# Journey to Net Zero: a rapid review of the challenges for the UK Industrial Sector

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# Executive summary

This report presents a rapid and broad review of decarbonisation challenges faced by UK industries. UK industries, classified against the UK Standard Industrial Classification (SIC) Hierarchy, will play a key role in the pathway to achieve Net Zero by 2050 as set out by national targets.

This report explored four key challenges in each sector: reducing financing and operational costs of low-carbon pathways; fostering innovation practices, knowledge and behaviour change; minimising emissions while adopting a whole supply chain perspective; and enabling a just transition towards a low carbon economy.

The rapid review has allowed the identification of challenges that, while manifesting in different ways and to different degrees, are particularly significant in the manufacturing (heavy industry), construction and transport sectors. Table 1 provides an overview of the cross-sectoral challenges and Table 2 provides a summary of the key challenges and key recommendations by sector.

Table 1: Overview of key cross-sectoral challenges

| | |
|---|---|
|  | **Reducing financing and operational cost of low-carbon investments**<br>Key barriers to investing in Net Zero solutions and infrastructure highlighted by research to date are cost and lack of support from stakeholders, which can reinforce lock-ins and path dependencies [1] . Policy drivers include market-development measures to target technological innovation, financial incentives and carbon tax. |
|  | **Unlocking innovation practice in business models and enabling behaviour change**<br>Lack of knowledge about low carbon alternatives, lack of benchmark quality insights and data, lack of information about low carbon alternatives are key barriers . Innovation is therefore key for decarbonisation [2,3]. |
|  | **Adopting a whole supply chain perspective**<br>Vertical integration and strong buyer-supplier ties can pose a significant barrier for the introduction of low carbon products and practices. The challenge refers to the consideration of embodied emissions that occur across the supply or value chain and that can be hidden at the sale point [4]. |
|  | **Identifying a just transition decarbonisation pathway**<br>The effects of decarbonisation can potentially result in real damage to regions and communities (e.g., loss of jobs, low-paid jobs) and could exacerbate UK regional imbalances. However, this could also represent an opportunity to strengthen the UK economic output if Just Transition considerations that enable workers to move from high carbon to low carbon employers are mainstreamed across UK decarbonisation policies and strategies [5]. |

The review highlights the interconnections that exists between and within industries. This is particularly relevant for some heavy industries within manufacturing, such as cement production, which are closely linked to key sector (e.g. construction) construction sector and face challenges that will not be overcome without adopting a fuller whole supply chain perspective. The analysis also revealed the importance of non-technical interventions. For example, decarbonising the transport sector requires a widespread shift in public attitudes and behaviours.

Alongside large scale and high-capital innovations and approaches, such as large-scale renewable energy schemes or Carbon Capture and Storage, the report highlights some promising solutions such as Green Infrastructure and urban mining which will deliver co-benefits in key areas such as air pollution and public health, as well as enabling direct involvement of local authorities and strengthening the implementation of circular economy principles.

While the technical options and the foundations for a Net Zero transition seem to be in place, and the progress in reducing carbon emissions over the past decade have been substantial, there now needs to be a rapid step up in the adoption and the delivery of these solutions. The role of the UK Government in providing leadership and space for collaboration in the longer term that makes the most of between-sector interdependencies will be key, as well as providing the appropriate policy incentives/disincentives and accountability mechanisms. The UK Government will be also key in ensuring that emission reductions follow a Just Transition pathway and that further risks stemming from macro-level disruptions and events such as COVID-19 or Brexit are accounted for and minimised.

Table 2: Summary of key challenges and key recommendations by sector

| Sector | Key Challenge | Key enabling processes |
|---|---|---|
| **Agriculture, forestry, and fishing** | The key challenge for the sector is to overcome resistance to consumer and farmer behaviour change and to implement innovative practice that will reduce diffuse pollution from agriculture. Decarbonisation in the fishing sector is highly dependent on the decarbonisation of the shipping industry. | Increase deployment of action-based engagement activities and training and of collaborative pilot schemes aimed at improving efficiency in fertilisers, resource use and land management practices. |
| **Mining and Quarrying** | The key challenge for mining and quarrying is to overcome barriers to capital and operational investments that would enable a switch to greener energy sources and optimise extraction processes, logistics and transportation vis-à-vis projections that point to increased demand. | Global coordination and governance should encourage technological innovation and capital investments, as well as setting energy efficiency and circular economy benchmarks. |
| **Manufacturing** | The key challenge for manufacturing is to integrate a whole supply chain perspective in their carbon accounting practice. Within the manufacturing sector, some industries like cement and steel are considered to be harder to abate as well as facing growing demand. | Full integration of whole supply chain carbon accounting (cradle-to-grave and, where appropriate, cradle-to-cradle) and carbon labelling could enable environmentally-conscious customers to make informed choices in favour of more sustainable options, as well as supporting practices to prevent waste and exploit circular economy opportunities. |
| **Electricity, Gas, Steam and Air Conditioning Supply** | The key challenge for the electricity and gas sector is to ensure an orderly transition to minimise financial risks to both consumers and the sector, including credit risks and market risks, and uneven distributional impacts if prices for renewables are high or perceived to be unaffordable. | Regulatory regimes, taxes and subsidies should reflect a prioritisation and support of renewable energy technologies over high carbon sources. Research and Innovation could support the sector in overcoming existing technological limitations of large-scale renewable schemes. |
| **Water supply, sewerage, waste management and remediation activities** | The key challenge for the water and waste management sector is to exploit demand management opportunities aimed at minimising consumption and integrating circular economy principles. | Behavioural change campaigns and demand management interventions should target domestic and agriculture users for win-win solutions. |
| **Construction** | The key challenge for the construction sector is to adopt a whole supply chain perspective to encourage the use of less carbon intensive material and reduce energy demands for electricity and heating purposes. | Fuller integration of environmental impacts during the design and manufacturing processes would minimise waste and emissions. Urban mining practices and Green Infrastructure would deliver benefits in terms of emissions reductions and increased resilience to climate change. |
| **Wholesale and retail trade** | The key challenge for the wholesale and retail sector is to account for embedded emissions and work with suppliers to address high carbon production, as well as working on behavioural change campaigns to encourage sustainable behaviours among customers, particularly in the textile and food sector. | Corporate Social Responsibility processes can be strengthened to integrate explicit carbon reduction targets in line with national and international targets. This means placing carbon data at the core of business and retail decisions and would enable customers to make more informed choice. |

| | | |
|---|---|---|
| **Transport** | The key challenge for the transport sector is to enable behaviour change and encourage sustainable and active travel without disproportionately affecting people from disadvantaged background. | Focus on non-technological measures to enable widespread behaviour change towards active and sustainable travel. Better integration between climate change actions and air quality management could deliver important co-benefits, including on public health. |
| **Accommodation and Food service activities** | The key challenge for the sector is to reduce emissions from on-site energy use and, with regards to food-related activities, to minimise food waste and embed carbon accounting in menus to enable environmentally-conscious choices. | Embodied carbon emissions should be fully integrated in marketing materials and menus to enable more informed choices. Clear targets should be set and monitored, including during the design stage. |
| **Information and communication** | The key challenge for the ICT sector is to reduce the carbon emissions across the supply chain, particularly during the manufacture and disposal stages. ICT could play a key role in driving down emissions in other sectors. | Minimising waste and enhancing circular economy practice will support achievement of Net Zero in ICT. This should be fully integrated into procurement processes. |
| **Financial and insurance activities** | The key challenge for the UK financial sector is to re-direct investments towards low carbon projects and infrastructure and to ensure that these are delivered in a socially just way that minimises potential adverse effects of low carbon transitions. | The sector should focus on green investments in infrastructure and innovation to support a low carbon economy more broadly while also adopting place-based approaches. The UK Government should integrate climate goals into financial regulations with clear targets for the sector. |
| **Real estate activities** | The key challenge of the real estate sector is to push towards more energy efficient buildings and emphasise the role of energy performance certificates. | The use of energy performance certificates, especially in commercial buildings, should be enhanced. Stricter building standards and retrofitting the existing housing stock will support decarbonisation in the sector. |
| **Professional, scientific and technical activities/Administrative and support service activities** | The key challenge for the professional service, scientific, technical sector and for the administrative support sector is to ensure that people are enabled to switch from high to low carbon employment. | Investment in active and sustainable commuting are key to achieve carbon neutrality in the sector. The UK Government should conduct a skills audit to enable workers to move from high to low carbon employment. |
| **Public administration and defence** | The key challenge of the public administration and defence sector is to accelerate progress towards low carbon estate management and enhance sustainable procurement policies with a particular focus on monitoring compliance. | Circular economy principles must be fully deployed across the public and defence sectors, including in procurement activities. Monitoring compliance with mandatory Government sustainable procurement buying standards should be enhanced. |

| | | |
|---|---|---|
| **Education** | The key challenge for the education and higher education sector will be linked to improvements in energy efficiency in buildings and campuses and in tackling emissions from travelling to and from schools and campuses. | The UK Government and local authorities should work together to strongly encourage active and sustainable travel to and from schools/campuses. This will result in significant co-benefits in terms of improved air quality and public health. Campuses and schools should collaborate to develop climate action toolkits that work for their contexts or make use of existing tools. |
| **Human health and social work activities** | The key challenge for the health sector is to tackle energy emissions from buildings and transport emissions (people travelling to the NHS). | Focus on active travel and energy savings in buildings and operations. |
| **Arts, entertainment and recreation** | The key challenge for the sector is to minimise the carbon footprint of events and tours by incorporating carbon accounting mechanisms in tour and event planning. Circular economy principles and sharing of equipment through collaborative schemes could also deliver carbon reduction benefits. | The sector should fully incorporate carbon accounting and circular economy principles into tour and event planning and should include consideration of how people travel to events. Collaborative schemes could enhance the sharing and re-use of equipment. |

# Introduction

## 1.1. Aims and scope of the report

This report provides findings from a rapid review that aimed to identify and synthesise up-to-date evidence on the decarbonisation challenges faced by the UK industrial sector, and to identify knowledge and evidence gaps and future research directions. We provided a rapid review of the latest available information drawn from both scientific and grey literature sources and developed a simplified framework in the form of a risk matrix to assess the degree to which each sector results to be exposed to the identified challenges. Our report also focused on identifying enabling processes and policy drivers that will support the sectors in achieving their carbon reduction targets. It should be noted that this report is not based a full systematic review of all available evidence for each sector and therefore the findings, conclusions and recommendations should be considered indicative of a direction of travel for each sector. The following sections present a broad overview of the research findings.

The report has four core sections:

1. Section 1: Introduction: This section provides an overview of the project and a short summary of the UK decarbonisation strategy and targets
2. Section2: Methodology: This section summarises the key methodological steps for the collation of the evidence used and a justification for the scoring matrix.
3. Section3: Results: This section summaries the evidence reviewed for each industrial sector.
4. Section 4: Conclusions: This section draws the evidence together to provide high-level concluding remarks for the decarbonisations challenges for the UK industrial sectors.

## 1.2. Journey to Net Zero: UK targets and industrial decarbonisation strategy

The UK Government aims to reach Net Zero by 2050, with an ambitious intermediate target of 78% emissions reduction by 2035 compared to 1990 levels [6]. Decarbonising UK Industry will play a key role in achieving this overall goal and create a low carbon economy. The 2021 UK Industrial Decarbonisation Strategy sets out a vision for how the Net Zero transition will take place across the UK economy [7]. Part of the strategy will include measures to encourage green investments and getting consumers to choose low carbon products; adopt low-regret technologies and building infrastructure; improving energy and resource efficiency; accelerate innovation of low carbon technologies. The UK Industrial Strategy has explicit links to the UK Government levelling up agenda to attract investments and jobs in areas where salaries fall below the UK average [7].

Previously in 2020, the Ten Point Plan for a Green Industrial Revolution focussed on the role of green technologies and considered the following: advance offshore wind; drive the growth of low carbon hydrogen; deliver new and advanced nuclear power; accelerate the

shift to zero emission vehicles; green public transport, cycling and walking; low carbon aviation and green ships; greener buildings; invest in carbon capture and storage; protect the natural environment; green finance and innovation [8].

A breakdown of recent emissions (Figure 1) highlights that currently the transport sector is responsible for the bigger share of carbon emissions (27%); followed by energy supply (17%) and business (15%) [9,10].

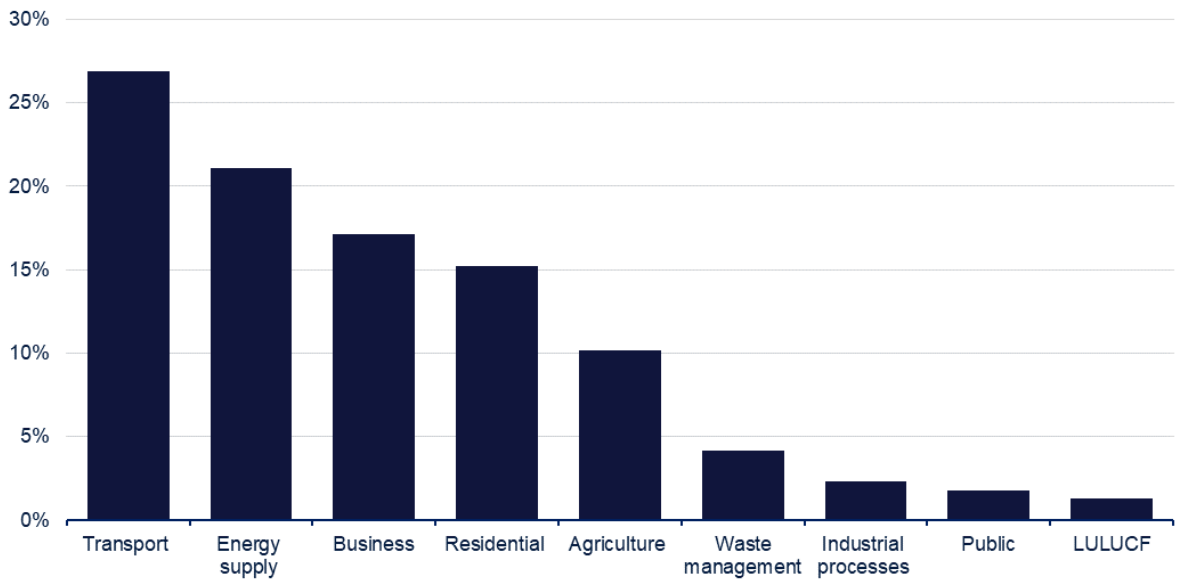


**Figure 1 Territorial UK greenhouse gas emissions by NC sector, 2019 (%) (Source: ONS, UK Environmental Accounts, 2021).**

It is interesting to note that the UK's Sixth Carbon Budget incorporates aviation and shipping emissions for the first time.

In their 2021 Progress Report, the UK Committee on Climate Change estimated that in order to be in line with the recommended pathway of the Sixth Carbon Budget, every sector beyond the power sector will need to step up their efforts to cut emissions by a significant margin (See Figure 2). The underlying data to the 2021 Progress Report shows that between 2009 and 2019[1] the UK achieved a total GHG reduction of 147Mt. If maintained, this trend would deliver a further reduction of 131Mt by 2035, while the recommended pathways to meet the Sixth Carbon Budget require a reduction of 328Mt by 2035. This means that, as Figure 2 shows, by 2035 the UK will need to address a gap of around 200Mt between current trend and the recommended GHG emission reduction targets.

[1] We are not including 2020 as a reference year because 2020 emissions were heavily affected by national lockdown measures.

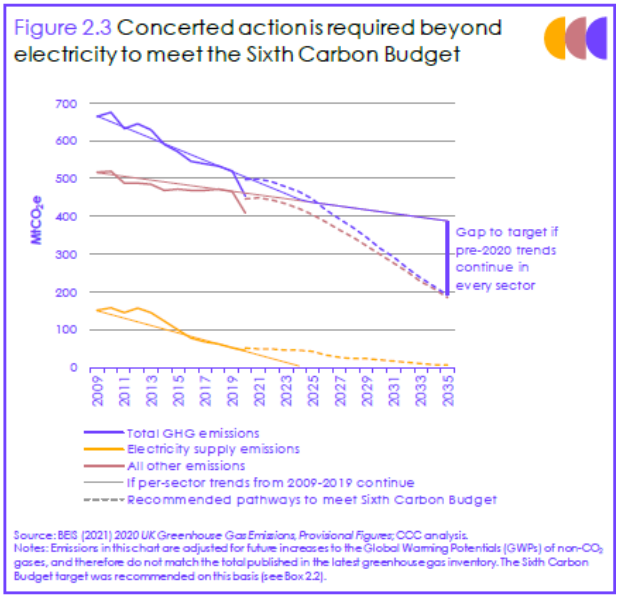


**Figure 2: Gap to Sixth Carbon Budget if past-2020 trends continue (source: UK Committee on Climate Change, 2021 Progress Report, p. 63)**

According to the UK CCC, this will depend on the successful development and delivery of Net Zero policies at a greater pace and will require a concerted and coordinated effort of the UK Government. The 2021 Progress report shows that currently, some key sectors are at risks of falling behind mostly because there is a lack of specific policies in place that could match ambitions (although there is a recognition that in some cases also ambitions are not high enough). Figure 3 from the UK CCC 2021 Progress report shows the UK CCC assessment of risks based on current ambitions and policies, and required abatement.

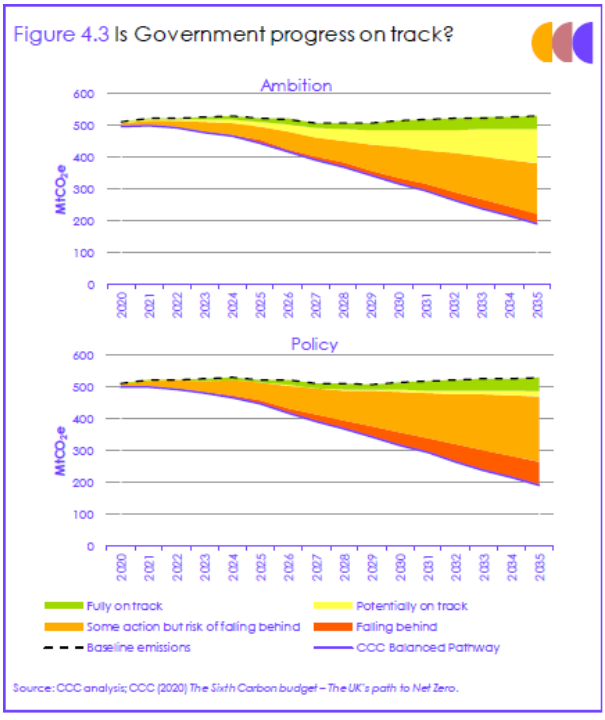


**Figure 3: UK CCC analysis of progress (ambition and policy). (Source, UK Committee on Climate Change 2021 Progress Report, p. 154).**

## Cost of decarbonisation

The cost of inaction on climate change mitigation were highlighted in the 2006 Stern Review on the Economics of Climate Change [11]. Later, it has been highlighted that the cost of inaction is likely to be higher than expected while the cost of action has gone down as the cost of green technologies has reduced more substantially than expected [12].

The UK Committee on Climate Change (CCC) has highlighted that the transition to Net Zero will be capital intensive, with an overall Net Zero cost as 1-2% of GDP in 2050, however these estimates could be conservative and overstating the cost due to uncertainty over technological progress and other macro-economic factors. This is expected to be a much smaller cost than the expected impacts of climate change and of adaptation cost, especially once the co-benefits are accounted for (the largest of which stems from reducing air pollution and the subsequent public health benefits) [13].

A breakdown of cost by the UK Climate Change Committee is publicly available on the organisation's website and the key highlights are reported in the Committee's Net Zero Technical Report [14] and a section of the dataset is summarised in Table 3.

**Table 3: Section of the Costs of Net Zero Dataset (source: Committee on Climate Change, 2019)**

| | Core (77% GHG reduction) | | Further Ambition (96% GHG reduction) | | Additional cost to achieve net-zero target through GHG removals | |
|---|---|---|---|---|---|---|
| | £ billion | Percentage of GDP | £ billion | Percentage of GDP | £ billion | Percentage of GDP |
| Power | -2.4 | -0.1% | 4.0 | 0.1% | | |
| Buildings | 10.5 | 0.3% | 14.7 | 0.4% | | |
| Industry | 0.3 | 0.0% | 7.7 | 0.2% | | |
| Transport | -2.6 | -0.1% | -5.1 | -0.1% | | |
| Agriculture[1] and Land use | 0.5 | 0.0% | 1.9 | 0.0% | | |
| Waste and F-gases[1] | 0.1 | 0.0% | 0.1 | 0.0% | | |
| Aviation[1] and Shipping | 4.6 | 0.1% | 5.4 | 0.1% | | |
| Engineered GHG removals | 2.6 | 0.1% | 8.6 | 0.2% | 13.5 | 0.3% |
| **Total** | **13.6** | **0.3%** | **37.3** | **1.0%** | **13.5** | **0.3%** |

[1] Our analysis resulted in negative abatement costs (i.e. cost savings) in the Agriculture, F-gases and Aviation sectors. Given the uncertainty around these figures we assume costs in these sectors in our aggregate cost estimates to be zero rather than negative. As such, the costs in the table above are higher than those in the calculations below.

The cost of adaptation and the cost of the impacts that cannot be neither mitigated nor adapted to will outweigh the cost of mitigation actions [15,16]. Furthermore, each year of delay will create additional cost and make mitigation actions more expensive [17]. This argument becomes even more compelling in light of the recent IPCC Sixth Assessment Report [18] which has stressed that decarbonisation in all sectors of society, including industries, must become a pressing priority for all Governments, including the UK Government.

# Methodology

## 1.3. Overall approach

The objectives outlined in Chapter 1 were addressed by conducting a rapid review of available scientific and grey literature, including key policy documents and national strategies.

For the purposes of this report, key industrial sectors were identified following the UK Standard Industrial Classification (SIC) Hierarchy.

- Agriculture, forestry and fishing
- Mining and Quarrying
- Manufacturing
- Electricity, Gas, Steam and Air Conditioning supply
- Water supply, Sewerage, Waste management and remediation activities
- Construction
- Wholesale and retail trade; repair of motor vehicles and motorcycles
- Transportation and storage
- Accommodation and Food service activities
- Information and communication
- Financial and insurance activities
- Real estate activities
- Professional, scientific and technical activities
- Administrative and support service activities
- Public Administration and defence; compulsory social security
- Education
- Human Health and Social Work Activities
- Arts, Entertainment and Recreation

We followed this classification as closely as possible although some minor modifications were implemented to better reflect the findings[2]. While this classification enabled a broad overview of decarbonisation challenges in the UK industrial sector, it must be noted that the UK industrial sector is very diverse [19] and that there are important within-classification differences that this approach does not capture. Furthermore, it should be noted that the analysis considers estimates of emissions and related decarbonisation challenges by sector (rather than by source). Therefore, challenges related to electricity use in a certain sector (e.g. mining or manufacturing) are not attributed to the energy supply sector, albeit we must stress the importance of these interdependencies and inter-sectoral challenges.

We retrieved targeted peer-reviewed academic papers using the Scopus database. We complemented peer-reviewed academic papers with strategies, documents and reports

[2] Steam and air conditioning supply; repair of motor vehicles and motorcycles were not treated separately but included in the relevant macro-sectors; water supply, sewerage, waste management and remediation activities were analysed under the more generic categories of water management and waste management.

(grey literature) selected from organisations and institutional websites, including ENDs reports, UK Government websites, House of Commons Library, UK Committee on Climate Change, consultancies and sector-specific sources. This approach proved particularly valuable for certain sectors for which substantial and well-established academic literature was not available.

To retrieve academic literature, search terms were standardised and recorded to facilitate transparency and reproducibility. Search terms were themed and included to reflect the key subject areas. Review and expertise was sought from across the Project Team and in consultation with Third City to agree and finalise the search strategies and identification of search terms.

Search terms followed these two key themes:

**Search 1 (Decarbonisation challenges for the UK industrial sector)**: Industrial sectors (focused terms and related issues) + UK + challenges + Decarbonisation + (focused terms and related issues) (TITLE-ABS-KEY search)

**Search 2 (Policy drivers)** Industrial sector (focused terms) + Decarbonisation + (focused terms) + Approaches (interventions, policies, measures) (TITLE-ABS-KEY search)

Search 1 returned a generic overview of the key challenges faced by the UK industrial sector and aimed at identifying and explore the key challenges across different sectors. Content analysis of the documents focussed specifically on identifying, under each of the key challenges, what sectors are particularly exposed.

Search 2 focussed on policy drivers and specific interventions (existing or recommended) to tackle the key challenges. We restricted the literature search to the following search parameters:

- Dates of search (13 July 2021 – 13 August 2021)
- Search parameters (e.g. scientific literature published since 2016 – last 5 years)[3]
- Search terms for Scopus (full details in Appendix)
- Sources for supplementary materials (ENDs database, UK Climate Change Committee, Office for National Statistics, and UK Government websites, reputable websites from sector-relevant organisations)
- Disciplinary scope (social sciences field only)

[3] Particularly relevant older literature was also considered and included.

The academic literature was selected and scored according to the framework presented in Table 4.

Table 4: Evidence Quality Assurance Model

| Literature type | Quality Assurance Statement | Weighting |
|---|---|---|
| Academic literature/ Grey literature/ published reports | Challenges/drivers without quality statement | 1 |
| | Elements of challenges/drivers with an explicit quality statement | 2 |
| | Primary focus on challenges/drivers with an explicit quality statement | 3 |

The initial search, which included the comprehensive list of industrial sectors and with the application of the parameters, returned a total of 297 academic papers. Further analysis based and integration of grey literature documents and reports retrieved from reputable organisations, (including UK Government; UK Climate Change Committee, etc.) resulted in a total of 184 references which constitute the evidence basis for this report.

The key trends, challenges and policy drivers identified through the search represent the core elements of our model to assess and compare decarbonisation challenges faced by individual sectors, which will be detailed in the Sectoral analysis section.

To facilitate a comparative overview of the findings we use a qualitative framework to assess the impacts of each sector on UK decarbonisation goals (Table 5). The operationalisation of the framework considers current trends and key challenges and it is based on a thematic assessment of the reviewed literature. As such, it reflects the authors' professional judgement and this subjectivity is a limitation of this matrix (this will be discussed more in detail in the *Limitations of this report* section).

Table 5: Risk assessment matrix

| | |
|---|---|
| Maximum 5 | Likely to have a very high negative impact on decarbonisation goals |
| High 4 | Likely to have a high negative impact decarbonisation goal |
| Medium 3 | Likely have a moderate impact on decarbonisation goal |
| Low 2 | Likely to have a low negative impact on decarbonisation goal |
| Minimum 1 | Likely to have a very low negative impact on decarbonisation goal |

# Results

## 1.5. Key cross-sectoral challenges identified

Key cross-sectoral challenges emerged from our reading of the academic and grey literature, which although manifesting differently across sectors and producing different impacts, represent common barriers in becoming a low carbon industry sectors. We used a thematic analysis of the literature to identify the key cross-sectoral challenges and targeted the search strategy to identify the key challenge in each sector. The identification of the key challenge(s) was based on criteria such as degree of path dependence and opportunities. Table 6 presents an overview of the challenges considered in this report.

Table 6: Overview of the key challenges explored in this report

| | |
|---|---|
|  | **Reducing financing and operational cost of low-carbon investments**<br>Key barriers to investing in Net Zero solutions and infrastructure highlighted by research to date are cost and lack of support from stakeholders, which can reinforce lock-ins and path dependencies [1] . Policy drivers include market-development measures to target technological innovation, financial incentives and carbon tax. |
|  | **Unlocking innovation practice in business models and enabling behaviour change**<br>Lack of knowledge about low carbon alternatives, lack of benchmark quality insights and data, lack of information about low carbon alternatives are key barriers . Innovation is therefore key for decarbonisation [2,3]. |
|  | **Adopting a whole supply chain perspective**<br>Vertical integration and strong buyer-supplier ties can pose a significant barrier for the introduction of low carbon products and practices. The challenge refers to the consideration of embodied emissions that occur across the supply or value chain and that can be hidden at the sale point [4]. |
|  | **Identifying a just transition decarbonisation pathway**<br>The effects of decarbonisation can potentially result in real damage to regions and communities (e.g., loss of jobs, low-paid jobs) and could exacerbate UK regional imbalances. However, this could also represent an opportunity to strengthen the UK economic output if Just Transition considerations that enable workers to move from high carbon to low carbon employers are mainstreamed across UK decarbonisation policies and strategies [5]. |

## 1.6. Sectoral analysis and insight

The following sections provide an overview of the challenges faced by key UK industrial sectors in their decarbonisation journey, with a focus on core elements (the current issues, risks and opportunities, policy drivers and recommendations). The key sectors that we analysed include:

Agriculture, forestry and fishing

Mining and quarrying

Manufacturing

Electricity and Gas

Water management and waste management

Construction

Wholesale and retail

Transport

Accommodation and Food service activities

Information and Communication (ICT)

Financial and insurance activities

Real estate activities

Professional, scientific, and technical activities/administrative and support service activities

Public administration and defence

Education

Human health and social work activities

Arts entertainment and recreation

## AGRICULTURE FORESTRY AND FISHING

*Emissions trend: broadly stable with a slight increase between 1990 and 2018* [20]

**Current Issues**

Agriculture accounts for roughly 10% of total GHG emissions in the UK and it is the largest contributor to methane shares (around 45%) [21]. The biggest source of these emissions are livestock and manure (56%), the use of synthetic fertilizers (31%), fuel and machinery (12%). Agriculture is identified as having a key role in achieving national decarbonisation targets. The National Farming Union (NFU) has set the goal of reaching Net Zero in England and Wales by 2040, ahead of the national target, thus signalling a strong overall ambition[22]. The sector has so far struggled to meet the Government's targets relating to planting trees and restoration, which are important drivers for increasing carbon sink [23]. The fishing sector is highly exposed to the risks from climate change, which will have severe impacts on the marine environment [24]. The UK marine fishing industry provided an added £1.53 billion to the UK economy. Its distribution is mainly concentrated in a few large ports (although small fisheries represent an important value for local livelihoods and culture). The Committee on climate change estimated that agroforestry could substantially contribute to carbon emissions savings by 2050 [25].

**Risks & opportunities**

- A key policy challenge is represented by the diffuse nature of pollution and emissions coming from agriculture which will require a strong focus on behaviour change and innovation practices implemented by individual farmers [26,27]. Farmers' attitude and knowledge of low-carbon alternative practices and of more efficient use of pesticides and fertilisers whilst maintaining production levels and profitability is crucial to achieving Net Zero and for other environmental challenges such as air pollution, water pollution, biodiversity loss [21,28]. This will also reduce risks of increase carbon emissions across the supply chain.
- In 2020 DEFRA reported that 30% of farmers do not consider GHG reductions when making decisions, thus highlighting the significance of this challenge [28]. This indicates a risk that some farmers could fall behind on the decarbonisation journey.
- Achieving Net Zero by 2040 is highly dependent on a reduction in consumption of high emission food, strengthening the behavioural change dimension of a low carbon transition in this sector. Consumers are moving towards less carbon-intensive diets. If maintained, this trend should encourage a shift in production, but this has so far received limited policy support[28]. A shift in production would bring about a reduction in direct GHG emissions and also increase carbon storage capacity.
- Food waste reduction represents a significant economic potential and efforts should be maximised in this area [29].
- Cost saving and emission savings could be achieved by implementing alternative farming methods, including rooftop farming and vertical farming.

- Major changes have occurred in the sector due to the UK departure from the European Union and the new 2020 Agriculture Act[30]. However, uncertainty remains as to how the new legislative framework will support farmers in pursuing Net Zero.
- Decarbonisation in the fishing sector is highly dependent on the decarbonisation of the shipping industry. Hybrid or electric vessels or alternative fuels could contribute to the low carbon transition [31]. Another challenge is represented by the need to have equipment for refrigeration. Technical improvements to introduce alternative refrigeration systems have been explored in the literature and could deliver significant carbon reductions[32].
- Forestry plays a key role in climate mitigation and various forest-sector mitigation activities can enhance carbon stocks (sinks) and reduce emissions (sources) [33].
- Agroforestry in the UK remains lower compared to other temperate countries [34,35].

**Key challenge**

|  |  |  |  |
|---|---|---|---|
| **Capital and operational investments** | **Innovation practice & behaviour change** | **Whole supply chain perspective** | **Just transition** |
| 3 | 5 | 3 | 4 |
| The key challenge for the sector is to overcome resistance to behaviour change and to implement innovative practices that will reduce diffuse pollution from agriculture. Decarbonisation in the fishing sector is highly dependent on the decarbonisation of the shipping industry. | | | |

**Enabling processes**

- The Climate Change Committee has identified three core measures that focus on improving efficiency in fertilise and resource use, and in planting more trees. Diversification and the adoption of agroecological approaches have shown mitigation potential.
- The Agricultural sector is highly exposed to the impacts of climate change from a climate change adaptation perspective [36,37]. Action-based communication strategies could focus on cost-saving benefits and other co-benefits from investing in low-carbon measures and from directly contributing to mitigation targets [38,39].
- The UK Government should ensure stronger coordination and integration between Government, industry representatives (e.g. National Farming Union), the Environment Agency and other key delivery organisations, including Natural England. This would enable knowledge exchange, awareness raising and trust building [40]. Pilot schemes and demonstration projects conducted in individual farms have shown potential to drive behaviour change and are likely to increase acceptability of mandatory systems to cut emissions. This will also minimise the risk of putting more conservative farmers at a disadvantage and will strengthen the Just Transition pathway.

- Adoption of sustainability indicators as a measure of success alongside productivity and crop yields could encourage longer-term and more strategic thinking and better integration with landscape management and territorial planning initiatives
- Improved land and forest management and innovative practice such as precision agriculture and agroforestry can mitigate carbon emissions in the sector[33,41].
- Nature-based solutions and Green Infrastructure could provide benefits in terms of Nitrogen Removal and Recovery, thus reducing greenhouse gases emissions from the sector [42,43].

## MINING AND QUARRYING

*Trend: Decreased from 1990 levels, but broadly steady since 2016* [44]

**Current Issues**

The mining and quarrying industry in the UK provides energy minerals, construction minerals (the largest non-energy minerals market), industrial minerals and metal minerals. Energy use is the biggest source of emissions within the industry[45]. Transportation, the process of crushing and grinding minerals (comminution) and heat and ventilation represent the most energy demanding phases. The mining industry is pivotal to decarbonisation pathways in other sectors that are heavily reliant on raw material (e.g. transport, construction) [46]. In the short term, recycling and circular economy will not meet the current demand and new mined-resources will be needed. While our focus is on the UK mining industries, the sector poses significant global policy and governance challenges as it contributes to the global supply chain and has significant implications on international trade and has potentially important Just Transition implications.

**Risks and Opportunities**

- The sector will have a key role in determining the overall success of the UK decarbonisation pathway. The Climate Change Committee stated that opening new deep coking coal mines will increase emissions and will have a significant impact on the UK Carbon budget [47]. This risk could be minimised only if emissions from coking coal used in steelmaking beyond 2035 is captured and stored. Technological alternatives such as the use of hydrogen should be considered.
- Demand is set to increase for certain metals, including key raw material that underpin low carbon technologies (graphite, cobalt, lithium, etc); an increase in mining activities could represent a risk in terms of carbon emissions within the sector, if energy transition is not pursued by the industry.
- Decarbonising the mining industry will be in the short term more expensive than business as usual. The consultancy Wood Mackenzie estimated that mining companies would need a $1.7 trillion investment (globally) for decarbonisation [48].
- Currently, capital investment to enable supply in line with decarbonisation pathways represents a significant barrier and the most significant risk to decarbonisation of this sector.
- Changes in primary materials to foster more sustainable production in other sectors that rely on mining and quarrying could pose a risk of job losses in mining activities that supply high carbon activities.
- Technological improvements during comminution could deliver significant emission reductions.
- Switching to renewable sources for electricity supply and optimising transportation would deliver significant emission reductions, including through generating less heat and reducing need for ventilation. Replacing diesel-powered equipment with electric machineries (if they are based on low carbon energy sources) would also deliver

other environmental benefits [49]. These measures are achievable but require a change in practice and behaviours to be successfully implemented, thus posing a moderate risk to a successful decarbonisation.

- Reducing emissions from burning and refining processes could be achieved using biomass instead of fossil energy.
- Circular economy processes are more challenging to implement within the mining industries and present limitations due to issue with suitability of recycled materials. There is scope for a fuller understanding of the application of the circular economy concept within the mining industry [50,51].

**Key challenge**

|  |  |  |  |
|---|---|---|---|
| **Capital and operational investments** | **Innovation practice & behaviour change** | **Whole supply chain perspective** | **Just transition** |
| 5 | 3 | 3 | 5 |
| The key challenge for mining and quarrying is to overcome barriers to capital and operational investments that will enable a switch to greener energy sources and optimise extraction processes, logistics and transportation vis-à-vis projections that point to increased demand. | | | |

**Enabling processes**

- Currently, there is a lack of international governance and policies despite the key role of the mining industries to deliver a low carbon economy. Global coordination and governance, and agreements on global targets for the mining industries are needed to push the mining industry towards more efficient carbon emission performances[50]. This would encourage technological innovation aiming at improving extraction processes.
- A push of the environmental and social responsibility agenda would help overcoming resistance to capital investment. These voluntary mechanisms could make more extensive use of information and data gathering tools, such as energy audits and Certified Trading Chains programmes as a way to improve responsibility in mining [52]. Corporate accountability could also reduce community opposition and enable just transition as demand for metals like silver, copper, cobalt increase.
- Research and development should focus on applications of circular economy principles within the industry. New benchmark and standards for recyclability would represent and important development.
- There is potential for improving tracking of mineral use and raise customers' awareness of mineral use, which could increase domestic consumption and support circular economy in the sector.

## MANUFACTURING

*Emissions Trend: Decreased from 1990 levels. Broadly stable since 2010* [53]

**Current Issues**

The Manufacturing sector is the third largest sector in the UK economy, after business services and retail, in terms of GDP. The manufacturing sector overall represents 20% of industrial emissions (ONS, 2020) but there are within-sector variations. Two-third of these emissions are estimated to come from energy intensive industries, including steel, glass, and cement. According to an estimate by McKinsey & Co., cement generates more emissions per revenue dollar, followed by Iron and Steel, Oil and Gas, Mining, Chemicals [54]. Interdependence within the sector is high, with outputs from one manufacturing industries being inputs for other industries (e.g. steel and automotive industry) [55]. An area of growing research focus has been food manufacturing as part of the food system because of its very high production volumes and distribution channels; this includes all activities during the processing, preservation and manufacture of food and it is carried by a very diverse set of enterprises, from small companies to multinational corporations. In the UK, 96% of manufacturing enterprises in this sector are SMEs and the food and drink industry represents the largest manufacturing sector [56]. It is considered a moderately energy intensive industry [41].

**Risks and Opportunities**

*Risks and opportunities for the manufacturing sector overall*

- A recent white paper by the consultancy Vendigital found that strong senior-level commitment hasn't always been translated into action, thus stressing the importance of encouraging innovation practice and behaviour change [57].
- Long investment cycles mean that manufacturers face major challenges and significant investment requirements which impact the whole supply chain. It is important that replacement assets are low carbon ready.
- Manufacturers face challenges associated with competition from carbon-intensive products from abroad. Information about embedded carbon emissions are therefore key to inform consumer choices in support of low-carbon products. This would also require a better understanding of emissions related to individual products as well as processes which will enable innovation and behaviour change.
- Carbon Capture and Storage (CCS) can play crucial role in driving down the final emissions in some parts of the manufacturing sector [58].

*Risks and opportunities for the Steel and Cement manufacturing industries*

- Significant challenge remains in energy-intensive productions, particularly steel, cement and chemical products due to very high heat demand and processes. Cement and steel will remain key materials for productions in the building industry, thus adding also increased demand to the decarbonisation challenge. A study by Millward-Hopkins et al. [59] highlighted significant challenges of highly interconnected

sectors and specifically for the cement industries (especially considering that reductions in UK coal-based electricity and primary steel production are reducing the availability of cement replacements). This suggests that not adopting a whole supply chain perspective will seriously undermine a low carbon transition.

- A study by Serrenho et al. found that UK climate policies have a limited effect on reducing global emissions from steel productions [60]
- Decarbonisation pathways for the cement industries require large-scale technological investments. However, operational advances could also present some opportunities for sustainable constructions.
- CCS plants could be attached to cement kilns to capture the carbon [61].

*Risks and opportunities for other manufacturing industries*

- Significant emission reductions could be achieved through preventing food waste in food manufacturing (particularly during the manufacturer/retailer interface[62] and through optimising processes [63].
- The automotive manufacturing is energy demanding and relies on significant quantities of raw materials and water. Energy efficiency in the plants is a key area for the current automotive industry. The 2018 Automotive Sector Deal between the UK Government and the automotive manufacturers has identified key strategies, including the realisation of ultra-low or zero emission vehicles. Circular economy mechanisms will support the sector in reducing energy consumption and waste management [64].

**Key Challenge**

| Capital and operational investments | Innovation practice & behaviour change | Whole supply chain perspective | Just transition |
|---|---|---|---|
| 5 | 5 | 5 | 4 |

The key challenge for manufacturing is to integrate a whole supply chain perspective in their carbon accounting practice. This could enable informed customer choices and support preferences for more sustainable options as well as supporting practices to prevent waste and exploit circular economy opportunities. Within the manufacturing sector, some industries like cement and steel are considered to be harder to abate as well as facing growing demand.

**Enabling process**

- There is significant scope for developing tools to calculate Scope 1, 2 and 3 emissions at company-level to enable integration of carbon consideration into decision-making (particularly with regard to sourcing) and the setting up of company-level and product-level carbon emission targets.

- Electrifying cement production is early stages but could be key to achieve carbon neutral cement production, according to the IEA.
- Increasing UK domestic use of scrap will reduce dependence on steel imports and new steel productions [60].
- Based on Milward-Hopkins et al's [59]scenarios, reducing GHGs from concrete production can be achieved through reducing consumption through efficiency in production, maintenance, design, and end-of-life management.
- Disruptive policies can accelerate change. For example, the ban on the sale of new fossil fuel-based vehicles from 2030 has accelerated the production of electric vehicles.
- The food manufacturing sector could achieve substantial carbon reductions through minimising food waste, switching to renewable forces, through sustainable packaging initiatives and through demand management measures [41].
- The UK All-Party Parliamentary Manufacturing Group highlighted opportunities for green jobs that would help to achieve the UK's net-zero targets. This would need to be supported by long term regulation and standard set by the UK Government.
- Manufacturers must identify and develop within their workforces the skills required in a low carbon economy (local, employer-led, green skills system) [65].
- Benchmarks and "green" standards/certificates could give companies an advantage with clients that want to invest in sustainable products or buildings.

## ELECTRICITY AND GAS

*Trend: Declining markedly from 1990 levels* [66]

**Current Issues**

Emissions from electricity generation have fallen markedly since 1990 and in particular in the last decade, reflecting a shift away from coal towards gas and low-carbon generation. The sector accounts for 15% of UK emissions in 2018. The Climate Change Committee estimates that gas contributes to 70% of power emissions and provide 40% of total electricity generation; coal accounts for 23% of emissions while providing only 5% of generation. Renewable energy now account for 22% of electricity generation. Nuclear accounts for around 20% of UK electricity (with zero emissions). In 2018 there was a drop in both residential and industrial electricity consumption, reflecting an increase of renewable energy into the national grid, energy efficiency improvements and structural changes in manufacturing (particularly iron and steel, chemicals, and car manufacturing) and construction.

**Risks and Opportunities**

- Reducing emissions from this sector requires increasing the role of renewable energy sources, with potential contributions also coming from hydrogen and CCS.
- The electricity sector is characterised by significant historic path dependencies that reinforces the position of incumbent utilities, which poses barriers to decarbonisation goals [1].
- Infrastructural investment in the energy sector have a long life cycle, therefore new investments need to be compatible with a low carbon pathway.
- Renewable energy brings about wider societal benefits as it generates about 6 times more jobs than nuclear in the UK [67].
- A scenario developed by the Climate Change Committee estimates that capital cost for the power sector in terms of annual investment should rise to around £20 billion [68].
- The UK has developed an offshore wind supply chain, which is associated with over 7,000 jobs with regional clusters (Humber and East Anglia), according to a recent estimate by the HM Treasury[69]. The report estimates that increased offshore wind capacity could support up to 27,000 jobs that will replace jobs in high-carbon sectors, including in manufacturing and create additional jobs [70].
- The Solar Photovoltaic (PV) technologies have received attention within the literature, which explored localised technical challenges and solutions on integrating large-scale PV systems into the main grid. These challenges include partial unpredictability, non-controllable variability, location dependency [71]. Potential solutions that have been suggested include the installation of large-scale energy storages to stabilise the grid and an increase transmission flexibility to balance local and regional deficits and excesses.

- Some renewable energy technologies such as heat pumps still suffer from high upfront cost and performances.

**Key challenge**

|  |  |  |  |
|---|---|---|---|
| **Capital and operational investments** | **Innovation practice & behaviour change** | **Whole supply chain perspective** | **Just transition** |
| 4 | 4 | 2 | 3 |
| The key challenge for the electricity and gas sector is to ensure an orderly transition to minimise financial risks, including credit risks and market risks, and uneven distributional impacts if prices for renewables are high or perceived to be unaffordable. | | | |

**Enabling processes**

- The UK Government should ensure that regulatory regimes, taxes and subsidies reflect a prioritisation and support of renewable energy technologies over high carbon sources. This could unlock the potential of some renewable energy solutions that are still behind [72].
- Government's commitment to ending the use of coal by 2024 has accelerated the move towards more sustainable energy mixes. However, fossil fuel subsidies still represent a significant issue which should be tackled.
- Subsidies for renewable investments can support market players to overcome historic path-dependency.
- Including co-benefits in macroeconomic modelling and final policy considerations would highlight the near-term benefits of emissions abatement (including reduction of cost of premature deaths from air pollution).
- The UK Government should focus on supporting research on identifying solutions to challenges of applying large-scale solar PV technologies and ensure energy security.
- The renewable energy sector has potential to support the economy and jobs. The UK Government should focus on providing appropriate training and skills and support educational providers to develop programmes to maximise this potential.

## WATER MANAGEMENT AND WASTE MANAGEMENT

*Emissions trend: slightly increased from 1990 levels (after declining by 2010, emissions increased between 2014 and 2018)* [73]

**Current Issues**

The water industry contributes 0.8% of UK GHG emissions and 5.5% if emissions resulting from heating water in domestic settings are considered [74]. The Environment Agency estimates that 30% of water used in homes is heated [75]. The emissions are largely driven by energy-intensive pumping and treatment activities and more work is needed to integrate carbon emissions embodied in existing and new water and wastewater infrastructure. Greenhouse gas emissions from the waste sector mainly comprise methane released from landfill sites the remainder from wastewater treatment and incineration. Currently, around 45% of household waste and 55% of commercial and industrial waste is recycled in the UK[76].

**Risks and Opportunities**

- Water supply and wastewater management could become more energy intensive if construction outputs are set to increase.
- UK water utilities have started to develop in-house carbon emissions calculation tools, but these tools are limited by the lack of data from manufacturers and suppliers on products and materials' embodied emissions. Water resources management plans now require water utilities to assess their carbon footprint, but this does not typically extend to the whole life cycle.
- Resource development options (which are sometime part of climate adaptation strategies, such as desalination plants) are relatively energy intensive, both operationally and in the construction phase [77].
- DEFRA estimates that recycling or incineration with energy recovery could result in net reductions of emissions of GHG through energy recovery or material savings from recycling.
- The CCC identified potentially low cost GHG savings from recycling and banning biodegradable waste from landfill [76].
- The diffuse nature of the waste sector represents an additional challenge and variations between local authorities' waste management and recycling approaches creating additional barriers.
- Reducing waste emissions will deliver important co-benefits including on air, soil and water quality.

**Key challenge**

|  |  |  |  |
|---|---|---|---|
| **Capital and operational investments** | **Innovation practice & behaviour change** | **Whole supply chain perspective** | **Just transition** |
| 3 | 5 | 4 | 1 |
| The key challenge for the water and waste management sector is to exploit demand management opportunities aimed at minimising consumption and integrating circular economy principles. | | | |

**Enabling processes**

- There is scope to exploit synergistic potential and design win-win solutions by integrating agro-environmental measures, water quality legislation and GHG emission reductions. Integration of mitigation goals into river basin management (with measures such as wetland restoration, extensification of farmed lowland areas, manure treatment for biogas production, etc.) would prove cost effective [78].
- Demand management options focused on water efficiency, particularly those aimed at reducing hot water use in domestic settings, can significantly promote water and energy efficiency and represent win-win solutions.
- Research by Eunomia found that by increased effectiveness in collection and sorting of recyclable material and food waste, moving from open dump waste to managed residual treatment and removing remaining recyclables prior to incineration and landfill, the sector could make significant carbon reductions [79].
- Optimisation and conversion of wastewater treatment plants to advanced anaerobic digestion systems, as well as early leak identification would bring about significant carbon emission reductions.
- The CCC estimated total added investment cost of Net Zero above the baseline of around £175 million/year in 2035.

## CONSTRUCTION

*Emissions trend: increasing* [80]

**Current Issues**

The emissions associated with this sector come primarily from the embodied energy required to produce all the required materials [79]. The UK construction sector faces the challenge of meeting ambitious carbon emission reduction targets vis-à-vis expanding production. Projected urbanisation over the next decades means that demand for construction (and therefore cement and concrete) will increase, thus making the minimisation of the environmental impact of this industry a key priority. At the time of writing, the UK Environmental Audit Committee is conducting an inquiry to examine the sustainability of the built environment. The UK Government aims to build 300,000 new homes per year. This represents a significant environmental challenge for the sector.

**Risks and Opportunities**

- A study by Dadhich et al. [81]highlighted how emission hotspots across the lifecycle of products can be identified to target interventions to reduce emissions.
- The construction sector has been slow in the up-take of innovative practices and is typically risk-averse. Nonetheless, minor improvements across the value chain (particularly across the cement and concrete value chain) could potentially deliver emission reductions of up to 50% [82].
- Improvements in efficiency in the built environment and green retrofits will support reduction in electricity demands for heating purposes.
- The embodied carbon cost of construction is not required by current regulation and is only reported on a voluntary basis.
- The CCC has highlighted that UK homes are not currently fit for the future. The Future Homes Standard will come into effect in England in 2025.
- There are currently no incentives to move away from energy-intensive materials (e.g. concrete and steel) and there are no legal requirements to meet reduction targets for embodied carbon in the UK [83].

**Key challenge**

| Capital and operational investments | Innovation practice & behaviour change | Whole supply chain perspective | Just transition |
|---|---|---|---|
| 4 | 5 | 5 | 4 |

The key challenge for the construction sector is to adopt a whole supply chain perspective to encourage the use of less carbon intensive material and reduce energy demands for electricity and heating purposes.

**Enabling processes**

- Required improvements come from design, materials and on-site activities, with additional contributions from CCS [19]. The literature focuses on key areas with improvement potential: green retrofits of existing buildings [84]; circular economy, urban mining [85], and use of digital technologies to achieve this; as well as business practices that encourages collaboration, data sharing and learning.
- Business models that take into account the whole supply chain (end-to-end supply chain perspective) are needed to support the decarbonisation pathway of the construction industry. The Climate Change Committee recommended disclosure of whole-life carbon in buildings which could help tackling embodied emissions in the construction industry [86].
- Consideration of environmental impacts during the design and manufacturing processes minimises waste and emissions [81]. However, limited knowledge and skills of subcontractors have been identified as a barrier to sustainable design [87]. The skills gap has been highlighted by the CCC as a limiting factor that needs to be addressed by the UK Government, with potential for connection with the Levelling Up agenda.
- Urban mining can reduce the need for natural raw materials [88,89]. Urban mining should be supported through integration of building component recovery as part of existing demolition processes within a city. This, however, requires collaborative planning.
- Big data and digital technologies can enhance urban mining potential. Digitalisation can also improve performance of existing buildings and infrastructure [90].
- Choice of low-carbon material and an increase of reuse through a circular economy will help to decarbonising the construction industry [91]. This can be supported by a Government procurement practice that stipulates targets and standards. The 2019 CCC report “UK Housing Fit for the Future” recommends incentivising increased use of wood in construction, which could minimise whole-life carbon emissions of new buildings [92].
- A cultural change in favour of collaboration across the supply chain is needed. This could, for example, entail data sharing practices on carbon emissions along the supply chain and learning from best practice [93,94].
- New homes must be built to be low-carbon and climate resilient. The CCC recommends that from 2025 at the latest, no new homes should be connected to the gas grid and instead should be heated through low-carbon sources. Similarly, existing homes must be retrofitted to be low carbon and carbon resilient [92].
- Biodiversity should be fully integrated within design considerations. Green infrastructure should be integrated in building practice as they could contribute to reducing electricity demand and increasing resilience and adaptation capacity, for example through cooling during heatwaves, creating habitats, reducing run-offs and the risk of flooding, as well as delivering a number of important co-benefits [95,96].

## WHOLESALE AND RETAIL TRADE

*Emissions trend: broadly stable; slightly increasing* [97]

### Current Issues

The retail sector includes businesses involved with selling products to customers (shops, department stores, supermarkets, etc). The wholesale sector is considered a related sector as it supplies retailers. The total economic output of the retail sector in the UK was 5.0% in 2020 (a 2.5% decrease from 2019, which reflects the impact of the coronavirus pandemic)[98]. Overall, the British Retail Consortium (BRC) has committed to reach Net Zero by 2040 and ensure that by then products will have minimal impact on the environment [99]. The category of goods with the largest share of carbon emissions is Food, Drinks and Tobacco (62%), due to the larger volumes of grocery sales in the UK.

### Risks and Opportunities

- Logistics and the movement of high volumes of goods represent a significant source of carbon emissions.
- The consultancy Deloitte reveals that in the retail sector, the shift to digital is consolidating and online sales [100] which will have significant implications on logistics and provides opportunities for decarbonisation.
- Waste is a significant barrier to decarbonising the retail sector. Textiles are associated with one of the most carbon intensive waste stream.
- The BRC highlighted major energy improvements in retail operations and stores through better monitoring of energy use and control systems, more efficient refrigerators, installation of LED lights, and other small-scale operational optimisation measures [41].

### Key challenge

| Capital and operational investments | Innovation practice & behaviour change | Whole supply chain perspective | Just transition |
|---|---|---|---|
| 2 | 4 | 5 | 3 |

The key challenge for the wholesale and retail sector is to account for embedded emissions and work with suppliers to address high carbon production, as well as working on behavioural change campaigns to encourage sustainable behaviours among customers.

**Enabling processes**

- Business practices should be reorganised to put low-carbon emissions at the core of decision-making, including reducing emissions from shops and logistics and prioritising sustainable sourcing, together with supporting customers and employees to switch to more sustainable lifestyles.
- CSR processes can be strengthened to integrate carbon reduction targets in line with the national targets [101]. Placing carbon data at the core of business decisions will enable this pathway.
- Retailers need to understand the scale of the carbon reductions required, which should include Scope 3 emissions and accounting for carbon emissions across the entire value chain.
- The focus of the retail sector should be to drive down textile and food waste in retailing activities and customers' homes, as well as supporting low carbon choices [102,103]. Emissions factors for products could be reflected directly at the point of sale, thus increasing customers' awareness of the carbon intensity of the goods. A study by Sharp and Wheeler [104] showed that formats that show emissions relative to other products or traditional traffic light colour system were more effective in raising consumers' carbon literacy and supporting informed choices. A study by Vanclay et al. [105] found that when green-labelled products were also the cheapest, there was a substantial shift from black-to green-label sales.
- Circular economy is considered to be key to minimise waste of material and food and can generate emission savings.
- There is a need to provide training and information to employees on low carbon lifestyles and on providing climate guidance to customers.
- The UK Government should work with stakeholders and wholesale and retail companies to enable behaviour change and support informed choices. The BRC suggested that the UK Government could develop consistent carbon accounting mechanisms, linked to pricing frameworks [106].

## TRANSPORT

*Emissions trend (Road Transport): increased by 29% between 1990 and 2018* [107] .

**Current Issues**

Transport is the largest emitting sector of GHG emissions in the UK (27% of UK's total emissions in 2019, down by 1.8% from 2018), taking over from the power sector. Road traffic increased by 29% between 1990 and 2018[107]. Road transport accounts for more than 90% of transportation emissions in the UK, with passenger cars representing the biggest contributor due to the number of private licensed vehicles on the road. Carbon emissions from private cars are higher than carbon emissions from public transport. Total UK aviation emissions increased by 0.8% year-on-year in 2018, which corresponds to 124% above 1990 levels[108]. The Sixth Carbon Budget by the UK Committee on Climate Change states that shipping emissions represented 3% of greenhouse gases emissions in the UK, down by 21% 1990 levels. This represents a slow downward trend due to reductions in domestic journeys and international export shipping [109].

**Risks and Opportunities**

- Current projections of road transport emissions point to a declining trend in the coming years against the backdrop of increase uptake of electric vehicles in the UK.
- Electrification of trains would produce lower carbon emissions than hydrogen trains. However, this measure alone will not be enough to achieve substantial emission reductions [110].
- Studies have shown that there has been a relatively low decoupling of transport emissions in the UK between 1997 and 2015.
- The phasing out of the sale of diesel HGVs by 2040 and Net Zero aviation by 2050 are in line with the UK CCC recommendations, but meeting Net Zero will require significant interventions on the demand side [111]. A study by Geels showed that deeper system reconfiguration is required to unlock low carbon transport pathways in the UK [112].
- There is currently a lack of demand management interventions to limit aviation.
- Data from the Department for Transport (DfT) shows that out of approximately 29.4 million licensed vehicles in the UK, around 0.2 (0.5%) are ultra-low emissions.
- The UK Government announced that it would include international aviation in its carbon emissions targets, following a recommendation from the UK Climate Change Committee.
- The Sustainable Aviation Alliance aims to reduce or offset the sector's net emission by 15% in 2030 from 2019 levels and by 40% in 2040 [113].
- The UK Clean Maritime Plan states that by 2050 all vessels operating in UK waters must maximise energy efficiency options. The Clean Maritime Plan is explicitly linked to[114] the UK Clean Air Strategy. However, the plan focuses on voluntary targets and therefore there are risks to the effectiveness of this plan [115].

- The UK is working on a Clean Maritime Clusters focussed on innovation and zero emissions technologies and infrastructure.

**Key challenge**

|  Capital and operational investments |  Innovation practice & behaviour change |  Whole supply chain perspective |  Just transition |
|---|---|---|---|
| 4 | 5 | 4 | 4 |
| The key challenge for the transport sector is to enable behaviour change and encourage sustainable and active travel without disproportionately affecting people from disadvantaged background. | | | |

**Enabling processes**

- Enhanced passenger experience is crucial to increase attractiveness of public transport [116,117].
- Technological measures which encourage the use of vehicles that use alternative fuels (such as electric cars) must be part of the solution, but they have limitations.
- Future policies to tackle emissions from transport should integrate consideration of local contexts to avoid implementation gaps [118,119].
- Policies should avoid over-reliance on technological fixes and focus on behavioural changes [120]. Breaking carbon-intensive habits needs long-term changes in the socio-technical systems[119].
- Better integration between climate change policies and air quality management could deliver important co-benefits, including on public health and ecosystem health [121].
- It is imperative that the UK Government works to reduce the attractiveness of private cars [122].
- To reduce emissions from the aviation sector, demand management policies could be introduced, together with fleet-efficiency measures and sustainable aviation fuels [108].
- Decarbonisation in the shipping sector is unlikely without a major shift in policies, including policies focused on the widely adoption of low carbon technologies, demand management and efficiency in operational measures[123]. The UK Government should work on regulatory measures alongside voluntary measures to achieve decarbonisation in this sector.

## ACCOMMODATION AND FOOD SERVICE ACTIVITIES

*Emissions trend: slightly increased from 1990 levels – broadly stable/slightly increasing since 2014* [124]

**Current Issues**

In the medium to long term, the UK accommodation sector will mostly rely on buildings that already exist. The key challenge for the sector is to reduce emissions from on-site energy use and, with regards to food-related activities, to minimise food waste and embed carbon accounting in menus to enable environmentally-conscious choices.

**Risks and Opportunities**

- Energy performance certificates and sustainability schemes would support the sector in reducing operating costs and achieve energy renovation targets [125–127], although their effect on sales values is not well understood in the literature [128].
- Organisations and networks such as Sustainable Hospitality Alliance could provide knowledge and best practice sharing platform to implement energy efficiency design and operational innovation.
- The Carbon Vision Building Programme has assessed the feasibility of cutting emissions by 50% by 2030 using two UK hotels as case studies [129]. The study identified mechanisms to cut emissions without negatively affecting guests' comfort. These particularly stem from improvements in energy efficiency.
- In working towards achieving carbon neutrality in the hospitality sector, there are strong interdependencies that make assessing and ranking interventions problematic.
- A report by ARUP in collaboration with Gleeds, IHG and Schneider Electric, developed a Net Zero design approach based on a mix of active and passive measures aimed at: reduction of energy usage, efficient energy supply and use, and carbon offsetting mechanisms [130]. The report identified also design principles that can maximise energy efficiency through natural light and ventilation.
- Lowering energy demands and the use of renewable energy or on-site microgeneration systems is considered to be key to meeting carbon reductions targets [131].
- In the UK, initiatives to support pubs and bars in reducing carbon emissions are gaining traction [132].
- Universities are investing in zero carbon student accommodation buildings [133]. For example, the University of the West of England (UWE) have approved a phased development which would become one of the largest Passivhaus student accommodation in the world (around 2,000 beds) [134,135].

**Key challenge**

|  |  |  |  |
|---|---|---|---|
| **Capital and operational investments** | **Innovation practice & behaviour change** | **Whole supply chain perspective** | **Just transition** |
| 4 | 4 | 3 | 1 |
| The key challenge for the sector is to reduce emissions from on-site energy use and, with regards to food-related activities, to minimise food waste and embed carbon accounting in menus to enable environmentally-conscious choices. | | | |

**Enabling processes**

- Embodied carbon emissions should be fully integrated in marketing materials and menus to enable more informed choices. Clear targets should be set and monitored.
- The adoption of sustainable design principles, energy efficiency certificates and sustainability schemes can reduce emissions and costs linked to operational practice and on-site activities.
- A mix of active and passive measures to reduce energy use would deliver important benefits. These could include, for example, the use of more efficient lights and showers/taps.
- Guests can be engaged in activities to reduce energy and water use in rooms.
- Integration of Green Infrastructure within existing buildings could deliver adaptation and energy efficiency benefits.
- Restaurants should promote vegan and vegetarian menu options as well as integrating information on embedded carbon in menus [136].
- Restaurants should minimise food waste.

## INFORMATION AND COMMUNICATION (ICT)

*Emissions trend: broadly stable (but evidence not conclusive)*[137]

**Current Issues**

The UK ICT sector is one of the largest ICT markets in the world, with substantial contribution to GDP and jobs [138]. It is estimated that ICT manufacturing, use and disposal could be responsible for 3% of global emissions. ICT in the public sector is responsible for around 35-38% of ICT-related greenhouse gas emissions [139].

**Risks and Opportunities**

- The use of energy-efficient ICT tools could be used as an alternative for travel and reduce overall carbon emissions, provided that the use of ICT follows best practice and circular economy principles [140]. A study by BT found that the ICT sector could contribute substantially to achieving the UK carbon neutrality goals through decoupling economic growth from emissions [141].
- Efficiency improvements have so far offset rising demand but they could slow after 2025 [142]. Moreover, ICT energy consumption might be underestimated but evidence is not conclusive as there are studies that point to a sustained reduction of the ICT carbon footprint [143].
- The UK is one of the first countries to focus on Green ICT practice but a comprehensive review and evaluation of practices is needed [144,145].
- ICT could be instrumental in achieving carbon emissions reductions in other sectors [146]. There is a substantial body of research on the role of Smart Cities in driving down carbon emissions [147].
- The UK Government set out a Greening ICT strategy that includes potential pathways and case studies describing successful initiatives that could be replicated in other organisations[148] .
- The UK Government is working on consolidating data centres and serves and many ICT systems have been designed to ensure resilience [149].
- Revisions to the ISO standards have strengthened the requirements for companies to ensure compliance [150].

**Key challenge**

|  |  |  |  |
|---|---|---|---|
| **Capital and operational investments** | **Innovation practice & behaviour change** | **Whole supply chain perspective** | **Just transition** |
| 3 | 4 | 4 | 1 |
| The key challenge for the ICT sector is to reduce the carbon emissions across the supply chain, particularly during the manufacture and disposal stages. ICT could play a key role in driving down emissions in other sectors. | | | |

**Enabling processes**

- The UK Government and the UK Public Sector when working with suppliers should implement practices, including procurement practices, that embed green ICT principles across the life cycle, from production & design to disposal. This is important as a large part of the environmental impact of ICT devices is linked to the manufacture and disposal phase. Designers should work on better considering reuse, recyclability and disassembly. Similarly, for the disposal phase companies should engage with reputable providers. Urban mining could provide solutions for obtaining and reusing materials and metals.
- ICT teams should be trained in Green ICT practices to ensure sustainability principles are fully embedded within this sector.
- Minimising waste and enhancing circular economy practices will support the achievement of Net Zero in ICT.
- The UK Government should extend and adapt the principles set out in the Green ICT strategy to target the role of ICT in households' energy consumption [151].
- More vigorous *Switching off* campaigns targeting office environments could deliver significant savings in terms of cost and carbon emissions.
- Investments in fast broadband could support the role of ICT sector in decoupling economic activities from carbon emissions.

## FINANCIAL AND INSURANCE ACIVITIES

*Emissions trend: decreasing between 1990-2008 but broadly stable since 2009* [152]

### Current Issues

A recent study by South Pole found that emissions linked to the financial sector (not including insurance) are high and could account to 805 million tonnes of $CO_2$ in 2019[153]. This is mostly linked to investments, which is the main issue to be addressed. Through place-based investments and through closely working with local stakeholders, the finance and insurance sector will be key to ensuring a just transition to a low carbon economy.

### Risks and Opportunities

- The insurance sector has been increasingly focussed on the risk from not decarbonising and the benefits of investments in energy efficient buildings.
- The Financial and Insurance sectors in the UK could play a pivotal role as capital providers for green projects. The Grantham Institute recommends green and sustainable bonds as one area for further policy consideration.
- The Bank of England has aligned the Bank's corporate bond purchase scheme with the UK Net Zero goals [154]. Central banks can support climate policies, but a study by Sawyer has found that their role is still limited [155].
- A newly founded "Net-Zero Insurance Alliance" of major insurance companies have committed to individual net-zero goals and to advocate national Governments to enable "science-based and socially just transition of economic sectors to Net Zero" [156].
- Net-zero investment generates significant savings both in terms of emissions and costs. At the moment, however, there is a lack of a common framework to track and assess financial investments for climate action [157].
- Clients and consumers are increasing pressure for actively tackling carbon emissions.

### Key challenge

| Capital and operational investments | Innovation practice & behaviour change | Whole supply chain perspective | Just transition |
|---|---|---|---|
| 2 | 4 | 4 | 3 |

The key challenge for the UK financial sector is to re-direct investments towards low carbon projects and infrastructure and to ensure that these are delivered in a socially just way that minimises potential adverse effects of low carbon transitions.

**Enabling processes**

- Research by the Grantham Research Institute on Climate Change and the Environment has highlighted that the UK finance sector has been successful in mainstreaming green principles into financial operations. The focus however now needs to shift to green investments in infrastructure and innovation that can foster a low carbon economy more broadly, as well as divesting from carbon intensive activities.
- The Grantham Research Institute highlights that integration of sovereign green bonds in the Green Finance Strategy could have an important effect and could also help to channel investments in areas that tend to be under-supplied, including regional just-transition activities.
- The UK's finance sector has not integrated climate reduction goals. The UK Government should integrate climate goals into financial regulation, with net-zero targets clearly set out for the sector.
- The Climate Change Committee has advised the Government to fast-track green investment for the post-COVID-19 recovery plan and set up a National Investment Bank with clear commitment to Net Zero targets.
- Banks could work with local stakeholders to ensure place-based and low carbon investments that also enable a just transition [158]

## REAL ESTATE ACIVITIES

*Emissions trend: gradually increasing* [159]

### Current Issues

The real estate sector is closely linked to the construction and built environment industry and constitutes an important part of the UK economy. The real estate sector (residential and commercial) includes activities relating to the selling and buying of properties. The two key areas of focus for real estate activities are: removing fossil fuels and improving energy efficiency of buildings.

### Risks and Opportunities

- Demand is increasing in the marketplace for higher performing buildings and prospective clients are expressing interest in sustainable options. This could potentially drive efforts to boost energy efficiency in buildings.
- The threat of stranded assets linked to climate risks could encourage innovation in the sector [160].
- Energy Performance Certificates (EPCs) are key for building improvements [160]. There is generally a positive relationship between observed market prices and EPCs, which indicate efficiency. However, energy upgrades do not always outweigh the value gain [161]. This practice should be encouraged through behaviour change interventions as it will will enable innovation within the sector.

### Key challenge

| Capital and operational investments | Innovation practice & behaviour change | Whole supply chain perspective | Just transition |
|---|---|---|---|
| 3 | 3 | 4 | 2 |

The key challenge of the real estate sector is to push towards more energy efficient buildings and emphasise the role of energy performance certificates.

### Enabling processes

- A report by Deloitte highlighted that real estate professionals need to develop skills and understanding of climate mitigation issues and integrate these considerations in their activities. Lower operating costs and increased marketability linked to green buildings should be highlighted benefits [162].
- Real estate companies should enhance the role of energy performance certificates, especially in commercial buildings.

- The real estate sector should closely work with the UK Government to increase standards on energy regulation and ensure that UK housing are fit for climate targets (adaptation and mitigation targets).
- The UK Government should set stricter building standards and retrofit the existing housing stock.

## PROFESSIONAL, SCIENTIFIC, AND TECHNICAL ACTIVITIES/ADMINISTRATIVE AND SUPPORT SERVICE ACTIVITIES (SERVICE SECTOR)

*Emissions trend: Professional, scientific, and technical activities: slightly decreasing but broadly stable since 2014* [163]*; administrative and support service activities: broadly stable (slightly increasing since 2014)* [164]*.*

**Current Issues**

Emissions from the service sector increased from the early 1970s to mid 1990s in many OECD countries, mostly linked to the increase in office spaces and in the role of the sector in OECD economies. In the past few decades, this was mitigated by significant improvements in energy efficiency in buildings and by progress in the electricity sector [165]. The UK followed this trend.

**Risks and Opportunities**

- Emissions in the service sectors are highly interdependent on other sectors, primarily electricity, transport, and energy efficiency in buildings. Because of this it cannot be considered low emission when accounting for all inputs. This creates a risk of under-estimating the carbon footprint of this sector [166].
- Jobs in the professional, scientific and technical activities sector might be active part of the low carbon transition as they move from high carbon sector to low carbon sectors. This might create a risk of job losses but also important opportunities to create added value for the UK economy if mechanisms that ensure a just transition are properly in place.
- The UK decarbonisation policy and industrial strategy does not embed the idea of a just transition in the professional, scientific and technical sector. This challenge is closely linked to the Just Transition challenge in key industries, namely the energy sector, manufacturing and mining [5].
- There are skills gaps in the low-carbon energy sector and the training support should be enhanced for workers who could transition from a high to low carbon employment.

**Key challenge**

| Capital and operational investments | Innovation practice & behaviour change | Whole supply chain perspective | Just transition |
|---|---|---|---|
| 1 | 4 | 4 | 5 |

The key challenge for the professional service, scientific, technical sector and for the administrative support sector is to ensure that people are enabled to switch from high to low carbon employment.

**Enabling processes**

- The UK Government should ensure that workers in professional, scientific and service sector in high-carbon industries can be reskilled and enabled to transition to low carbon industries (e.g. renewable energy). This would create an added value for the UK economy and would particularly benefit certain regions of the UK (e.g. the North of England, which already host a leading low-carbon goods and service sector) and should be part of the levelling up agenda.
- The UK Government should explicitly embed the concept of just transition in its decarbonisation strategy and industrial strategy.
- A skills audit would be beneficial, and training should be made easily available to enable workers to move from high to low carbon employment.
- The UK Government should closely work with employers in the service sector to encourage schemes for active or sustainable commuting.

## PUBLIC ADMINISTRATION AND DEFENCE

*Emissions trend: decreasing* [167]

**Current Issues**

While the emissions in the public sector have decreased, driven by energy efficiency improvements and increased use of renewables, defence is the largest contributor to greenhouse gas emissions within the UK central Government (with around half of all Government greenhouse gas emissions). Two third of fuel consumption within defence is linked to military aviation (not including the British arms industry). The Ministry of Defence recognises Climate Change as a threat to peace.

**Risks and Opportunities**

- The UK Government Greening Government Commitments set out actions that UK Government departments and agencies will take to contribute to Net Zero targets and minimise their environmental impacts. These focus particularly on the negative effects of Government's estates and operations. The 2018-19 annual report states that emissions have dropped by 46% in 2018/19 on 2009/10 and that 28% of this reduction stemmed from improvement in the management of the estate and a further 18% was linked to the decarbonisation of the national grids. This led to substantial savings (estimated £128 million in 2018/19).
- There is a separate Greening Government ICT and digital services report that details the carbon and energy footprint of all Government ICT services (including cloud services and the Government's handling of ICT waste) [168]. The 2019-20 report highlight that 0.023% of ICT waste was disposed of to landfill, in line with the Zero waste to landfill target by 2020. This was achieved through increased reuse and recycling.
- The UK Ministry of Defence (MoD) has outlined the plan to reduce the UK armed forces' contribution to carbon emissions. The Climate Change and Sustainability Strategic approach is centred around the need to be less dependent on fossil fuels [169].
- The MoD aims to have carbon-neutral estates by 2040 and the strategy includes the ambition to shift to alternative techniques aimed at reducing actual training flights and alternative fuel.
- Within the military sector, concerns about performance of green equipment might constitute an internal barrier that will need to be addressed.
- Positively, the MoD reports that new recruits are increasingly showing concern about climate change.
- The MoD has reduced carbon emissions along the supply chain but there are areas for improvements. Moreover, the long working life of equipment means that it is difficult to achieve Net Zero emission targets in the short term.

**Key challenge**

|  |  |  |  |
|---|---|---|---|
| **Capital and operational investments** | **Innovation practice & behaviour change** | **Whole supply chain perspective** | **Just transition** |
| 3 | 2 | 4 | 1 |
| The key challenge of the public administration and defence sector is to accelerate progress towards low carbon estate management and enhance sustainable procurement policies with a particular focus on monitoring compliance. | | | |

**Enabling processes**

- Circular economy principles must be fully deployed across the public sector and defence, including in public procurement.
- The Defence sector must be fully involved in UK-wide decarbonisation policies.
- The MoD should work closely with manufacturers to ensure low carbon and circular economy principles are fully embedded across the whole supply chain. A specific area to address is monitoring compliance with mandatory Government sustainable procurement buying standards. This issue was highlighted by a recent Environmental Sustainability report by the National Audit [170]
- The MoD should accelerate progress towards low carbon estates and energy efficiency in buildings.

## EDUCATION

*Emissions trend: decreasing (but broadly stable since 2014)* [171]

**Current Issues**

Emissions in the education and higher education sector are linked to the built environment and buildings. The UK department for Business, Energy and Industrial Strategy (BEIS) has introduced the voluntary target for 30% carbon emissions reduction by 2021/21 against a 2009/10 baseline. The Department of Education reports that the Education sector has reduced greenhouse gas emissions by nearly half (43%), together with cutting waste production by 62% and reducing water consumption. This has led to important financial savings. The UK Government has recently raised the ambition to cut emissions from the education sector by 50% by 2030 (against a 2009/10 baseline). In Higher Education sector, buildings are the most significant contributors to carbon emissions [172]. A systematic review has identified a wealth of research and initiatives to improve energy efficiency on campuses [172] showing that several universities adopt smart energy interventions and benefit from their institution's research capabilities for implementation and monitoring. Initiatives often include technical and non-technical interventions that show a joined-up approach.

**Risks and Opportunities**

- Ahead of the COP26 to be held in Glasgow in November 2021, the Climate Commission for UK Higher and Further Education has encouraged every University and College to sign up to the Race to Zero for Universities and Colleges with the aim to achieve 100% of UK institutions committed to the pledge.
- There are many freely available climate action toolkits that schools, FE and HE institutions can use to develop and monitor their climate action plans.
- 91% of HE students are fairly or very concerned about climate change and might push for greater ambition.
- Adapting buildings to future climate-related challenges will be a priority. Thermal efficiency must account for increased temperature.
- A systematic review is required of smart building principles and smart energy systems in the UK
- Distance-learning HE courses involve 87% less energy and 85% lower $CO_2$ emissions than full-time courses held on campus. Part time courses reduce energy and carbon emissions by 6%5 and 61% respectively. This is mainly linked to a reduction in travel to and from campus and a reduction of energy consumption (however, energy savings could be offset by increase in domestic energy consumption) [173].
- Several organisations have produced toolkits and reports with best practice that would support schools reducing their carbon footprint [174].

**Key challenge**

|  |  |  |  |
|---|---|---|---|
| **Capital and operational investments** | **Innovation practice & behaviour change** | **Whole supply chain perspective** | **Just transition** |
| 3 | 2 | 3 | 1 |
| The key challenge for the education and higher education sector will be linked to improvements in energy efficiency in buildings and campuses and in tackling emissions from travelling to and from schools and campuses. | | | |

**Enabling processes**

- Encourage the development of new or the use of existing climate action toolkits to enhance sustainability on campuses.
- University staff and researchers should be increasingly involved in urban and national sustainability initiatives.
- Green Infrastructure and Nature Based Solutions should be widely deployed on school grounds and campuses, which will provide benefits in terms of cooling and reduce the risk from overheating [175].
- It is important to enhance monitoring and evaluate different approaches to enhance replicability potential.
- Campuses should refine their Scope 1, 2 and 3 accounting.
- Short courses and CPD could be run online to reduce emissions and energy consumption on campus, but this option should be assessed against learning needs and best practice in teaching. The pros and cons of online education as a carbon reduction measures have been covered in the literature [176].
- The UK Government and local authorities should work together to strongly encourage active and sustainable travel to and from schools/campuses. This will result in significant co-benefits in terms of improved air quality and public health.
- Children and students could be directly involved in monitoring and implementation activities, which will then have educational benefits.

## HUMAN HEALTH AND SOCIAL WORK ACTIVITIES

*Emissions trend: decreasing (but broadly stable since 2014)* [177]

**Current Issues**

The NHS is responsible for over 3,000 properties and as such plays an important part in the journey to Net Zero. Energy consumption and heat are important contributors to emissions from the sector. The NHS is the largest employer in Britain and is responsible for around 4% of national carbon emissions, and 25% of public sector emissions. A breakdown of the NHS carbon footprint reveals that 22% of its emissions come from energy consumption; 18% from travel; 60% from procurement [178].

In 2020 he NHS was the first national health system to commit to Net Zero– focussing on the emissions that can be controlled directly by 2040 (with an ambition to reach an 80% reduction by 2028-2032) and to a Net Zero for emissions they can influence by 2045 (with an ambition to reach an 80% reduction by 2036-39).

**Risks and Opportunities**

- In April 2020 NHS Property Services announced new energy supply contracts to move the entire building portfolio to 100% renewable electricity and invested in energy saving schemes including installation of LED lighting [179].
- Reduction in carbon emissions will have co-benefits on air quality and public health.
- The NHS is working towards greening the fleet and is working towards a zero-emission ambulance.
- Against the backdrop of the COVID-19 crises health professionals around the world have called for a healthy recovery that focuses on climate prevention strategies [180]. However, in the UK significant challenges remain to close the gap to Net Zero
- Approximately 3.5% of all road travel in England relates to people travelling to the NHS, contributing to around 14% of the system's total emissions [181].

**Key challenge**

| Capital and operational investments | Innovation practice & behaviour change | Whole supply chain perspective | Just transition |
|---|---|---|---|
| 3 | 4 | 4 | 2 |

The key challenge for the health sector is to tackle energy emissions from buildings and transport emissions (people travelling to the NHS).

**Enabling processes**

- Innovation is required in delivering care at or closer to home to reduce patient journeys to hospital.
- NHS staff should receive formal training and education in energy conservation measures and on how to optimise energy use.
- The NHS and the UK Government should enhance campaign to encourage active travel focussing on personal health benefits

## ARTS ENTERTAINMENT AND RECREATION

*Emissions trend: decreasing (but broadly stable since 2014)*

**Current Issues**

In 2012 the Arts Council England became the first cultural body to integrate an environmental action plan in their funding agreements. The 2017/18 Environmental Programme showed a 35% reduction in carbon emissions and 23% reduction in energy consumption, which resulted in substantial cost savings. There are important variations within the entertainment industries with differences for examples between theatres, arenas and stadium venues.

**Risks and Opportunities**

- National portfolio organisations are required to annually monitor their environmental impacts using carbon footprint accounting tools.
- A "Beyond Carbon" online tool is available to organisations to report on environmental practice beyond carbon emissions. An evaluation of this tool reported financial, reputational benefits as well as improved team morale.
- Key drivers of the arts and entertainment sector in the UK (e.g. West End) has relied on global visitors reliant on air travel.
- A study conducted by Centre for London found that touring bands, orchestras and companies do not systematically embed carbon footprints in their touring planning [182].
- Big events are energy intensive and produce significant amount of waste.

**Key challenge**

| Capital and operational investments | Innovation practice & behaviour change | Whole supply chain perspective | Just transition |
|---|---|---|---|
| 3 | 4 | 4 | 1 |

The key challenge for the sector is to minimise the carbon footprints of events and tours by incorporating carbon accounting mechanisms in tour and event planning. Circular economy principles and sharing of equipment through collaborative schemes could also deliver carbon reduction benefits.

**Enabling processes**

- Arts and Entertainment industries could play a key proactive role in driving pro-environmental behaviours through appropriate and tailored story-arcs that show people how to engage in sustainable behaviours. The UK Government should acknowledge and fully support this role [183].

- The Arts, culture and entertainment industry needs to reduce the day-to-day carbon emissions that stem from vehicles, energy consumption of buildings and touring. Carbon emissions should be embedded into tour planning and priced. These considerations should include also strategies to minimise waste.
- Reductions could be achieved through re-use, recycling and sharing of production and staging equipment.
- The UK Government should support integration of environmental training in sector relevant qualifications.

# Concluding remarks

This rapid evidence review highlighted how most industry sectors in the UK are not on track to achieve their climate targets. While some sectors like Electricity and Gas have achieved substantial emission reductions through moving away from coal and fossil fuels, it must be stressed that they are still among the highest emitting sectors. The report has included concrete and achievable options available in each sector that, if implemented as soon as possible and with a strong drive and commitment, will create a low carbon economy. Beyond the more obvious investments such as in large-scale renewables or CCS, other smaller-scale approaches appear promising and have the potential to be implemented at multiple scales, thus fostering collaboration and involvement of local authorities, and would also deliver adaptation benefits and other ecosystem services. These include Green Infrastructure whose co-benefits and environmental services have been very well covered in the literature, and urban mining practices, which could benefit from innovative digital technology platforms and coordination at the city scale, which would implement circular economy principles in harder to abate sectors such as construction.

The UK Climate Change Committee has stressed that while the foundations are in place to reach Net Zero, policy must be ramped up significantly and delivery must progress with far greater urgency [68]. This report supports this view. The report has highlighted some sectors which can be considered harder to abate, such as (but not limited to) construction, manufacturing (heavy industry) and transport. The overall risk matrix in Table 7 provides a breakdown of the estimated magnitude of the challenges faced by each sector following our qualitative risk matrix.

Table 7: Overall risk matrix

| Sector/Challenge | Capital and operational investments | Innovation practice & behaviour change | Whole supply chain perspective | Just transition |
|---|---|---|---|---|
| Manufacturing | 5 | 5 | 5 | 4 |
| Construction | 4 | 5 | 5 | 4 |
| Transport | 4 | 5 | 4 | 4 |
| Mining | 5 | 3 | 3 | 5 |
| Agriculture | 3 | 5 | 3 | 4 |
| Wholesale and retail | 2 | 4 | 5 | 3 |
| Financial and insurance | 2 | 4 | 4 | 3 |
| Electricity and gas | 4 | 4 | 2 | 3 |
| Human health and social work activities | 3 | 4 | 4 | 2 |
| Water and waste management | 3 | 5 | 4 | 1 |
| Service | 1 | 4 | 4 | 4 |
| ICT | 3 | 4 | 4 | 1 |
| Real estate | 3 | 3 | 4 | 2 |
| Accommodation and food activities | 4 | 4 | 3 | 1 |
| Arts entertainment and recreation | 3 | 4 | 4 | 1 |
| Public Administration and defence | 3 | 2 | 4 | 1 |
| Education | 3 | 2 | 3 | 1 |

The sectors are indicatively ordered in Table 7 by the magnitude of the overall challenge that they face (from largest to smallest) based on the thematic analysis of the evidence conducted in this report. However, there are substantive considerations to be taken into account before deriving a formal ranking from this table. First, the scoring does not integrate the relative importance of each sector for the UK economy, nor their relative contribution to emissions. Second, challenges manifest differently in different sectors, so a full comparative analysis is not possible without identifying some more specific challenge related selection criteria. Third, the table does not indicate whether it will be easier to decarbonise for a sector with a high scoring matrix in one dimension and low scores in other dimensions or for a sector that displays moderate risks across the four challenge dimensions.

Nonetheless, there are some conclusions that can be derived from this simplistic scoring exercise and from this broad review. For instance, it is important to acknowledge the significance of enabling innovation practices and behaviour change, a significant challenge for most of the sectors that could hamper progress towards Net Zero; and the importance of adopting a whole supply chain perspective focussed on implementing circular economy principles. This is linked to the interconnected nature of industries' decarbonisation pathways and the existing interdependencies of common supply chains. This means that many sectors have the same shared risks and opportunities (e.g. mining and electricity; construction and mining; manufacturing and transport) that should be tackled following a system perspective, thus addressing silos and unexpected negative consequences of actions along the supply chain. However, it should be recognised that shared risks does not necessarily mean equal risks across sectors (i.e. some sectors may be more exposed than others to a shared risk).

These interdependencies should be fully integrated in carbon accounting (Scope 1, 2 and 3), which must focus on the whole life cycle of products' carbon emissions. Carbon accounting methodologies based on the territorial scale are blind to the emissions embodied in trade, which this report has stressed as a key challenge common in many key and harder to abate sectors. Consumption-based accounting addresses this blindness by considering the full supply chains of goods and services and should be encouraged as it could support a whole supply chain perspective. Furthermore, more research is needed to investigate better practice to exploit the opportunities of these interdependencies while minimising the risks and what lessons can be replicated in other sectors or at a different scale and minimise cost.

Operationally, potential solutions to minimise cost of Net Zero infrastructure (e.g. Carbon Capture and Storage, CCS), would entail infrastructure re-use (e.g. pipelines), optimisation of data use, development of the project in separate stages of activities. Additional strategies should focus on building strong relationships with regional-level stakeholders and policymakers and better aligning communication about CCS projects to local and national decarbonisation targets.

The UK Government should play a key role in providing a platform for coordinating system-level actions as well as providing strong leadership. For example, policy instruments that create incentives or disincentives (in the form of regulation, taxes, or subsidies) should be

aligned to national climate change targets and further research could look into what individual policy instruments deliver the biggest progress towards Net Zero. Policies should also include a mix of technological and non-technological (behavioural) measures. This report has stressed that some sectors (e.g. Agriculture or Transport) need a widespread shift in individual practices to achieve Net Zero despite the fact that these are relatively easy and cost-effective to decarbonise from a technical point of view. A focus on behavioural measures will also unleash more co-benefits (particularly in terms of improved air quality and public health benefits, noise reductions, etc.) and will also strengthen reductions in energy consumptions, alongside a switch to renewable sources.

Targeted policy instruments could provide the required support for research and innovation to overcome some technological challenges that characterise some areas, for example large-scale applications of some renewable energy technologies (e.g. solar PV or heat pumps) or a fuller development of CCS technologies, which, as this report has showed, will play a crucial, albeit narrow, role to bridge the final gap towards carbon neutrality.

A cross-cutting issue that should be fully integrated in UK Government's climate change strategies is the Just Transition. While this report did not include a policy document analysis, the links between the UK industrial decarbonisation strategy and the UK Government levelling up agenda do not seem to go far enough. A transition towards a low carbon economy requires a transition from high carbon employment to low carbon employment. However, mechanisms should be in place to ensure that this transition is smooth, timely and does not result in job losses. A Just Transition is a critical factor to ensure a successful pathway to Net Zero [184]. The UK Government can and should ensure that this transition is enabled through proper economic support mechanisms, training and skills development programmes, to be developed in collaboration with educational providers.

## Limitations of this report

This report is based on a rapid evidence review of the UK industrial sector decarbonisation challenges and does not constitute a full systematic analysis of individual sectors' barriers to decarbonisation, which is beyond the scope of this report. The scope and breadth of this work mean that there are some further limitations that need to be acknowledged.

First, this report followed the UK Standard Industrial Classification (SIC) classification to ensure a broad overview of UK industries. However, this means that some sectors are aggregated to a very high-level (e.g. manufacturing) and, therefore, it is difficult to disentangle and pinpoint variations in emissions and challenges within individual sub-sectors. While the narrative in the report signposts where possible these variations, this limitation must be acknowledged. Further and more extensive research should analyse each sector and focus the analysis at a more disaggregated level.

Second, the report offers a snapshot of current challenges as highlighted in the literature and its methodology does not go far enough to enable a deeper nuanced discussion and reflection on whether decarbonisation will be harder for sectors that have fewer but higher risk scores (e.g. 5) or lower risk scores distributed across different challenges (e.g. 3). We

must stress that the risks scores were derived from thematic considerations based on the reviewed literature, and as such they reflect the authors' professional judgement. This subjectivity is a limitation of the risk matrix and further work should be done to test this model and our scoring against other frameworks. We consider the formalisation and refinement of this framework to be an interested future research direction that could enable a fuller comparative analysis.

Third, while for some sectors we found ample coverage in the academic literature, in other cases this has been more limited; to overcome this, we have relied more substantially on grey literature and reports from reputable and relevant sources.

Finally, this report did not address the impact of recent disruptions and events such as COVID-19 and Brexit, which could have implications in term of cost and operational practice in some key sectors, including those like manufacturing and construction that are harder to abate. This, in our view, constitute a further important area for more detailed study.

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# Appendix A – Scopus search terms

- **Search 1 (Decarbonisation challenges for the UK industrial sector)**: Industrial sectors (focused terms and related issues) + UK + challenges + Decarbonisation + (focused terms and related issues) (TITLE-ABS-KEY search)
- **Search 2 (Policy drivers)** Industrial sector (focused terms) + Decarbonisation + (focused terms) + Approaches (interventions, policies, measures) (TITLE-ABS-KEY search)

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|---|
| **Industrial Sectors (focused terms)**<br>("Industrial sector*" OR "Agricultur* sector" OR "Forestry sector" OR "Fishing sector" OR "mining sector" OR "quarrying sector" OR "manufacturing sector" OR "Electricity sector" OR "Water supply sector" OR "Waste management sector" OR "construction sector" or "wholesale sector" or "retail trade sector" OR "transportation sector" OR "accommodation sector" OR "food service sector" OR "Information and communication sector" OR "financial and insurance sector" OR "real estate sector" OR "professional, scientific and technical sector" OR "Administrative sector" OR "public administration sector" OR "education sector" OR "human health and social work sector" OR "arts, Entertainment and recreation sector") |
| **Decarbonisation**<br>("low carbon" OR "Decarbonisation" OR "Net Zero" OR "low-fossil-fuel" OR "Decarbonis*" OR "climate change mitigation" OR "climate emergency" OR "carbon emission* reduction* OR "hard to abate") |
| **UK**<br>(UK OR "United Kingdom" OR "Britain" OR "British") |
| **Challenges**<br>(Challeng* OR risk* OR barrier* OR obstacle* OR exposure OR susceptibility OR vulnerability OR difficult* OR hurdle* OR cost* OR investment* OR transition* OR "just transition* or "climate risk*") |
| **Drivers**<br>("policy drivers" OR "polic*" OR "intervention*" OR "mitigation measure*" Or "journey" OR transition* OR support OR enables OR "enabling factor*" OR Strateg*) |