices, and driving innovation in low carbon technologies. However, they must balance accuracy and accessibility to avoid confusion during the purchasing process. Using colour codes or scales can simplify messaging but may sacrifice scientific precision. Business-to-business transactions may also require support to bridge knowledge gaps between purchasers and suppliers, such as Japan's Act on Promoting Green Purchasing[64] and the Buy Clean California Act.[65]

Regulatory frameworks and standardised emissions accounting and reporting methodologies will need to be utilised by all suppliers to enable companies further down the value chain to make informed choices over how best to reduce their scope 3 emissions. Attempts and plans to design reporting protocols and mechanisms for specific sectors or product categories are already in place in the UK[66] and the EU.[67] However, carbon content accounting and reporting mechanisms in the UK would ideally be aligned internationally and across sectors to make it easier to compare the carbon content of materials and intermediate products in multiple countries.[68] The EU has already announced plans to implement a mechanism for information sharing, the Digital Product Passport (DPP). However, this is not yet complemented by shared standards for embodied carbon accounting and reporting.[69] It is in the UK's best interest to collaborate with trusted trade partners with similarly ambitious climate targets (for example, the EU, US and Japan) to design regulatory frameworks on embodied emissions accounting and reporting.

Shared accounting and reporting mechanisms are necessary for implementing many other regulatory tools, such as standards that set maximum acceptable embodied carbon content for products[59] and bans on the sale of manufactured materials using emission-intensive processes.[61] Such sale bans could effectively set near-zero-emission requirements for certain products, accelerating the phase-out of carbon-intensive production processes.

The announcement of plans for a future sales ban would also send a strong signal to producers, financing institutions and other stakeholders, incentivising them to invest in the shift to a carbon-neutral society.

The downside of embedded emissions accounting and reporting standards is that they may attract vocal opposition from companies that either do not wish to share their data or who find the task of implementing the methodologies economically unviable.[70] For example, the development of specific methods for embodied carbon accounting in the cement industry has proven challenging: the most accurate measure – which calculates CO*2* emissions based on the weight and composition of carbonates in raw materials and fuel sources, the emissions factor of carbonates and the proportion of calcination achieved – is also the most data intensive, and therefore may be difficult to implement in practice.[71]

Financial support and fiscal incentives

Financial support (such as grants and subsidies) and fiscal incentives (such as favourable tax treatment) have been widely used to nudge individuals, households and companies to make more sustainable choices, particularly in relation to energy use, energy efficiency and transport choices. For example, they have been effective in increasing the adoption rates of solar PV by business and households and the sale of electric vehicles. Financial support and fiscal subsidies, with long-term sustainability objectives, also feature prominently in the 2022 US Inflation Reduction Act.[72]

Grants, subsidies, subsidised loans, and fiscal incentives can take many different forms and be deployed to influence the behaviour of actors across the value chains. For example, the UK Government could support the very early stages of innovation and demonstration of new technologies and production processes by issuing grants and low-cost loans for universities and the private sector for R&D in developing and testing of transformational technologies and new approaches. However, it may also choose to make some financial incentives available for companies to purchase or commit to the purchasing of low carbon materials (such as Steel Zero and Concrete Zero featured in the Technical Report), companies who invest in new product designs to improve recyclability or companies that either expand their existing operations or emerge, to improve recycling of materials within the UK. Some examples of ongoing initiatives from other countries include the Netherlands' CO_2 performance ladder, which assists organisations, companies and projects to reduce their carbon emissions. By obtaining a certificate on the Ladder, organisations can gain a competitive advantage in their bids for tenders.[73]

Risk sharing and risk mitigation mechanisms

There are multiple policy solutions that could be implemented to incentivise innovation by de-risking investment by guaranteeing demand and revenues. De-risking investment can be achieved through conventional methods to guarantee revenues, such as regulations or product standards (eg, electric vehicle innovations are de-risked through banning ICE sales in the long term) or through subsidising innovative products and processes through financing instruments (eg capital subsidies or subsidized loans).

De-risking can also be achieved by directly guaranteeing revenues up to a given level. Examples include feed-in-tariff and Contract-for-Difference (CfD) systems, whereby governments make advance commitments to pay a fixed CO_2 price to investors. CfDs have previously been used in the energy sector but could also be applied to foundation industries that commit to producing materials with low embodied carbon content.[74]

One de-risking mechanism that is increasingly important as industries develop innovative solutions – which may impact on the material composition of products – is the need for innovative products and technologies to be insurable. Taking out insurance is a standard risk-mitigation mechanism that, in some instances, is legally mandated, such as public indemnity insurance for property developers. The inability to insure 'novel' or less well-known products or technologies, or excessively high insurance premiums, presents a major disincentive to innovation and the upscaling of innovation.

Public sector investment

Public sector investment will need to play a key role in accelerating demand for low carbon materials and products, as well as creating enabling conditions for effective supply-side response to demand signals. Some of these, such as grants, loans, subsidised loans, subsidies and fiscal incentives are already mentioned above.

As a significant consumer of many foundation industry materials, the UK government, devolved administrations (Northern Ireland, Scotland, Wales and England), and local authorities can accelerate demand for low carbon materials and products through the adoption of public sector procurement rules that are aligned with the UK's net zero targets. The scale of public sector spending is substantial: in 2019/20, a total of £295.5 billion was spent by over 10,000 public sector authorities and organisation in private sector procurement of various goods and services, accounting for about a third of public sector spending (32 per cent).[75] Net zero aligned public sector procurement rules could set embodied carbon limits or recycled content requirements on all materials that are used in public sector infrastructure projects.[39] Suppliers could be informed of the policy through official channels, with compliance being monitored through inspections or audits.

There is also a substantial need for the government, at all levels of governance, to invest heavily in developing the infrastructure needed to facilitate foundation industry decarbonisation along the pathways described in Section 4 of this briefing. To enable an efficient supply-side response to any demand signals, this would need to encompass waste management and recycling, electricity grids, and hydrogen supply and distribution.

5.2 Demand-side policies in action: Using the steel sector as an illustrative example

This section illustrates how some of the demand-side policies mentioned above can be applied to the steel sector. Strong demand-side signals and policies to support effective and efficient decarbonisation need to flow through the entire value chain, including all sectors that use large quantities of steel (such as construction, transport, appliances, and the intermediate products going into the manufacturing processes). This demand, together with enabling policy frameworks, can then support the development of low carbon, resource efficient steel markets.

Targeted procurement policies: As the UK government funds the majority of infrastructure projects in which large quantities of steel are consumed, it could lead the way in mandating low-CO_2 steel, measured by emission factor and/or recycled content. Procurement policies that mandate a minimum amount of UK-produced steel to protect local industry against cheap imports could, alongside anti-dumping policies, provide an assurance of demand to manufacturers so they can invest in decarbonised technology and practices.

Consistent, cross-border carbon pricing. A consistent, effective carbon price for all steel producers is necessary to level the playing field. Given the global nature of steel markets, domestic climate policies must consider the existing policy environment in trading partner countries to (i) assure market competitiveness and (ii) reduce the risk of carbon leakage. One policy solution would be to impose comparable penalties to the UK carbon price on imported products based on their embodied carbon content through a UK Carbon Borden Adjustment Mechanism (CBAM). It has been argued that a CBAM would benefit the UK steel sector[76] by increasing steel import prices. Some revenue from carbon pricing schemes should be fed into industrial decarbonisation support. However, because of the necessary phasing out of free ETS allowances, a UK CBAM would decrease the competitiveness of UK exports of steel and steel-containing products in jurisdictions where the carbon price is not as high as in the UK or where steel manufacturers are eligible for free allowances.

Fair and visible lifecycle emissions accounting. To support carbon pricing, strong industrial regulations must be enforced for embodied carbon certification within steel products, and a standard global emissions accounting method agreed upon that covers the entire product lifecycle. Alongside transparent embodied carbon declarations, publicly-available supply chain information should be mandated and normalised in annual company reports.

Stable renewable power supply and a fair price for electricity are needed to support the electrification and decarbonisation of steel manufacturing. To do so, the national electricity grid capacity needs to increase. Energy sources switched to renewables and/or captive, islanded, renewable energy systems need to be developed specifically for high demand uses, such as the steel industry. Since the Electric Arc Furnace (EAF) works in flexible batch mode, it can be integrated with variable renewable energy to optimise available resources as a demand-response management technique to balance the power grid. Current industrial electricity tariffs in the UK (£137/MWh, inc. taxes), are 40 per cent higher than the EU median and 120 per cent above the US prices.[77] Globally, electricity accounts for approximately 12 per cent of EAF steel costs.[78] This percentage would be much larger in the UK. A fair price on electricity is required to enable today's scrap-based EAF steel-making facilities to regain market competitiveness and future electricity-intense steel production to have a viable business case.

Electricity market reform will be required to appropriately reflect the growing share of cheap renewables: electricity auctions for UK offshore wind are reaching £48/MWh[79] (in today's money) for production in 2026/27, more than 60 per cent below the current industrial electricity tariffs. Nearly half of the UK's delivered power in 2020 was zero-carbon, with renewables accounting for 43 per cent, and nuclear 16 per cent,[80] and the UK government has committed to complete decarbonisation of the power grid by 2035. Novel renewable electricity contracts such as long-term Power Purchase Agreements (already in place) and Green Power Pools (recently proposed)[39] may be successful in supporting low carbon electricity generation, consumption, and the maintenance of efficient supply-demand market dynamics. The recent subsidies available to UK steel producers under the Energy Bill Relief Scheme, which capped electricity prices at £211/MWh for businesses for six months up until March 2023,[81] were insufficient to effectively address the high electricity costs and to provide long-term certainty for industry.

6. Conclusions

This policy briefing outlines the challenges and potential solutions to achieving net zero emissions in foundation industries and their value chains through fostering demand-led innovation. Evidence from macroeconomic modelling demonstrates an economic benefit to be gained from decarbonising through demand-led approach decarbonising that goes beyond just delivering emissions reductions in alignment with climate ambitions. Real-life industry case studies illustrate how demand from the downstream value chain plays a crucial role in enabling foundation industry decarbonisation, the delivery of a less wasteful and more circular economy, and the development of a robust green hydrogen industry.

As demonstrated in this briefing, there is value to be gained from investment in decarbonisation in the long term. However, the **current challenges of the high capital cost of production technologies, a supply-demand catch-22, exposure to trade-related competitive risks, lack of standardised data on embodied emissions and lack of familiarity with new materials** slows down innovation and the growth of low carbon technologies. Moreover, regulatory frameworks do not always adequately incentivise innovation or the early adoption of low carbon technologies. Given these challenges, the ability of private sector actors is constrained by conditions that either prevent large-scale demand from emerging or make it difficult for the supply side to respond effectively to demand-side signals. In this context, intervention from the government through appropriate policy measures could play an important role in driving the innovation and uptake of low carbon technologies, processes and practices across the foundation industry value chains.

In collaboration with industry partners, the research informing this briefing **identified four key decarbonisation pathways: electrification, circularity, novel technologies, and innovative processes**, highlighting the key role demand across the value chains plays in driving progress along these pathways. To address the key barriers to low carbon innovation and upscaling, the research developed a policy framework that could support demand creation and establish enabling conditions to facilitate success. Some policies are needed to create demand locally and globally, while others are required to create contextual conditions to enable innovation and scale-up demand.

Although the UK government has written strategies and plans to support industrial decarbonisation in recent years, the UK's industrial strategy needs to be further developed and better connected to the net zero strategy. Many challenges and potential solutions are similar across several foundation industries, but some are sector-specific and require targeted action. It is also important for the government to design and implement a comprehensive policy framework that details how the various targets outlined in the industrial strategy are to be achieved and how the government intends to support demand creation for low carbon materials and products.

However, in addition to government action, non-governmental organisations and non-departmental government bodies facilitate these processes by bringing companies together, facilitating dialogue and information sharing, and encouraging higher ambition. Moreover, grants and loans to support knowledge generation and collaboration between academic institutions and the private sector to address specific challenges can facilitate the emergence of new insights, best practices and innovative solutions.

We are now only one industrial investment cycle away from 2050, by which the UK foundation industry should have reduced their emissions by at least 90 per cent. To support the transition required to meet the target, new policies to create markets for low carbon basic materials are urgently needed to incentivise innovation and to remove barriers to scaling up new, innovative solutions that are currently being piloted. To be effective, these policies will need to address all stages of the industrial production value chain.

As highlighted in section 2.1 of this briefing, developing the necessary technologies to decarbonise basic materials production presents an enormous opportunity for the UK industry. Large economies such as the US and the EU have acknowledged the substantial economic benefits and competitive advantage that early investment in low carbon innovation and adoption can deliver. These are reflected in the US Inflation Reduction Act (IRA) and the EU's Green

Deal Industrial Plan (GDIP)[5] and Net-Zero Industry Act,[6] which seek to support the scaling up of the manufacturing of clean technologies in these jurisdictions.

In the race to net zero, failing to address the industrial decarbonisation challenge can result in carbon leakage, growing import dependency and loss of revenue. This is a race that the UK cannot afford to lose. Therefore, we would encourage the UK government to be wary of relying heavily on CCUS and hydrogen as silver bullets to deliver on its industrial decarbonisation targets, but instead to incorporate them into a more comprehensive policy framework. Considering the multiple benefits that demand-led approaches could deliver, as outlined in this briefing, we would invite the government to undertake urgent action to:

1) Design and implement **policies to create demand for low carbon products and materials.**
2) Design and implement **policies that support contextual conditions to encourage innovation or support the scaling up demand for innovative technologies and approaches** by businesses across the foundation industry value chains.
3) Establish **international collaboration to accelerate demand for low carbon materials and products globally.**

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