

The Sixth Carbon Budget

Manufacturing and construction

This document contains a summary of content for the Manufacturing and construction sector from the CCC's Sixth Carbon Budget Advice, Methodology and Policy reports.

Introduction

The Committee is advising that the UK set its Sixth Carbon Budget (i.e. the legal limit for UK net emissions of greenhouse gases over the years 2033-37) to require a reduction in UK emissions of 78% by 2035 relative to 1990, a 63% reduction from 2019. This will be a world-leading commitment, placing the UK decisively on the path to Net Zero by 2050 at the latest, with a trajectory that is consistent with the Paris Agreement.

Our advice on the Sixth Carbon Budget, including emissions pathways, details on our analytical approach, and policy recommendations for the Manufacturing and construction sector is presented across three CCC reports, an accompanying dataset, and supporting evidence.

- **An Advice report:** *The Sixth Carbon Budget – The UK's path to Net Zero*, setting out our recommendations on the Sixth Carbon Budget (2033-37) and the UK's Nationally Determined Contribution (NDC) under the Paris Agreement. This report also presents the overall emissions pathways for the UK and the Devolved Administrations and for each sector of emissions, as well as analysis of the costs, benefits and wider impacts of our recommended pathway, and considerations relating to climate science and international progress towards the Paris Agreement. Section 1 of Chapter 2 contains an overview of the emissions pathways for the Manufacturing and construction sector.
- **A Methodology Report:** *The Sixth Carbon Budget – Methodology Report*, setting out the approach and assumptions used to inform our advice. Chapter 1 of this report contains a detailed overview of how we conducted our analysis for the Manufacturing and construction sector.
- **A Policy Report:** *Policies for the Sixth Carbon Budget and Net zero*, setting out the changes to policy that could drive the changes necessary particularly over the 2020s. Chapter 3 of this report contains our policy recommendations for the Manufacturing and construction sector.
- **A dataset** for the Sixth Carbon Budget scenarios, which sets out more details and data on the pathways than can be included in this report.
- **Supporting evidence** including our public Call for Evidence, 10 new research projects, three expert advisory groups, and deep dives into the roles of local authorities and businesses.

All outputs are published on our website (www.theccc.org.uk).

For ease, the relevant sections from the three reports for each sector (covering pathways, method and policy advice) are collated into self-standing documents for each sector. A full dataset including key charts is also available alongside this document. This is the self-standing document for the Manufacturing and construction sector. It is set out in three sections:

- 1) The approach to the Sixth Carbon Budget analysis for the Manufacturing and construction sector
- 2) Emissions pathways for the Manufacturing and construction sector
- 3) Policy recommendations for the Manufacturing and construction sector

Chapter 6 of our *Advice Report* includes further information on competitiveness.

Chapter 1

The approach to the Sixth Carbon Budget analysis for the Manufacturing and construction sector

The following sections are taken directly from Chapter 4 of the CCC's Methodology Report for the Sixth Carbon Budget.¹

Introduction and approach

This chapter sets out the method for the manufacturing and construction sector Sixth Carbon Budget pathways.

The scenario results of our costed pathways are set out in the accompanying *Advice report*. Policy implications are set out in the accompanying *Policy report*.

For ease, these sections covering pathways, method and policy advice for the manufacturing and construction sector are collated in *The Sixth Carbon Budget – Manufacturing and Construction*. A full dataset including key charts is also available alongside this document.

We set out our analysis in the following sections.

1. Background
2. Options for reducing emissions
3. Analytical approach

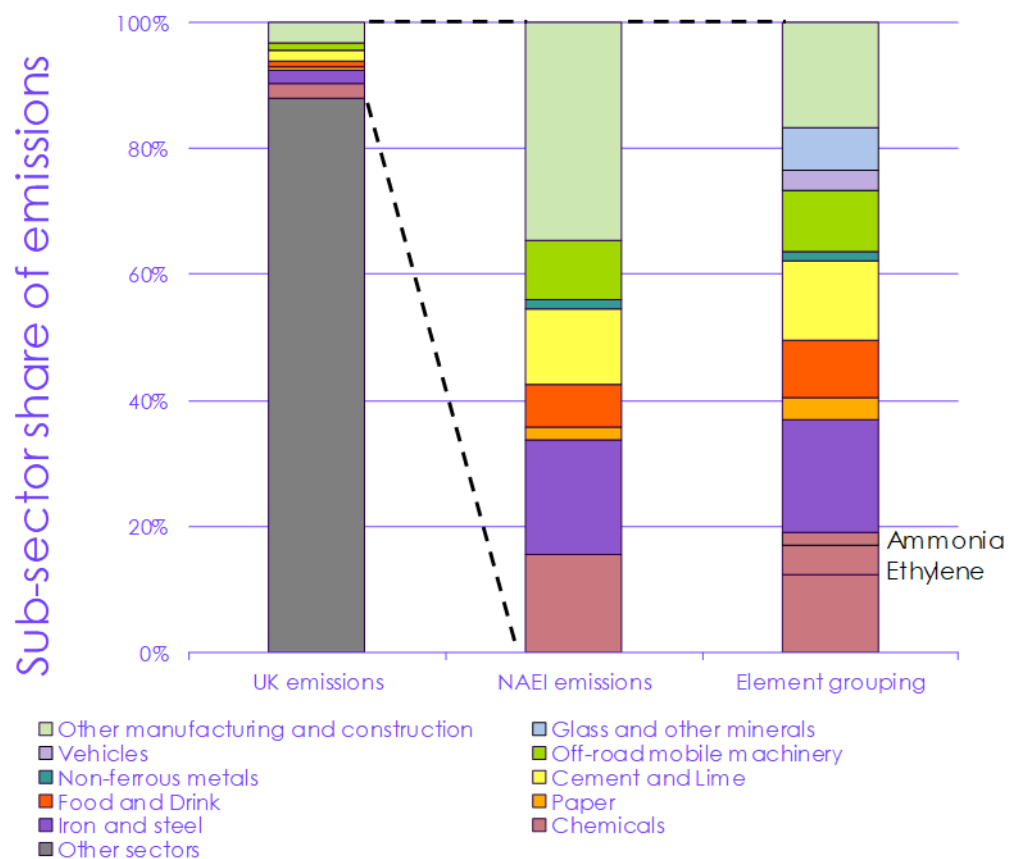
1. Background

a) Current emissions

Greenhouse gas emissions from manufacturing and construction were 66 MtCO₂e in 2018, 12% of the UK total (Figure 4.1):

- Manufacturing represents 90% (60 MtCO₂e) of this sector's emissions. Of these, 86% were from fuel combustion (for high- and low-grade heat, drying/separation, space heating and on-site electricity generation) and 14% were process emissions (which arise from a range of chemical reactions e.g. from the calcination of limestone for cement). Manufacturing emissions are spread across a wide variety of subsectors (e.g. cement, iron and steel, chemicals).
- The remaining 10% (6 MtCO₂e) of emissions were from off-road mobile machinery (ORMM). Off-road mobile machinery is 77% construction and 12% mining equipment. An additional 3% of emissions come from ORMM use in transport infrastructure (e.g. harbours, tunnels, bridges) with a wide variety of applications making up the rest of this subsector. Emissions in this sector come from the combustion of diesel, which is used as a fuel.
- Most (98.6%, 65.4 MtCO₂e) emissions were of CO₂, 0.6% (0.4 MtCO₂e) were of CH₄ and 0.8% (0.5 MtCO₂e) of N₂O.

Figure M4.1 Breakdown of manufacturing and construction emissions (2018, 66 MtCO₂e)



Source: National Atmospheric Emissions Inventory (2020) Breakdown of UK GHG emissions by source and greenhouse gas; CCC analysis.

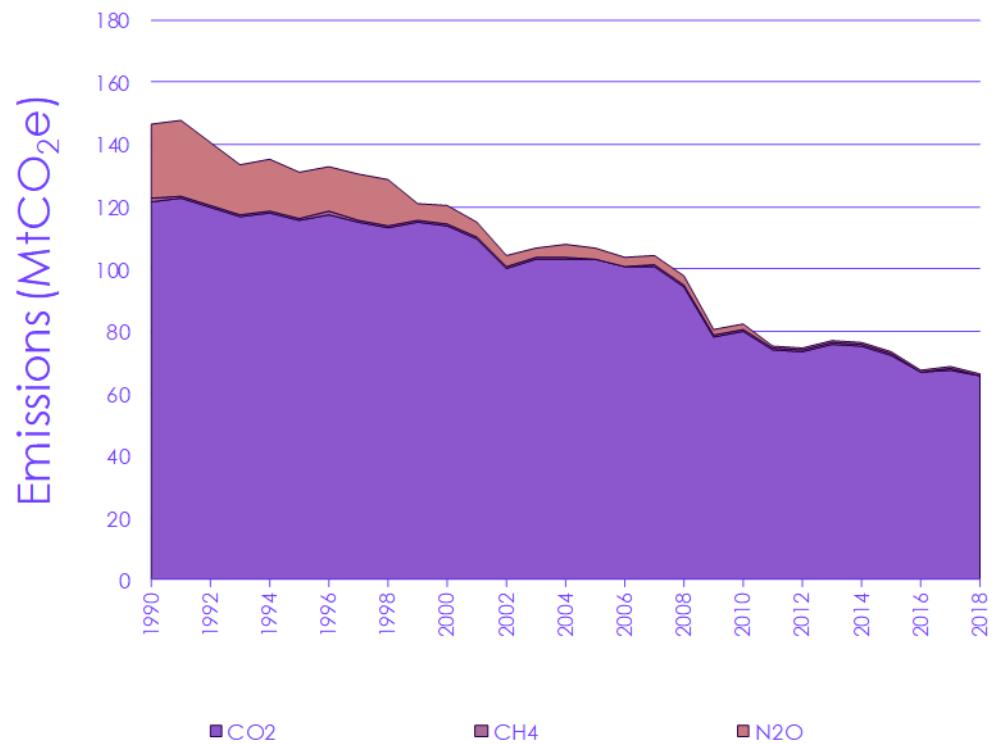
Direct emissions from manufacturing and construction fell by 2% in 2019. Emissions were 56% below the 1990 baseline (Figure 4.2). More detailed sectoral data are produced with a one-year lag. The 1% rise in emissions in 2017 was largely due to rises in chemical process emissions, as well as process emissions from food, drink and tobacco. This followed a drop in 2016 from a reduction in iron and steel production, following the closure of Redcar steelworks in Teesside.

We also analyse factors that contribute to a change in emissions, attributing changes to:

- Output effects (e.g. recession-related emissions reduction);
- Structural effects (e.g. manufacturing output moving towards less carbon-intensive sectors);
- Switching to fuels with higher or lower direct emissions (e.g. fossil fuel to electricity); and
- Energy intensity (e.g. due to energy efficiency, changes in plant utilisation or product mix).

Our decomposition analysis¹ suggests that over the period 2009-2017 industrial output grew 10%, and the 25% fall in direct CO₂ emissions can be attributed to a structural movement towards a less carbon intensive mix of industrial output (accounting for 25% of the change), improvements in energy intensity (50%) and changes in fuel mix (25%).²

Figure M4.2 Trends in manufacturing and construction emissions



Source: National Atmospheric Emissions Inventory (2020) Breakdown of UK GHG emissions by source and greenhouse gas; CCC analysis.

¹ Data supplied by Ricardo Energy and Environment

² Numbers rounded to nearest 5%.

2. Options for reducing emissions

This section sets out the different options for reducing emissions from manufacturing and construction in the UK.

a) Resource efficiency

Reducing the flow of materials through the economy and using products more efficiently (and for longer) can reduce manufacturing emissions, as part of a shift towards a more circular economy. A range of different measures are detailed in Box 4.1 in section 3, and fall into two categories: reduced end-user consumption of resources, and more efficient use of resources in production. Some of these measures involve behaviour change on the part of the consumer. These typically involve increased recycling, using products for longer, and sharing resources (e.g. car clubs).

b) Material substitution

Material substitution can reduce manufacturing emissions by switching from high-embodied-carbon materials to low-embodied-carbon materials. Measures include using wood in construction and using replacements to clinker (e.g. fly ash) in cement.

c) Energy efficiency

Using energy more efficiently reduces operating costs while cutting emissions. The energy efficiency measures that we include are 'low-regret' measures that often save significant fuel costs. Measures include process and equipment upgrades, installing/improving heat recovery systems, and clustering/networking with other sites and businesses to efficiently utilise waste heat and other by-products.

d) Fuel-switching

Fuel switching in manufacturing

Hydrogen, electricity and bioenergy can all be used to meet heat, motion (and electrical) demands, thus replacing the use of fossil fuels and reducing GHG emissions.

- There are a range of hydrogen, electrical and bioenergy heating technologies, which are designed to provide different types of heat demand.
- Some fuels or heating technologies have wider potential than others. For example, biomass is not always suited to replacing natural gas for direct high-temperature heating because the resulting combustion gases have a less desirable composition than those from natural gas.
- Biomass should only be used in applications with CCS in the long-term, based on the assessment of best uses in our Biomass Review.² This combination is referred to as Bioenergy Carbon Capture and Storage (BECCS) and has the net effect of removing CO₂ emissions from the atmosphere. These removals are counted in our Greenhouse Gas Removals sector (see Chapter 12).

- Each of these fuels is already used in the manufacturing and construction sector although sometimes they are not low-carbon and/or not used for energy. In 2018, 26% of energy demand in manufacturing and construction was met through electricity, with a further 12% from biomass and waste.
 - Electricity is currently used to meet a variety of energy demands in manufacturing and construction, including driving motors and to produce process heat. The largest electricity-using sectors are other manufacturing, chemicals, and food and drink.
 - Biomass and waste are currently used to produce electricity and heat in the cement and paper industries. Waste includes the use of waste solvents, wood, scrap tyres, and municipal solid waste.
 - Hydrogen is currently used in ammonia production, as an input to the Haber-Bosch process. This hydrogen is produced from fossil gas without CCS, so it is not low-carbon. Hydrogen production for fuel use is covered separately (Chapter 6).

We group a couple of other technologies in with fuel-switching, that may be regarded as a process change, rather than fuel-switching.

- In most existing primary steel production, coke (made from coal) is used as a reductant in blast furnaces. Hydrogen-based direct reduction of iron (DRI), can replace coke as the reductant with hydrogen (so, in part, the reductant is switched rather than the fuel). This process change leads to water vapour being produced, instead of CO₂.
- Electric arc furnaces (EAF) use different materials (e.g. recycled or scrap steel) to blast furnaces, so may be considered a different process, rather than fuel switching, although in this case the fuel is switched.

Fuel switching in off-road mobile machinery (ORMM)

Off-road mobile machinery (e.g. forklifts, generators) typically use diesel as a fuel. Multiple options are available to decarbonise ORMM, including electricity, hydrogen, and biodiesel. The sector will likely require a mix of these abatement options, given the wide range of equipment that aims to meet specific needs for construction and mining.

- Hydrogen and electricity are likely to provide long-term solutions for abatement. Not only would they reduce emissions, but they could lead to fuel cost savings that would benefit the sector, as both technologies are more efficient than burning diesel.
- However, the adoption of hydrogen depends on the development of a wider hydrogen infrastructure to reduce costs and ensure fuel availability for construction sites.
- There could similarly be barriers in the uptake of electricity, as construction sites will need to accommodate space for battery swapping or connections to the electricity grid.
- Biodiesel could play a role as a transition fuel to start decarbonising the sector, provided sufficient bioenergy is available.

e) Carbon Capture and Storage (CCS)

CCS can be used to capture CO₂ produced by larger industrial point-sources, and transport it to a CO₂ storage site, thus reducing emissions to the atmosphere. The captured CO₂ may alternatively be used in Carbon Capture and Use (CCU), although the potential amount that could be used is expected to be substantially smaller than that which could be stored.

CCS is particularly important in the manufacturing sector, as it can abate emissions that cannot be addressed simply by switching to low- or zero-carbon energy. This includes capturing non-combustion process CO₂ emissions (from chemical reactions such as the calcination of limestone in cement production) and combustion emissions, including those arising from the combustion of internal fuels (gases that are produced as part of the industrial process).

When capturing emissions from biomass combustion, reduction or fermentation, this results in BECCS.

f) Other

Greenhouse gas emissions from flaring in iron and steel production and leakage from processes in the manufacture of chemicals can also be addressed. Flaring emissions can be reduced by capturing methane and selling it. Leakage of methane in the chemicals subsector can be reduced through periodic leakage detection and repair or continuous monitoring, to find the leaks as early as possible and limit the volume of methane released.

3. Analytical approach

The Balanced Net Zero Pathway and the four exploratory scenarios in this sector vary in several ways, including their energy mix, levels of resource efficiency and rates of decarbonisation. More information on this is in Chapter 3, Table 3.3a of the *Advice report*, and the dataset that accompanies the report.

These pathways and scenarios are underpinned by new analysis in several areas, as well as some of the evidence and analysis used for our 2019 *Net Zero advice*³ and the accompanying *Net Zero technical report*.⁴

New analysis includes work commissioned from Element Energy on deep-decarbonisation pathways for UK industry and internal analysis of options for decarbonising off-road mobile machinery. We have also updated our synthesis of evidence on resource- and energy-efficiency options, and our baselines.

The structure of our analysis follows the following steps:

- It starts by considering a baseline world where there is no new climate change mitigation policy beyond 2019.
- From this emissions baseline we deduct, in sequence, abatement from resource efficiency, material substitution and energy efficiency.
- We then deduct abatement from 'deep decarbonisation' options: fuel-switching, CCS and measures to reduce methane flaring, venting and leakage.³

We set out the approaches we have taken for each of these steps, below.

a) Baseline projections

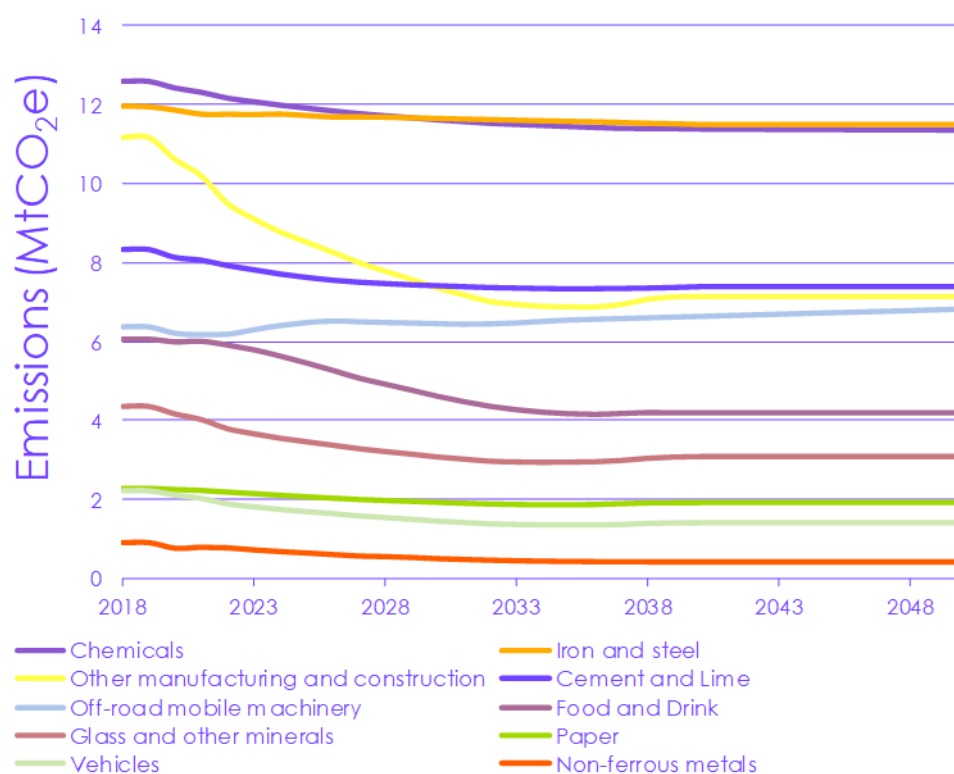
Our emissions baseline (Figure 4.3) starts aligned to historical emissions for 2018, the latest year with fully reported data, based on the National Atmospheric Emissions Inventory (NAEI).⁵ For combustion emissions, corresponding energy data are drawn from a mix of the NAEI and DUKES,⁶ allowing for the inclusion of existing electricity and bioenergy use (which are not reported in the Inventory).

Future energy and emissions are projected from the historical 2018 data using the scaling (% change from 2018) of the BEIS Energy and Emissions Projections 2019 reference case.⁷ This reference case accounts for a small amount of projected abatement from existing 'firm' policies. We made several bespoke assumptions in the use of these projections, in particular:

- We do not use the BEIS energy and emissions projections to project the change from 2018 to 2019. This reflects that the BEIS econometric methodology results in large jumps in emissions from the last historical year (2018) to the first projected year (2019), which we know from provisional data have not happened.
- We do not use the projections for the chemicals sector, for which the econometric method projects a very large decline in emissions, instead assuming that baseline emissions stay constant for most of the subsector.

³ There is only a small amount of the methane reduction measures required in this sector.

Figure M4.3 Baseline projections for subsectors in manufacturing and construction



Source: National Atmospheric Emissions Inventory (2020) Breakdown of UK GHG emissions by source and greenhouse gas; BEIS (2020) Updated energy and emissions projections: 2019; Element Energy (2020) Deep-decarbonisation pathways for UK Industry, report for the Climate Change Committee; CCC analysis.

b) Resource efficiency, energy efficiency and material substitution

To establish pathways for abatement from resource efficiency, energy efficiency and material substitution, we refreshed our synthesis of evidence on the abatement potential in these areas.

Resource efficiency

Resource efficiency measures are divided into two categories: more efficient use of resources in production and lower end-user consumption of resources. Box 4.1 sets out the evidence we used on resource efficiency and how we constructed our scenarios using this evidence. Table 4.1 summarises the resource efficiency measures included.

Measures that reduce consumption of resources (a third of the resource efficiency abatement) are assumed to result in lower industrial output, as we assume similar measures are applied by trading partners – for example as a result of the EU's work on the Circular Economy. For the purpose of our geographical analysis, where this reduced consumption, combined with baseline change, results in a reduction of a subsector's output, we assume that 80% of this reduction is achieved by site closures, while 20% comes from reduced output of the remaining sites.

Abatement from these resource efficiency measures is applied to the baseline before material substitution and energy efficiency.

Box M4.1:

Summary of latest evidence on resource efficiency and material substitution

Using a study from the University of Leeds and University of Manchester, and engaging with industry stakeholders, we have considered where resource efficiency can reduce UK greenhouse gas emissions. The measures we have considered are summarised in Table 4.1.

From the baseline, first we accounted for significant changes across the economy that would affect demand: the move away from petroleum for transport and other uses leading to big reductions in demand from oil refineries, and changes to the amount of waste arising.

We then included specific resource efficiency measures. The study produced three scenarios for material productivity (low, medium and high), reflecting different levels of ambition in changing production and consumption practices.

- The medium scenario leads to a 6% reduction in UK industrial emissions in 2050 and is implemented for our Headwinds scenario. The high scenario leads to an 13% reduction in UK manufacturing and construction emissions in 2050 and is implemented for our Balanced Net Zero Pathway, Widespread Engagement and Tailwinds.
- In the Widespread Innovation scenario, we anticipate lower consumer engagement on the consumption of resources savings compared to Widespread Engagement, although further potential for improvements in resource use in production may be realised through new innovations. Therefore, the Widespread Innovation scenario uses a medium-high material productivity scenario, slightly lower ambition than Widespread Engagement, resulting in an emissions reduction of 11% in 2050 across the manufacturing and construction sector.
- The Balanced Net Zero Pathway follows the high scenario, which is an ambitious set of measures requiring changes to many people's lifestyles and industrial practices. However, there is evidence that even larger emissions savings are possible, with the Energy Transition Commission estimating that 40% of emissions from heavy industry can be avoided through circular economy strategies.

The study does not include financial savings and costs associated with the measures. We were also not able to find a wider evidence base on savings and costs of resource efficiency measures. Resource efficiency could lead to cost savings. However, these are dependent on structural changes in the economy for which there is little evidence available to date. It is unclear whether these would offset any costs associated with the uptake of resource efficiency measures. We have assumed that the savings balance the costs. We seek to improve our evidence base in this area in future, which would necessitate understanding how savings and costs flow through the economy.

Source: Scott, K., Gieseckam, J., Barrett, J. and Owen, A. (2018) *Bridging the climate mitigation gap with economy-wide material productivity*, Journal of Industrial Ecology, <https://doi.org/10.1111/jiec.1283>, Energy Transitions

Commission (2018) *Mission Possible*, <http://www.energy-transitions.org/mission-possible>

Notes: Scott et. al. scenarios have been adjusted to include CCC analysis on clinker substitution in cement, wood in construction, increase in use of recycled glass, and analysis from the Government's Industrial Decarbonisation and Energy Efficiency Roadmaps to 2050 for yield improvements in steel production.

Table M4.1

Summary of resource efficiency and material substitution strategies

Sector	Measures to reduce resource use in production	Measures to reduce end-user consumption of resources
Clothing and Textiles	<ul style="list-style-type: none"> – Efficiency improvements in fibre and yarn production, dyeing and finishing 	<ul style="list-style-type: none"> – Disposing of less and reusing and recycling more – Using clothes for longer
Food and Drink	<ul style="list-style-type: none"> – Reducing food waste in food services and hospitality sectors 	<ul style="list-style-type: none"> – Reducing household food waste
Packaging	<ul style="list-style-type: none"> – Eliminating or reducing weight of packaging (metal, plastic, paper, glass) – Increasing use of recycled glass 	
Vehicles	<ul style="list-style-type: none"> – Reducing steel, aluminium and additional weight without material or alloy changes – Yield improvement (metals) in car structures through cutting techniques – Steel fabrication yield improvement – Reusing discarded steel products 	<ul style="list-style-type: none"> – Shifting from recycling to refurbishing – Using car clubs – Using cars for longer
Electronics, Appliances, Machinery and Furniture	<ul style="list-style-type: none"> – Reducing steel without material or alloy changes – Steel fabrication yield improvement – Reusing discarded steel products in industrial equipment 	<ul style="list-style-type: none"> – Sharing less-frequently used electrical appliances, power tools and leisure equipment – Longer use of products – Remanufacturing instead of throwing away – Disposing of less and reusing and recycling more
Construction	<ul style="list-style-type: none"> – Design optimisation to reduce material inputs – Increasing use of wood in construction – Increasing clinker substitution in cement – Reusing materials 	

Material substitution

Next, we applied material substitution from high-embodied-carbon to low-embodied-carbon materials. This accounts for a decrease in cement, mortar and brick production and an increase in timber production for increased wood in construction. There is also an increase in substitution of high-carbon clinker for either waste products such as fly ash, or ground granulated blast furnace slag or innovative new types of lower-carbon cementitious materials. In addition, some raw material is replaced with cullet (from recycled glass) in glass production.

Energy efficiency

Our energy efficiency abatement pathways are primarily based on the 'Max Tech' scenarios from the '2015 BIS Industrial Decarbonisation and Energy Efficiency Roadmaps to 2050'⁸, but also assume some additional abatement from sectors not covered by the Roadmaps.

- We have evaluated the abatement costs for all of the measures in the Max Tech pathways and included all of those that are cheaper than 350 £/tCO₂e (consistent with our approach to carbon valuation – see Chapter 1), as well as the majority of measures which are overall cost negative.

- There are likely to be energy efficiency opportunities in the less-energy-intensive sectors, where energy efficiency opportunities may be less salient to decision makers. We assume a 12 TWh overall energy demand reduction across the less-energy-intensive sectors based on BEIS analysis.⁹

The energy efficiency measures covered by the roadmaps are generally cost-saving, so we have applied these measures across scenarios. We have updated the savings and costs from the 2015 roadmaps to reflect our updated energy costs.

c) Deep decarbonisation measures

To establish our pathways for abatement from deep decarbonisation measures we commissioned Element Energy to substantially extend previous analysis produced for the CCC and BEIS and develop pathways for the CCC (Box 4.2). This involved gathering new evidence and using this within a new Net Zero Industrial Pathways (N-ZIP) model. We also undertook new analysis internally on abatement pathways for off-road mobile machinery (Box 4.3).

The Element Energy evidence gathering, N-ZIP modelling and our subsequent pathways and scenarios have several key features. In particular, the results on the pace of deep decarbonisation were carefully considered and account for considerable new evidence.

- The pathway results account for time for supply chains to scale up and new low-carbon technologies to scale up, based on consultation with industry about what is possible if policy is put in place.
- The results allow time for infrastructure to be rolled out, for example for CO₂ and hydrogen networks and consider the interaction of the location of sites with when hydrogen or carbon capture and storage (CCS) options may become cost-effective.
- The results allow time for effective policy to be developed and implemented, before deployment.
- The modelling includes a broad set of technology options, with updated cost data.
- The pace of decarbonisation is established to reflect a level of effort that is consistent with that in other sectors of the economy, Net Zero ambition overall and the UK's commitments under the Paris Agreement. This is partly achieved through placing a value on carbon abatement to drive action (see Chapter 1). Accounting for this value of carbon, the N-ZIP model is used to identify when sites should decarbonise processes in order to maximise the net present value of their overall operations. It simultaneously accounts for the supply chain, infrastructure and policy considerations outlined above. This approach balances the value of action with waiting for a substantially cheaper technology.
- The scenarios account for non-cost factors, such as low salience of energy costs for very small sites and the potential for a preference towards retrofit over refitting.
- Our pathways of abatement from resource efficiency, energy efficiency and material substitution were input into the N-ZIP model as assumptions. This meant that deep decarbonisation measures were considered only for adjusted energy and emissions 'baselines' that account for the efficiency measures. Our analysis of fuel switching in off-road mobile machinery was also passed through the N-ZIP model for completeness.

- In the Balanced Pathway some deep decarbonisation actions are included in the early years to ensure that options for further deployment remain open in later years, reflecting real-life uncertainty about which technologies will prevail. This also helps to bring down costs of technologies.

A few small amendments were applied to the deep decarbonisation abatement measures coming from the manufacturing and construction pathways and scenarios from the Element Energy analysis, resulting in a difference between the results reported in the Element Energy report and our results.

In particular, CCS capture rates were adjusted in the period pre-2040 to 90%, from higher rates. A final version of our off-road mobile machinery analysis was also included at this stage.

Box M4.2

Summary of Element Energy analysis and report on Deep Decarbonisation Pathways for UK Industry

We commissioned Element Energy to improve our evidence base and develop pathways for deep decarbonisation from UK industry emissions – currently 110.6 MtCO₂e in total of which 66.2 MtCO₂e is manufacturing and construction, 39.2 MtCO₂e is fossil fuel supply (see Chapter 6) and 5.1 MtCO₂e is energy from waste (see Chapter 10).

The deep decarbonisation abatement technologies considered for each sector are detailed in the 'options to reduce emissions' section of the relevant chapter of this report (e.g. Chapter 4, section 2 for manufacturing and construction).

The research included four key components (a) advancing our evidence on the constraints on the pace of technology and infrastructure deployment (b) improving our evidence on technology availability, costs and non-cost factors determining technology choice (c) considering geographical resolution within both these aspects (d) combining these evidence bases in a net-zero industry pathways (N-ZIP) model to produce socially-optimal industry decarbonisation pathways.

Given (a) – (c), the N-ZIP model accounted for:

- absolute constraints on pace relating to technology availability, supply chain capacity, CO₂ and hydrogen infrastructure availability, biomass availability and time to develop policy;
- cost model of all relevant decarbonisation options, accounting for the location of a site relative to abatement options (e.g. hydrogen or CO₂ transportation), the levels of hydrogen and CCS use elsewhere in the economy, and the costs of scrappage; and
- salience of energy costs to the smallest energy users and the potential for a preference towards retrofit over refit.

These factors fed into criteria for deciding when and which abatement measure (if any) was socially-optimal to mitigate each emitting-process at each site:

- Net Present Value (NPV) at the site-level was used to make decisions. This considers the difference between the cost and benefits of abatement and the counterfactual. It accounts for the discounting and the value of emissions that are abated.
- The model ranks the available decarbonisation options for each site for each year by their NPV.
- The highest ranked option is initially chosen for each process on each site, providing the NPV is positive. This was then checked against the model constraints. If a model constraint was exceeded, the model switched to the next ranked option. Where multiple options exceed a model constraint, those with the highest NPV were prioritised.

Figure 4.4 sets out a schematic of the N-ZIP model methodology.

Key model assumptions included:

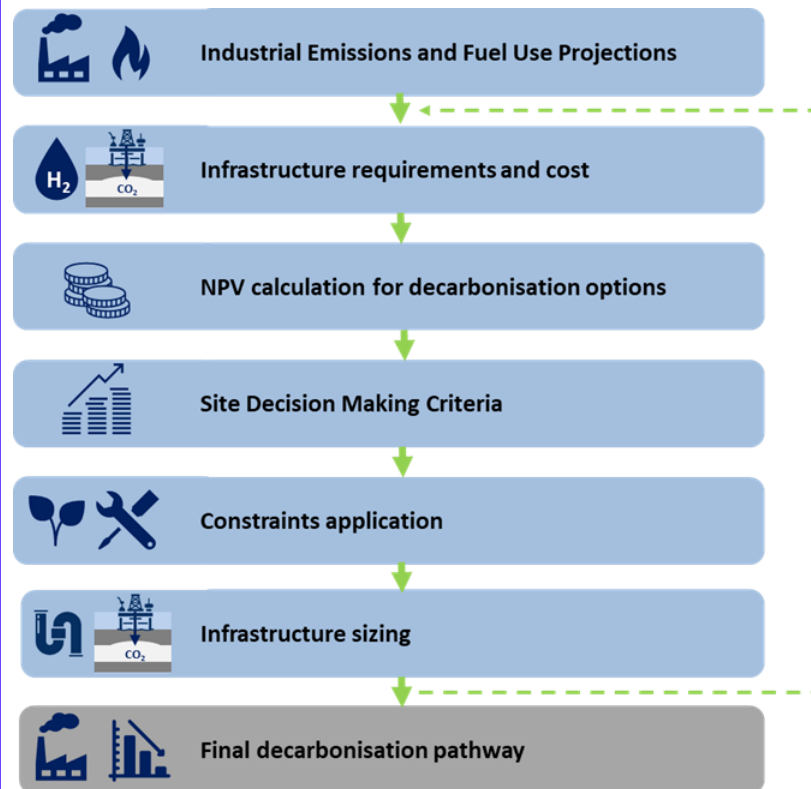
- Long-run variable costs for energy (i.e. excluding profit and policy costs), were used. These costs are consistent with fuel costs in the Sixth Carbon Budget analysis for other CCC sectors (see Chapter 1). Element Energy analysis informed the costs of CO₂ transport and hydrogen infrastructure.
- The capacity of supply chains limits the proportion of a subsector that can decarbonise each year through deep decarbonisation measures. Following a dedicated consultation, under the Balanced Net Zero Pathway the constraint was set at 5%/year of baseline emissions in 2025, and increased annually by 0.5%/year until reaching 10%/year, at which it was fixed from 2035 onwards. This constraint applied independently to other constraints, such as technology availability.
- Target consistent carbon values are as set out in Chapter 1 for the Balanced Net Zero Pathway, Headwinds, Widespread Engagement and Widespread Innovation scenarios. Tailwinds uses a higher carbon value path of £450/tCO₂e in 2050, discounted backwards by 3.5% per year.
- Where hydrogen can be used for fuel-switching, the existing appliance can be retrofitted to used hydrogen. It is assumed that existing appliances cannot be retrofitted to use electricity and that if conversion is applied before the lifetime end of the counterfactual technology, then a cost of scrappage is incurred.
- Biomass is only used in subsectors that are already using significant amounts of biomass and is allocated according to the CCC hierarchy for biomass use (see Chapter 6).
- The type of processes within industrial subsectors do not change in the period to 2050.
- The model used CO₂ capture rate of 95% for CCS in the Balanced Net Zero Pathway, Headwinds, and Widespread Engagement scenarios and a capture rate of 99% in the Widespread Innovation and Tailwinds scenarios. The CCC final results assume capture rates of 90% up until 2040.

Nearly all emissions were allocated at least one suitable abatement technology. Remaining emissions fell into two categories:

- Processes where no abatement was applied. This occurred where the abatement was too expensive or no suitable abatement technology was identified.
- Residual emissions from abatement technologies that do not remove 100% of emissions (e.g. CCS, reductions in flaring, venting and leakage).

Further details can be found in the Element Energy report published alongside this report: 'Deep-decarbonisation pathways for UK Industry'.

Figure MB4.2 Schematic of the N-ZIP model methodology



Source: Element Energy Element Energy (2020) *Deep-decarbonisation pathways for UK Industry, report for the Climate Change Committee*

Source: Element Energy (2020) *Deep-decarbonisation pathways for UK Industry, report for the Climate Change Committee*

Box M4.3:**Summary of new research on decarbonising off-road mobile machinery**

The analysis for off-road mobile machinery (ORMM) decarbonisation was carried out internally by the CCC.

- For electric or hydrogen machinery, we assumed that they are linearly deployed and displace conventional ORMM to reduce emissions.
- The composition of the fleet is based on the 2004 Department of Transport survey. For the purposes of our work, we created categories of ORMM to encompass the wider range of equipment that exists in the sector. These categories considered the power and usage to estimate the contribution to emissions of different types of off-road mobile machinery.
- Thereafter, we were able to cost the low-carbon ORMM in each category. We assume that the costs of electric and fuel cell batteries are the same in ORMM as in transport at £65/kWh and £174/kW in 2050, respectively. In addition, CCC analysis provided us with electricity and hydrogen fuel costs.
- The core of our analysis evaluated hydrogen, electricity and biodiesel as potential abatement options. In each of our scenarios, the option with the lowest NPV was selected to decarbonise each category of off-road. This varied for each category in the different pathways. In the Balanced Net Zero Pathway, deployment by 2050 is mostly hydrogen for large machinery and electricity for small and medium machinery.

Source: Department for Transport (2004) *Non-Road Mobile Machinery, Usage, Life, and Correction Factors*, CCC analysis

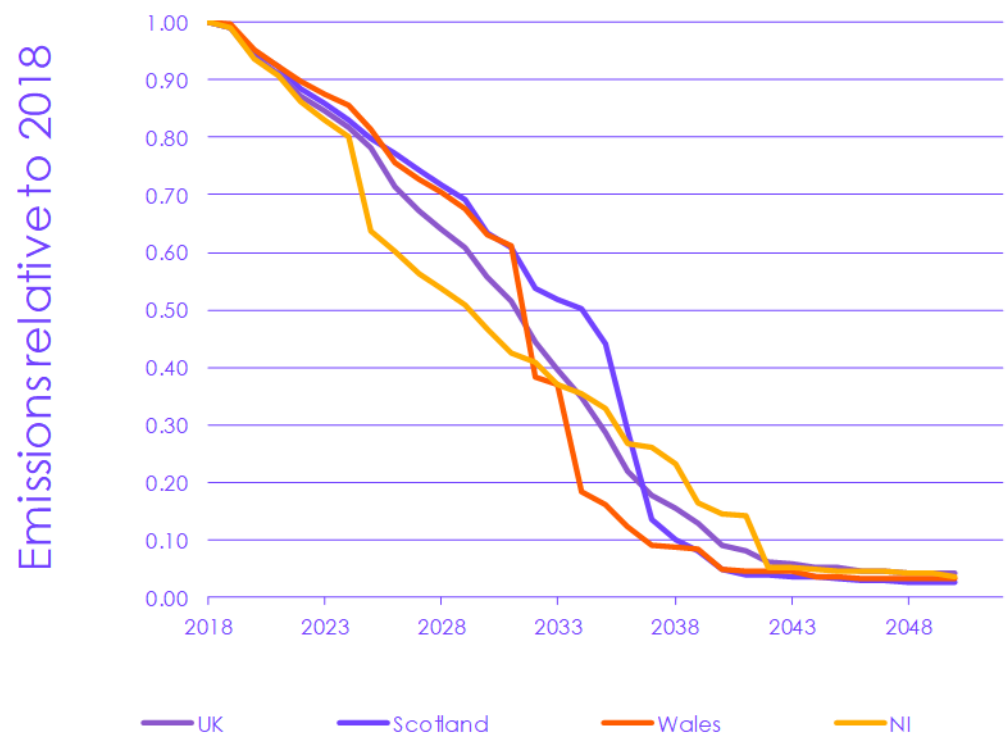
d) Deriving the emissions paths for the devolved administrations

The use of site-level (and for small sites and regionally assigned data) in the N-ZIP model provided emissions, abatement and costs data that could be attributed to the devolved administrations (DA). For off-road mobile machinery, we did not have regionally assigned data, so we assume the historical distribution of emissions across DAs remain the same over time.

We used this data to produce a pathway for each DA for each scenario. The Balanced Net Zero Pathway for manufacturing and construction in the devolved administrations is shown in Figure 4.4.

The steep decline in Welsh emissions in the early 2030s reflects the conversion to low-carbon production of Port Talbot Steelworks.

Figure M4.4 Balanced Net Zero Pathway emissions for manufacturing and construction in devolved administrations



Source: CCC analysis.

e) Uncertainty

We have used the results of our analysis to inform our recommendations around future deployment of industrial decarbonisation measures. However, there is much uncertainty about many of the assumptions that we have used in our analysis.

Therefore, we have considered a range of sensitivities to the assumptions, to form different pathways, with the purpose of identifying a range of different futures and the most – and least – robust conclusions of the analysis.

More detail on the model sensitivities relating to deep decarbonisation measures is given in the accompanying report by Element Energy.¹⁰ Sensitivities we explored included varying the following assumptions:

- **CO₂ and hydrogen demand from other sectors** did not result in significant changes to the amount of abatement or the options chosen.
- **Biomass availability** had a limited effect, but primarily because we constrained the sectors for which biomass could be used. If relaxed, we would expect a higher level of biomass uptake. However, even when using this bioenergy with carbon capture and storage (i.e. BECCS), this would not result in overall lower emissions across the economy, as this would divert biomass from other BECCS applications.
- **Carbon values.** We tested a higher carbon value in the Tailwinds scenario, which increased abatement, and brought forward the dates at which some abatement occurs.
- **Supply chain constraints** had an impact on the pace of roll-out of abatement technologies. As a result, Element Energy conducted additional research with stakeholders to inform this constraint.
- **Electricity network upgrade costs** had an impact on decision making. As a result, higher connection costs were explored in the Headwinds scenario.
- **Fuel costs** influenced the abatement measure where a site had multiple decarbonisation options, but only had a modest effect on the level and pace of abatement as can be seen from our Headwinds scenario.
- **Scrappage** was included in the cost of electrification. When scrappage was not allowed, this constrained the rate of electrification as an abatement option. To explore this, scrappage was not allowed in the Headwinds exploratory scenario.

We have used the results of these sensitivities to identify low-regrets options for the decarbonisation of manufacturing and construction, as well as low-regrets approaches to deploying hydrogen and CO₂ infrastructure. We have used the scenarios to identify important near-term actions required to keep important alternative pathways open.

Analysis on off-road machinery remains uncertain mainly due to the scarcity of data. Indeed, the latest survey on fleet composition dates to 2004. As a result, it is unclear how the fleet has and might continue to evolve in the future. In addition, decarbonising ORMM with hydrogen will require the development of a hydrogen infrastructure. Without hydrogen, reducing emissions would be possible, however access to electricity on construction and mining sites would need to improve.

Endnotes

- ¹ CCC (2020) *The Sixth Carbon Budget – Methodology Report*. Available at: www.theccc.org.uk
- ² Committee on Climate Change (2018) *Biomass in a low-carbon economy*.
<https://www.theccc.org.uk/publication/biomass-in-a-low-carbon-economy/>
- ³ CCC (2019) *Net Zero – The UK'S contribution to stopping global warming*
- ⁴ CCC (2019) *Net Zero – Technical Report*
- ⁵ National Atmospheric Emissions Inventory (2020) *Breakdown of UK GHG emissions by source and greenhouse gas*
- ⁶ BEIS (2019) *Digest of UK Energy Statistics*
- ⁷ BEIS (2020) *Updated energy and emissions projections: 2019*.
<https://www.gov.uk/government/publications/updated-energy-and-emissions-projections-2019>
- ⁸ DECC & BIS (2015) *Industrial Decarbonisation and Energy Efficiency Roadmaps to 2050*.
<https://www.gov.uk/government/publications/industrial-decarbonisation-and-energy-efficiency-roadmaps-to-2050>
- ⁹ BEIS (2019) *Leading on clean growth: government response to the Committee on Climate Change 2019 progress report to Parliament – Reducing UK emissions*
- ¹⁰ Element Energy (2020) *Deep-decarbonisation pathways for UK Industry, report for the Climate Change Committee*

Chapter 2

Emissions pathways for the Manufacturing and construction sector

3. Manufacturing and construction

Introduction and key messages

Our Balanced Net Zero Pathway involves manufacturing and construction (M&C) emissions cuts of 90% by 2040.

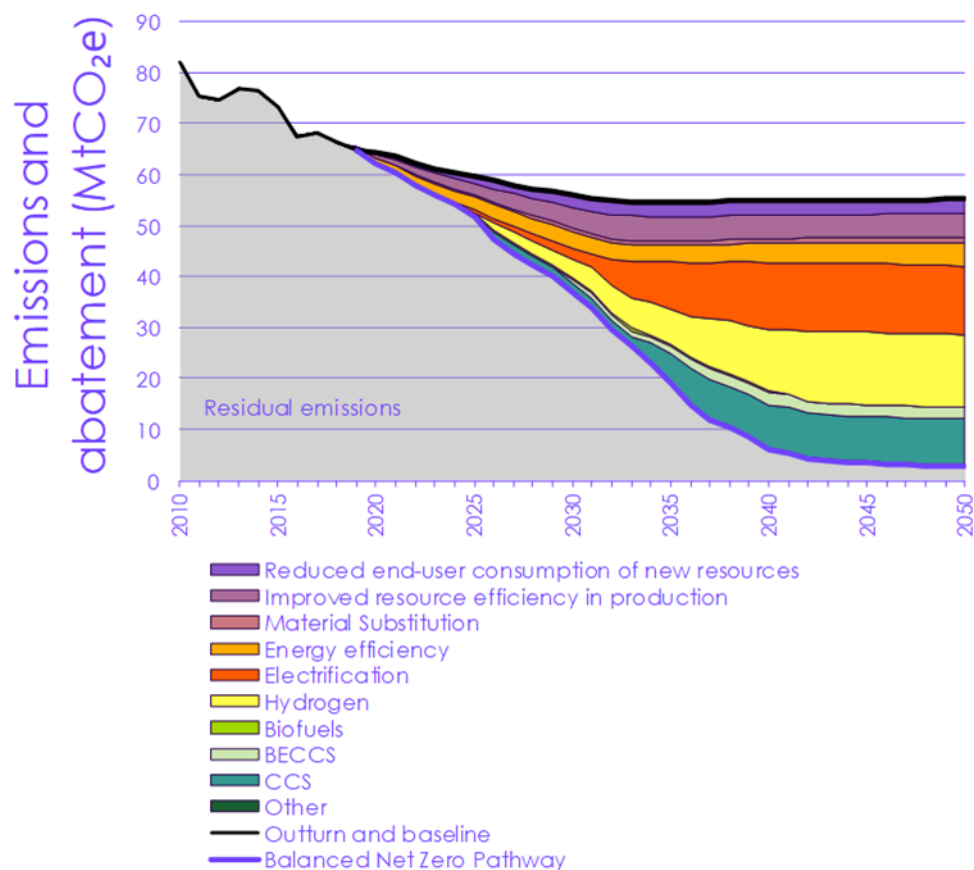
Our Balanced Net Zero Pathway sees manufacturing and construction emissions reduced by 70% by 2035 and 90% by 2040 from 2018 levels, based on fuel-switching, CCS and improvements to resource and energy efficiency (Figure 3.3.a).

This pathway has faster reductions than the pathway underpinning our 2015 Fifth Carbon Budget advice. This reflects substantially improved knowledge of deep decarbonisation and resource efficiency options (see Methodology Report) and the shift to an economy-wide Net Zero target.

The pathway requires policy to drive emissions reductions in a way that does not drive manufacturers overseas.

The pathway assumes that the Government establishes a policy framework to support UK manufacturing to reduce emissions in a way that does not drive manufacturers overseas and that benefits jobs and investment in UK manufacturing (see Chapter 4 in the accompanying Policy Report and Chapter 6 in this report for more on competitiveness and jobs).

Figure A3.3.a Sources of abatement in the Balanced Net Zero Pathway for the manufacturing and construction sector



This section is split into three sub-sections:

- a) The Balanced Pathway for manufacturing and construction
- b) Alternative routes to delivering abatement in the mid-2030s
- c) Impacts of the scenarios: costs, benefits and co-impacts on society

a) The Balanced Net Zero Pathway for manufacturing and construction

During the 2020s the Balanced Pathway has increasing implementation of new technologies, policy, resource efficient approaches, and development of infrastructure and supply chains.

The pace of decarbonisation in the Balanced Pathway for manufacturing and construction gradually accelerates through the 2020s to mid-2030s with the increasing implementation of new technologies, policy, resource efficient approaches, and development of infrastructure and supply chains. Most decarbonisation of the sector is complete by 2040. Figure 3.3.a presents an overview of the emissions reduction actions and timing of the Balanced Pathway actions.

- Improvements in resource and energy efficiency lead to the largest emissions reductions in the early 2020s, with smaller contributions from electrification, biofuel use and material substitution. Fuel-switching and CCS deployment scale up from 2025.
- Infrastructures for CCS and hydrogen are deployed from 2025 in the pathway, starting near industrial clusters. Electricity network connection capacity is also increased around newly electrifying sites. The 2030s sees substantial scale-up across these three major networks.
- Policy develops rapidly to ensure that it pays for companies to implement societally cost-effective measures and that non-financial barriers are addressed. See the accompanying Policy Report for policy recommendations.
- Supply chains scale up at pace in the pathway. More workers acquire skills to implement low-carbon measures, the supply of necessary technologies and equipment grows, and the availability of finance increases.

Recycling, reusing and sharing products, increasing product longevity and reducing material use through better design, all play a role in reducing M&C emissions in the Balanced Pathway.

Improvements in resource and energy efficiency and material substitution in the Balanced Pathway reduce emissions by 12 MtCO₂e per year by 2035, contributing 8 MtCO₂e, 3 MtCO₂e and 1 MtCO₂e respectively:

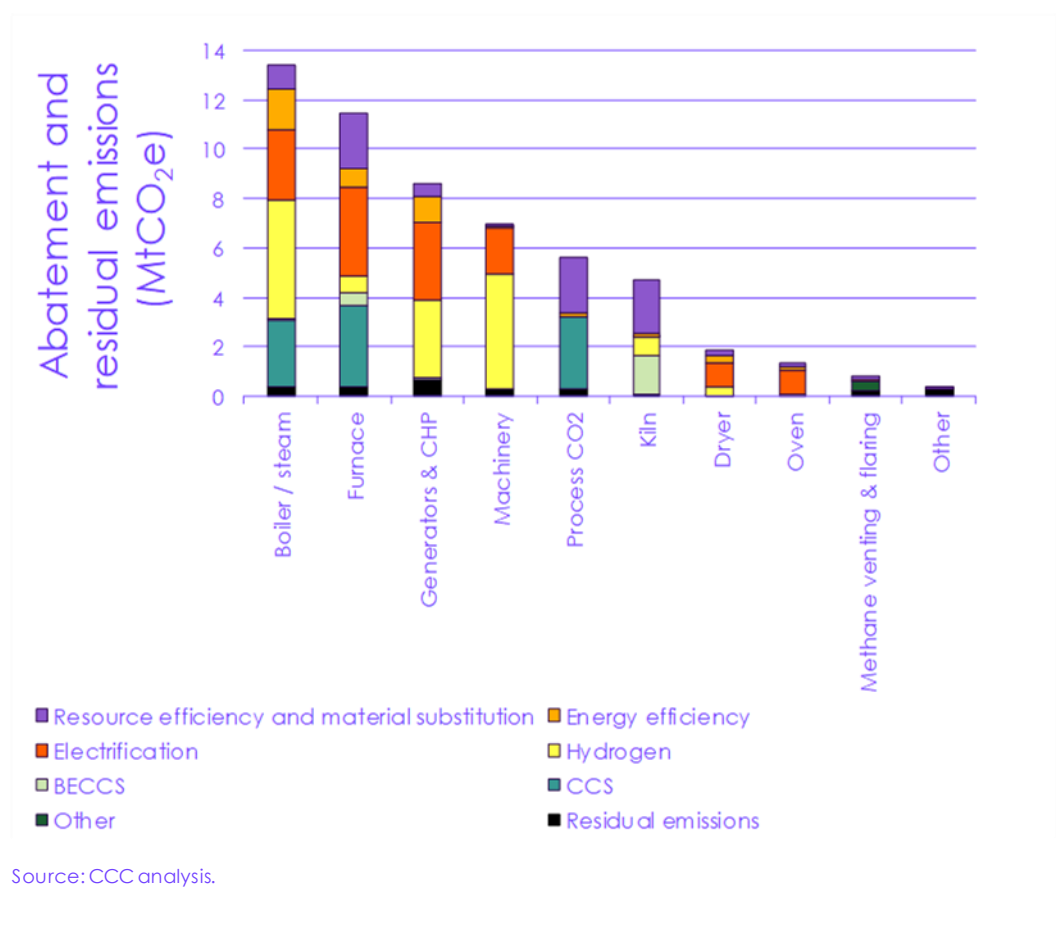
- **Resource efficiency** abatement gradually increases from 2020 to 2035.
 - Improvements that **reduce end-user consumption of new resources** cut emissions by 3 MtCO₂e per year in 2035 (Figure 3.3.a). This includes measures such as consumers using clothes and electronics products for longer, which may require improved durability.
 - Measures that **improve resource efficiency in production** reduce emissions by 5 MtCO₂e per year in 2035. This includes measures such as optimising building design to reduce material use.

Improvements in resource and energy efficiency lead to the largest emissions reductions in the early 2020s.

- The resource efficiency measures can alternatively be split into the following groups: design optimisation to reduce material inputs (3 MtCO₂e per year in 2035), increased recycling and reuse (3 MtCO₂e, of which half is through reuse of construction materials), increasing product longevity (2 MtCO₂e, largely from electronics), and increased product utilisation and sharing (1 MtCO₂e, including sharing leisure equipment and car clubs).

- **Energy efficiency** improvements achieve emissions reductions of 4 MtCO₂e per year by 2050. Measures in the most energy-intensive sectors are divided between heat recovery (0.5 MtCO₂e), process upgrade (1 MtCO₂e), equipment upgrade (1 MtCO₂e) and integration/clustering (0.5 MtCO₂e), with a further 1 MtCO₂e in less energy intense sectors.
- **Material substitution** measures in the pathway include partial substitution of clinker in cement and the use of wood in construction, and increase steadily over the period to 2050.

Figure A3.3.b Manufacturing and construction abatement and residual emissions in 2050 in Balanced Net Zero Pathway against counterfactual processes



Switching from fossil fuels to low-carbon fuels contributes the largest emissions reductions in the Balanced Pathway from the early 2030s.

Fuel-switching reduces sector emissions in the Balanced Pathway in 2035 by 18 MtCO₂e per year, increasing to 30 MtCO₂e in 2045 (Figure 3.3.a). In the 2020s, a mix of fuel-switching technologies are deployed to keep options open for subsequent deployment, given uncertainty about which fuel-switching options will prevail in the 2030s. In the 2030s options are deployed where they are cost-effective under

our cost assumptions - this results in a mix of electrification, hydrogen and bioenergy deployment, reflecting variation in cost-effectiveness between different applications and locations.

With falling electricity costs, the Balanced Pathway has an important role for electrification.

- **Electrification** reduces emissions by 9 MtCO₂e per year by 2035, increasing to 14 MtCO₂e by 2045. Electrification measures include electric boilers, switching from on-site generation to a grid connection, electric arc furnaces, electric mobile machinery, electric dryers and electric infra-red heaters (Figure 3.3.b).

Some electrification options are introduced in the early 2020s due to high levels of technology and commercial readiness. Some electrification measures involve scrapping existing assets before the end of their expected lifespan. This reflects preferable economics over the alternatives and the inability to retrofit some electrification options.

Hydrogen used in boilers, CHP, generators, mobile machinery, furnaces and kilns reduces M&C emissions by 7 MtCO₂e per year by 2035.

- **Hydrogen** use reduces emissions by 7 MtCO₂e per year by 2035, increasing to 14 MtCO₂e by 2045. Hydrogen measures include hydrogen boilers, CHP, generators, mobile machinery and kilns. Our latest evidence suggests that these measures can typically be retrofitted, limiting the need to wait for a replacement cycle or to scrap assets before fitting.
- **Bioenergy** use reduces fossil emissions by 2 MtCO₂e per year by 2035 increasing to 2.5 MtCO₂e in 2045. Its use is prioritised for sectors already using bioenergy, such as cement and pulp, or with the potential to fit CCS. CCS is applied to all new bioenergy use in manufacturing and construction⁴, apart from biofuel use in mobile machinery. In 2035, biofuels contribute 0.5 MtCO₂e per year of abatement, falling to zero by 2040. The application of CCS to bioenergy results in further abatement of 3 MtCO₂e in 2045 – this fraction of the BECCS is not accounted for in our manufacturing results, but rather in greenhouse gas removals (see section 11).

CCS reduces emissions where it is the only deep decarbonisation option available. It is also applied to fertiliser plants in the mid-2020s.

CCS reduces manufacturing emissions in the Balanced Net Zero Pathway by 6 MtCO₂e per year in 2035, increasing to 9 MtCO₂e by 2045 (Figure 3.3.a). In the pathway, CCS is applied to fertiliser plants, half of the UK's integrated steelwork capacity, and processes where it is the only deep decarbonisation option available.

- There is 5 MtCO₂e per year of abatement in 2045 from processes where we have not identified alternative options to reduce emissions to near-zero. This includes processes that a) produce CO₂ from non-combustion processes, such as cement production and b) combust fuels (sometimes called internal fuels or off-gases) that are produced as part of the industrial process.
- CCS is also applied as a lower-cost measure to existing ammonia/fertiliser plants in the mid-2020s and half of the UK's integrated steelwork capacity in the early 2030s. This contributes 4 MtCO₂e per year of abatement in 2045.
- Smaller scale, more expensive CCS is deployed in the late 2030s and 2040s.

The Balanced Pathway has substantial action focussed in industrial clusters. However, decarbonisation of dispersed sites is still considerable.

The geographical distribution of fuel-switching and CCS measures is focussed around industrial clusters. However, there is still substantial abatement outside of the clusters (Figure 3.3.c).

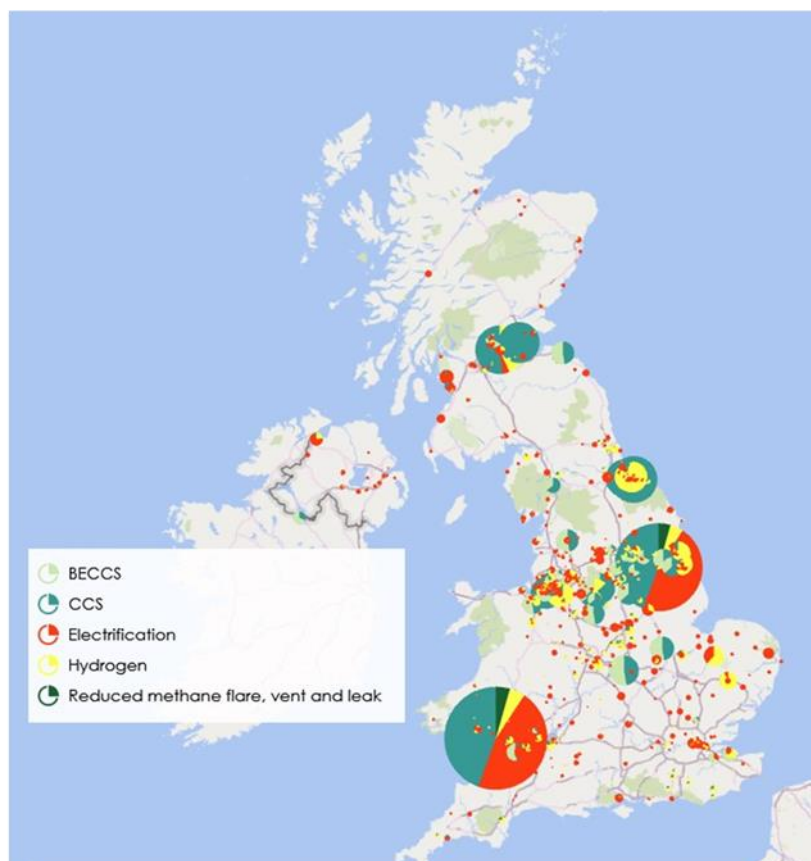
- The location of sites may affect the choice of deep decarbonisation option when multiple options are possible – our evidence suggests that

⁴ We have not accounted for the small amount of bioenergy that we expect may be introduced prior to the fitting of CCS.

electrification has an advantage over hydrogen at dispersed sites, due to differences in electricity and hydrogen distribution options and availability.

- Pipeline, train, truck or shipping are considered as options to transport CO₂ from dispersed sites where CCS is their only deep decarbonisation option, such as cement, lime and other mineral sites.

Figure A3.3.c Map of deep decarbonisation measures in the manufacturing and construction sectors in the Balanced Net Zero Pathway in 2050



Source: CCC analysis.

Notes: The individual pies represent emissions within a certain geographical radius and may include more than one site. Map excludes small sites where geographical data was not available, which includes all industrial off-road mobile machinery, together these constitute 42% of manufacturing and construction deep decarbonisation abatement. Map does not include abatement of emissions from electricity generation, fuel supply or waste. It does not include abatement from resource efficiency or energy efficiency measures.

Sectors with fewer sites, such as iron and steel, can see fast decarbonisation once started.

The different subsectors of industry have different mixes of abatement measures and slightly different paces of decarbonisation (Figure 3.3.d), reflecting their different technology options, geographical distribution, underpinning infrastructure requirements and opportunities for energy and resource efficiency.

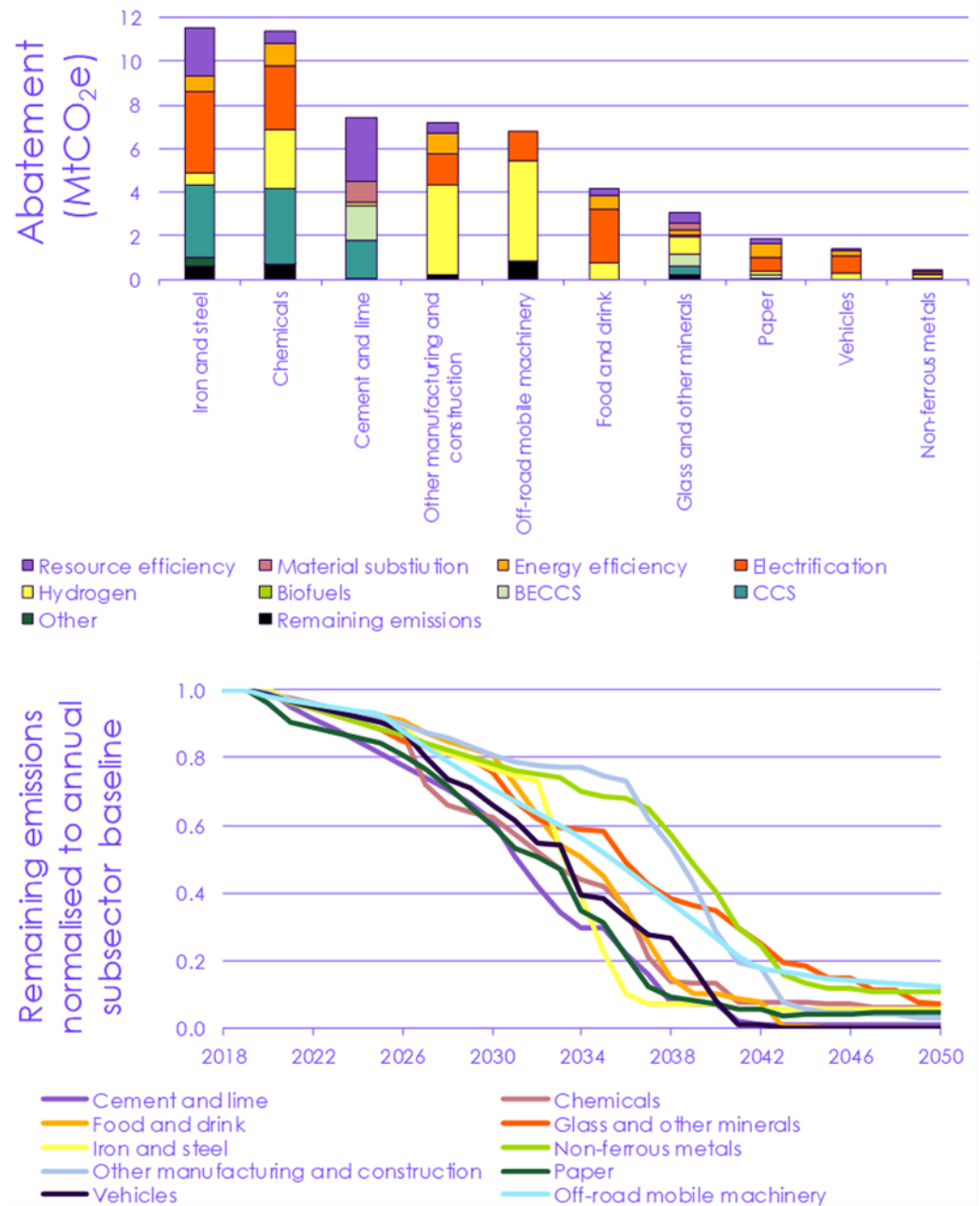
- Resource efficiency measures have the most substantial impact on the cement & lime and iron & steel sectors, particularly as a result of measures in the construction, vehicles and fabricated metal sectors. The paper sector has the highest fraction⁵ of abatement from energy efficiency (38% in 2050), with a substantial saving from clustering and using waste heat from other sites. The largest absolute abatement from energy efficiency is in the

⁵ Compared to other sectors.

chemicals sector (1 MtCO₂e in 2050), driven largely by equipment upgrades.

- Sectors with larger numbers of sites, smaller sites and more dispersed sites decarbonise slower, such as food and drink, other manufacturing and construction and off-road mobile machinery (which doesn't have fixed sites). Sectors with fewer sites, such as iron and steel, can see faster decarbonisation once started.

Figure A3.3.d Abatement and remaining emissions for manufacturing and construction subsectors in 2050

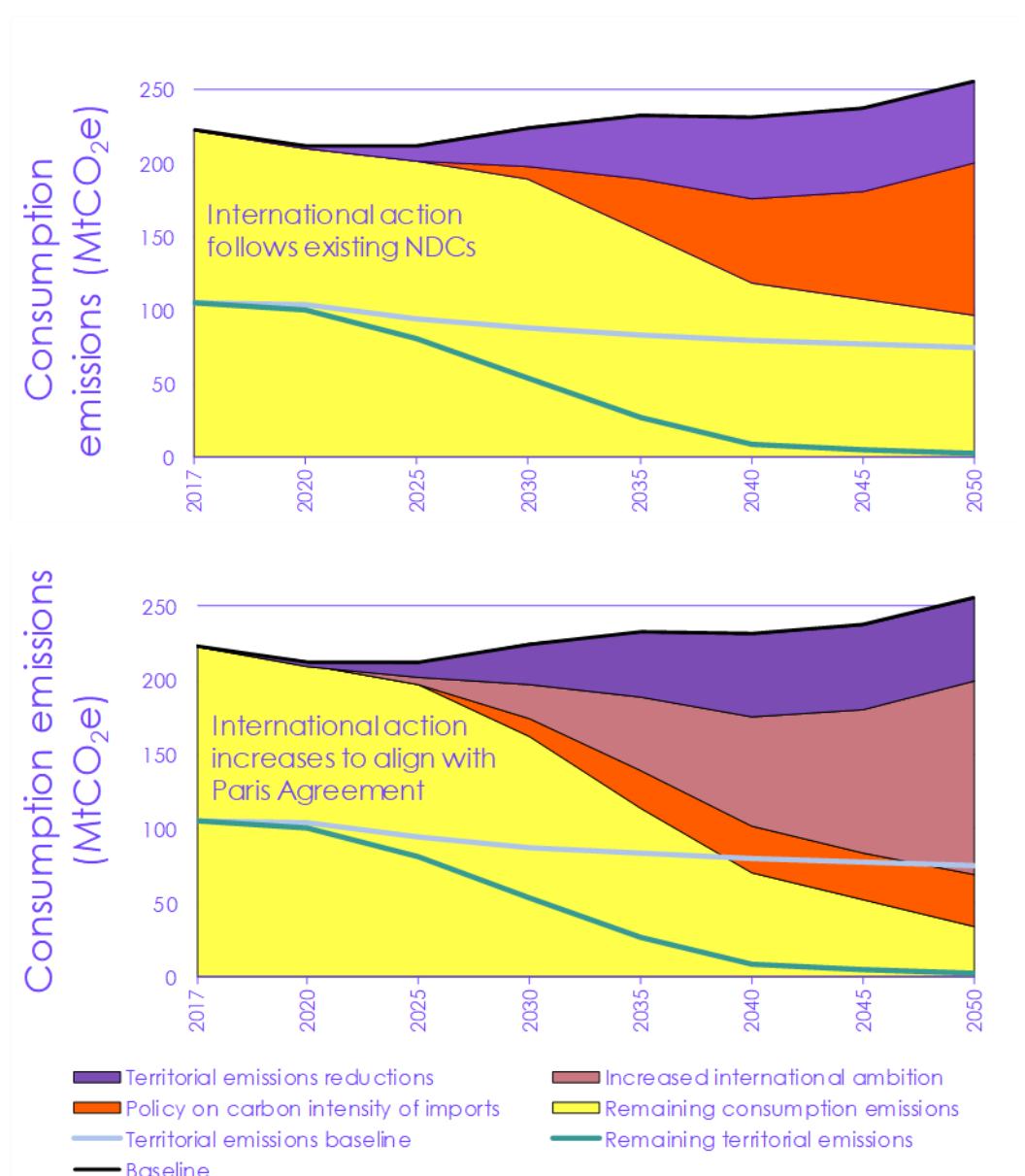


Source: CCC analysis.

Consumption emissions also decline in our Balanced Pathway, with a role for policy on the carbon intensity of imports.

Consumption emissions also decline on our Balanced Net Zero Pathway, reflecting domestic decarbonisation actions, reductions in consumption that reduce imports, and policy on the carbon intensity of imports (see accompanying Policy Report) and international decarbonisation action. Exploratory analysis of the effect of these actions on consumption emissions is set out Figure 3.3.e.

Figure A3.3.e Indicative consumption emissions for the combined manufacturing and construction and fuel supply sectors and effect of import policy under the Balanced Net Zero Pathway for two scenarios of international action



Source: CCC analysis.

Notes: Calculations are indicative. The consumption emissions baseline assumes simple % growth in consumption of different sectors combined with NDC level action internationally. The territorial emissions baseline uses a different methodology based on Government emissions projections (see Methodology Report). Import policy is assumed to gradually improve the carbon intensity of imports to manufacturing, construction and fuel supply is a production basis.

b) Alternative routes to delivering abatement in the mid-2030s

Our four exploratory pathways see different levels of electrification and hydrogen use. This reflects uncertainty about the relative competitiveness of the options in the future.

Our four exploratory scenarios vary by pace (Figure 3.3.f), the measures they contain, such as resource efficiency, fuel-switching, and CCS (Table 3.3.a) and assumptions (see Methodology Report).

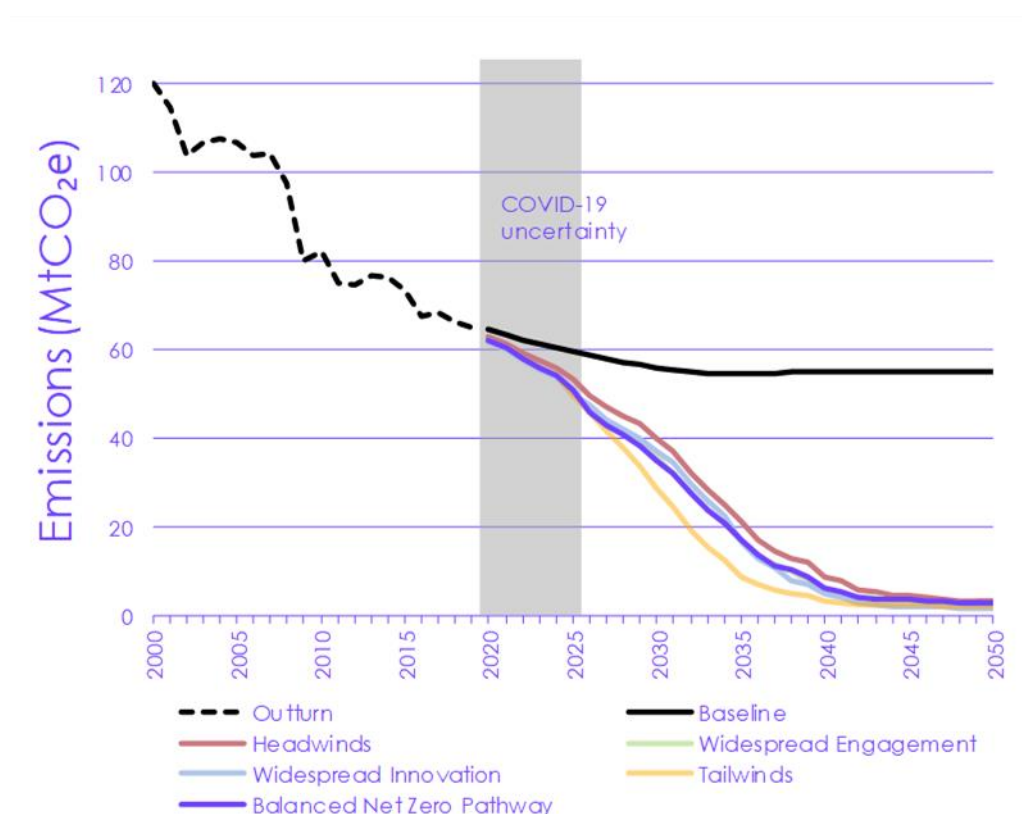
The main divergences in pace are in the Headwinds and Tailwinds scenarios (Figure 3.3.f). In Headwinds, pace is slower because technology and fuel costs are higher, there is less resource efficiency and companies are less willing to electrify because it involves a full equipment refit and possibly scrapping assets. In Tailwinds the combination of lower technology costs, more Government support, businesses acting beyond incentives and faster development of supply chains increase pace.

The most substantial variation in outcome between the scenarios is in the fuel-switching options. This reflects the uncertainty around whether, where and when electrification, blue hydrogen or green hydrogen will be most competitive, although all scenarios have a mix of electrification and hydrogen.

Low-regret options include CCUS on process emissions and energy efficiency.

Outcomes that vary less include energy efficiency and CCUS on process emissions. Both are low-regret actions. The former is low-cost and for the latter there is no alternative option.

Figure A3.3.f Emissions pathways for the manufacturing and construction sector



Source: BEIS (2020) Provisional UK greenhouse gas emissions national statistics 2019; CCC analysis.

Table A3.3.a

Summary of key differences in the manufacturing and construction sector scenarios

	Balanced Net Zero Pathway	Headwinds	Widespread Engagement	Widespread Innovation	Tailwinds
Resource efficiency	High level driven by mix of behaviour and innovation	Moderate levels	High level driven by consumer and business engagement	Moderate-high level driven by innovative techniques and business models	High level driven by behaviour and innovation
Fuel-switching and CCS	Balance of electrification and (mostly) blue hydrogen	More blue hydrogen than electrification. Wider use of CCS on combustion emissions	Mostly electrification, some green and blue hydrogen.	Electrification and green hydrogen. Higher CCS capture rates.	Electrification and green hydrogen. Higher CCS capture rates.
Business attitude	Most businesses follow incentives.	Business resistant to change, prefer to retrofit despite of incentives.	Most businesses follow incentives. Faster supply chain development.	Most businesses follow incentives.	Businesses follow incentives and go beyond. Faster supply chain development.

c) Costs and benefits of the Balanced Net Zero Pathway

The average cost of abatement in the M&C Balanced Pathway is £75/tCO₂e.

The Balanced Net Zero Pathway will incur additional financial costs in the manufacturing and construction sector, as well as some savings from resource and energy efficiency improvements. With well-designed policy, it can drive investment and support jobs in the manufacturing and construction sectors (see chapter 5).

We estimate the annualised cost⁶ of the Balanced Net Zero Pathway for manufacturing and construction to be around £1 billion/year in 2030, £2 billion/year in 2035 and reaching £4 billion/year through the 2040s. In 2040 this represents an average cost of abatement across all measures of around £75/tCO₂e.

Fuel switching and CCS in the Balanced Pathway increase M&C capital and operating costs by £3 billion/year in the early 2030s.

- Additional capital costs are around £1 billion/year in the late 2020s increasing to £2 billion/year in the early 2030s and peak at around £3 billion/year in the late 2030s, before falling to around £2 billion/year in the 2040s.
- Additional operational costs from fuel-switching and CCS are around £0.5 billion/year in late 2020s, increasing to £1 billion/ year in the early 2030s, £2.5 billion in the late 2030s and reaching £3 billion/year in the 2040s. These may be partially offset by savings of up to £1 billion/ year from the late 2020s from energy efficiency.

We estimate that the cost to the exchequer of enabling the deep decarbonisation measures - fuel switching and CCS - in the Balanced Net Zero Pathway, in a way that protects trade-exposed subsectors, would be around £2 billion/year in 2030. This cost could reduce over time as policy is applied to imports and industry are subsequently able to pass through costs to consumers. There may also be a further cost to remove legacy levy control framework costs from industry power bills, which is not accounted for in these estimates.

⁶ Where capital costs are spread over the lifetime of the investment.

Endnote

^{xi} CCC (2020) *The Sixth Carbon Budget – Advice Report*. Available at: www.theccc.org.uk

Chapter 3

Policy recommendations for the Manufacturing and construction sector

The following sections are taken directly from Chapter 4 of the CCC's Policy report for the Sixth Carbon Budget.¹²

Table P4.1

Summary of policy recommendations for manufacturing and construction

Setting vision and ambition	<p>Set out a comprehensive, ambitious vision for decarbonisation of manufacturing and construction.</p> <ul style="list-style-type: none"> • The Government's Industrial Decarbonisation Strategy should provide a clear vision of the long-term policy mechanisms for industrial decarbonisation, including how policy will maintain the competitiveness of UK manufacturing on the path to Net Zero. • To indicate ambition, Government should set targets for ore-based steelmaking and cement production in the UK to reach near-zero emissions by 2035 and 2040, respectively. This is crucial to build momentum following the step-change in ambition necessitated by Net Zero. • Decarbonisation of off-road mobile machinery should not be omitted from the Government's set of plans and strategies.
Maintaining competitiveness	<p>The design of policies to reduce UK manufacturing emissions must ensure that it does not damage UK manufacturers' competitiveness and drive manufacturing overseas.</p> <ul style="list-style-type: none"> • In the near term, taxpayer funding should be used to support deep decarbonisation in manufacturing sectors at risk of carbon leakage. • Work should begin immediately to develop the longer-term options of applying either border carbon tariffs or minimum standards to imports of selected emissions-intense products. This should include developing carbon intensity measurement standards, mandating these are disclosed and fostering international consensus around trade policies through the G7 and COP presidencies.
Funding for fuel switching and CCS	<ul style="list-style-type: none"> • Establish funding mechanism(s) to support operational and capital costs of both electrification and hydrogen-use in manufacturing, to be awarded from 2022. • Finalise the Contract for Difference mechanism to support industrial CCS. • Continue to support innovation and demonstration of fuel switching and CCS technologies.
Resource and energy efficiency	<ul style="list-style-type: none"> • Extend consumer product standards to cover how a product is made. • Work towards introducing a mandatory minimum whole-life carbon standard for both buildings and infrastructure.
Strengthening market mechanisms	<ul style="list-style-type: none"> • Create a clear incentive for non-traded manufacturing sectors to switch to lower-carbon energy sources by reforming energy and carbon pricing. • Strengthen carbon prices and taxes on manufacturers. • Reform electricity pricing to reflect the much lower costs of supplying low-carbon electricity in the mid-2020s and beyond. • Address manufacturers' low appetite for risk, either through loans or grants.
Infrastructure development	<ul style="list-style-type: none"> • Establish at least two CCS clusters in the mid-2020s, at least four by the late 2020s, and further clusters around 2030. • Work with the minerals industries to develop a detailed joint plan for CO₂ transport from dispersed sites. • Prepare to make decisions about whether initial areas of the gas transmission and distribution networks should be converted to hydrogen. • Plan for a potential increase in large localised network reinforcements for manufacturers.
Jobs and skills	<ul style="list-style-type: none"> • Design industrial decarbonisation policies to support and create jobs, especially in regions with reliance on industrial jobs. Prompt award of existing funding can help the recovery. • Develop the capacity of skills and supply chains.

The adoption of the Net Zero target means a step-change in ambition for decarbonisation of UK manufacturing. Improvements in the evidence base also support going considerably further than the pathway in our Fifth Carbon Budget advice from 2015.

In order to drive the necessary changes in manufacturing and construction set out in Chapter 3 of our *Advice report*, it will be necessary to move from the current piecemeal set of policies, to a framework that drives ambitious decarbonisation across the sector, without undermining the competitiveness of UK industries (see Chapter 6 of the *Advice report*). Table 4.1 sets out a summary of our key recommendations for how to enable this transition.

Alongside this report we have published three pieces of supporting work on policies for industrial decarbonisation.^{13, 14, 15}

In this chapter we set out:

1. The existing set of manufacturing and construction decarbonisation policies;
2. What policy is required to deliver our Balanced Pathway, in particular from the Industrial Decarbonisation Strategy.

1. Existing manufacturing & construction decarbonisation policy

There are several policies in place to support decarbonisation of manufacturing and construction. These can be broadly grouped into (a) capital funding, (b) ongoing decarbonisation incentives, (c) energy and resource efficiency policies, and (d) strategy development. However, the level of ambition is insufficient, the policies are frequently piecemeal, and recent progress on several existing policies has been slow.

Existing capital funding for manufacturing decarbonisation is worth around £800m.

a) Capital funding

The past three years have seen the launch of several capital funding schemes for innovation and deployment of established decarbonisation measures in the manufacturing and construction sector. Their total value is around £800m (Table 4.2), and around £35m has so far been awarded through these schemes. The Budget also suggested that the Energy Innovation Programme will support the development of near-zero GHG emission off-road mobile machinery.

In addition, there has been wider funding for carbon capture and storage (CCS), including a commitment to provide £1bn (increased from £800m previously) for CO₂ transport and storage infrastructure in the recent 10 Point Plan.¹⁶ A further £20m was spent on carbon capture, use and storage (CCUS) innovation through the Energy Innovation Fund.

The Clean Heat Grant will also provide upfront support for the use of heat pumps at up to 45kW capacity, which is applicable to some space heating of manufacturers' buildings, a small fraction of overall manufacturing emissions.¹⁷

Table P4.2
Summary of capital funds for manufacturing decarbonisation

	Scope	Public funding	Awarded to date	Spending timeline
Industrial Energy Transformation Fund	Manufacturing decarbonisation	£315m	£0m	Announced 2018. To be spent by firms by 2024.
Clean Steel Fund	Steel decarbonisation	£250m	£0m	Announced August 2019. To be spent by Government from 2024.
Industrial Decarbonisation Challenge	CCS and fuel switching sites within clusters	£170m	£10m	Announced 2018. To be spent by firms by 2024.
Transforming Foundation Industries Challenge	Energy and resource efficiency	£66m	£5m	Announced 2018. To be spent by firms by 2024.
Industrial Fuel Switching (Energy Innovation Fund)	Fuel switching pilots	£20m	£20m	Announced 2018. Awarded.
Green Distilleries Fund¹⁸	Fuel switching in distilleries	£10m	£0m	Announced 2020. To be spent by firms by 2023.
Off-road mobile machinery (Energy Innovation Fund)	Machinery previously using red diesel	Unknown	£0m	Unknown, suggested in 2020 Budget.

Government plans to bring forward a Contract for Difference to support the operational costs of industrial CCS.

b) Ongoing decarbonisation incentives

There are several policies that provide or propose insufficient or piecemeal ongoing incentives for deep decarbonisation in the manufacturing sector:

- The EU ETS and its successor from January 2021 (either an UK ETS or emissions tax)⁷ provides some ongoing incentive, although the carbon price has been too low to incentivise most deep decarbonisation measures. Free allowances are allocated to companies deemed to be at risk of carbon leakage.
- BEIS have committed to bring forward details of an industrial CCS Contract for Difference (CfD) in 2021 which would support the operational costs of manufacturing and refining CCUS.^{19,20}
- The 2020 Budget's removal of red diesel tax relief for industrial off-road mobile machinery from 2022 will help to encourage deployment of low-carbon off-road mobile machinery.²¹
- The Non-Domestic Renewable Heat Incentive has provided some limited support for the use of low-carbon heat in manufacturing. This will close in March 2022.

c) Energy and resource efficiency policies

In addition to the proposed capital funding from the Industrial Energy Transformation Fund and Transforming Foundation Industries Fund (Table 4.2), there are several policies that help to improve energy and resource efficiency.

- The Climate Change Levy and Climate Change Agreements (CCA) provide an incentive for energy efficiency. The 2020 Budget confirmed plans for CCAs to run until March 2025.
- Other policies to improve energy efficiency include Streamlined Energy and Carbon Reporting, Ecodesign and Energy Information (labelling) regulations, Energy Savings Opportunities Scheme, Industrial Heat Recovery Scheme as well as Buildings Regulations.
- The 2019-21 Environment Bill includes provisions to deliver the 2018 Resources and Waste Strategy.²² It includes powers to extend producer responsibilities, to incentivise producers to prevent products or materials from becoming waste and promote reuse and recycling of products or materials. It also provides powers for Government to set product standards and extend the charge on single-use plastics beyond carrier bags. It builds on the Circular Economy Package which transposed several EU regulations focused on reducing waste and improving recycling into UK law.

The Environment Bill is creating new powers for Government to improve resource efficiency.

d) Strategy development

The Government is planning to publish an Industrial Decarbonisation Strategy in spring 2021, which will set out its vision for "a prosperous, low carbon UK industrial sector" in 2050, that can "support industrial competitiveness and the green recovery" and identify "opportunities for new markets and sectors to develop". The strategy's sectoral scope includes manufacturing and refining, but not off-road mobile machinery.

The Government plans to set out its vision for a low-carbon UK industrial sector in spring 2021 in its Industrial Decarbonisation Strategy.

⁷ Yet to be announced at the time of writing

2. What is needed from the Industrial Decarbonisation Strategy

The Industrial Decarbonisation Strategy and wider Government policy should be comprehensive, provide a clear vision and be integrated with wider policy.

Substantial gaps and weaknesses remain in the Government's set of policies for decarbonisation of manufacturing and construction. We have identified gaps, weaknesses, or areas for continued focus in the following areas:

- a) **An overarching strategy.** Current policy on decarbonising manufacturing is piecemeal and needs an overarching strategy.
- b) **Supporting green jobs and the recovery.** Government should support and create jobs through its industrial decarbonisation policies.
- c) **A plan for competitiveness consistent with Net Zero.** Free allowance allocation may not be the most efficient way to achieve the combined goals of deep decarbonisation and avoiding carbon leakage, in future.
- d) **Carbon and electricity pricing for decarbonisation.** Existing carbon pricing is too weak and not applied to non-traded manufacturers, and electricity prices do not reflect costs appropriately.
- e) **Addressing manufacturers' appetite for risk.** UK manufacturers typically require investments to pay back within at least a few years.
- f) **Funding mechanisms for deep decarbonisation.** Policy lacks support for electrification and is too limited to upfront rather than ongoing costs.
- g) **Support for innovation and demonstration.** A range of key technologies still require development.
- h) **Policy to improve resource efficiency, energy efficiency and material substitution.** There are gaps in policy to support more resource efficient products and construction.
- i) **Off-road mobile machinery.** This area appears to have fallen through the gaps between Government Departments and planned strategies.
- j) **Infrastructure development.** Electricity, hydrogen and CO₂ networks will all require development or upgrade.
- k) **Target dates.** Current ambition on manufacturing decarbonisation is insufficient.
- l) **Skills.** The capacity of skills and supply chain needs to be encouraged.

The Government's upcoming Industrial Decarbonisation Strategy, policies to improve resource efficiency and future policy on off-road mobile machinery should address the gaps and weaknesses. We set out below our recommendations in these twelve areas.

a) An overarching strategy

Current policy on decarbonising manufacturing and construction is piecemeal. An overarching strategy is necessary to drive the changes necessary for Net Zero.

Government should publish an Industrial Decarbonisation Strategy in early 2021 that is comprehensive, provides a clear vision and is integrated with wider policy.

- **Comprehensive.** The strategy should address the gaps, weaknesses and areas for continued focus that we have identified. It should clearly cover all manufacturing emissions within the scope – areas that have fallen out of scope (off-road mobile machinery) should be clearly covered elsewhere (see subsection (i)).
- **Clear vision.** It should provide a clear vision of the long-term policy mechanisms for industrial decarbonisation. This is crucial to shift expectations and build momentum for decarbonisation of manufacturing.
- **Integrated.** It should set out how industrial decarbonisation policy will integrate with other strategies including the Hydrogen Strategy, National Infrastructure Strategy, Heat and Buildings Strategy and Energy White Paper.

b) Policy to support jobs and the recovery

Government should design its industrial decarbonisation policies to support and create jobs, especially in regions with high reliance on industrial jobs.

In our Progress Report in June, we recommended that Government should design its industrial decarbonisation policies to support and create jobs, especially in regions with high reliance on industrial jobs. The Government's recent Ten Point Plan recognises this opportunity for "economic transformation of the UK's industrial regions".

Prompt award of existing funding can help the recovery.

Opportunities remain for the immediate future. Several funding schemes that have already launched (see Table 4.2) can both support jobs and urgent priorities, including demonstration of industrial fuel switching and CCS technologies, development of industrial decarbonisation projects and the creation of a skilled workforce and strong supply chain. Government should take this dual opportunity, by ensuring prompt award through these schemes and by increasing the ambition of the schemes.

Chapter 6, Section 1 of our *Advice report* talks further about the implications and opportunities for employment.

c) A plan for competitiveness consistent with Net Zero

The design of policies to reduce UK manufacturing emissions must ensure that it does not damage UK competitiveness, leading to 'carbon leakage'.

The design of policies to reduce UK manufacturing emissions must ensure that it does not damage UK manufacturers' competitiveness and drive manufacturing overseas ('carbon leakage'). This would not help to reduce global emissions and would be damaging to the UK economy. This is an important consideration for the Committee. Our *Advice report* (Chapter 6, Section 2) sets out details of three pieces of work, published alongside this report, that we have commissioned or collaborated on to improve our understanding of the policy options.^{23,24,25} It also provides further details of the international context.

A key existing approach to decarbonise manufacturing without causing carbon leakage is to require large manufacturers to pay for emissions allowances from an Emissions Trading Scheme (ETS),⁸ but to provide a free allowance allocation to manufacturers at risk of carbon leakage, which they may sell or use to cover their emissions.

This combination of an ETS with free allowance allocation, *alone*, may not be the most efficient way to achieve the combined goals of deep decarbonisation and avoiding carbon leakage, in future.

⁸ Currently the EU ETS. From January 2021, the EU ETS will be replaced in the UK by either an equivalent UK ETS or a UK emissions tax.

An emissions trading scheme combined with free allowances, alone, is unlikely to provide a sufficient incentive to enable deep decarbonisation in the near term.

- **Free allowance allocation within an ETS** can protect competitiveness, but this combination alone is unlikely to provide a sufficient incentive to enable deep decarbonisation of manufacturing. In the longer term, there may be further issues, including relating to liquidity and consumption emissions.
 - The policy is unlikely to provide sufficient incentive to enable deep decarbonisation as a) costs for early manufacturing deep decarbonisation deployment will likely come at a premium above expected carbon prices b) the uncertainty of the carbon price level adds a further risk premium to costs. c) upfront capital support is likely to be required by manufacturers that seek very short payback periods (in addition to an ongoing carbon price incentive).
 - If a carbon tax combined with rebates or exemptions is implemented from January 2021 instead of a trading system, this is likely to reduce incentives for deep manufacturing decarbonisation further.⁹
 - The existing EU ETS (and potential subsequent UK ETS) plans to reduce free allowance allocation over the 2020s, which has left some companies concerned at the level of protection.
 - In the longer term, as the ETS cap falls, it may suffer from liquidity issues if a large proportion (or even 100%) of participants continue to be awarded free allowances.
 - This approach does not have the potential to reduce imported consumption emissions, which may be a longer-term consideration.

Taxpayer funding, border carbon tariffs and minimum standards offer alternative approaches.

Alternative approaches to enabling deep decarbonisation of manufacturing, while avoiding carbon leakage include taxpayer funding, carbon pricing combined with border carbon tariffs, and minimum standards. In the near term, taxpayer funding should be used to support deep decarbonisation in manufacturing sectors at risk of carbon leakage given the lead-times for other approaches and the need to make progress on decarbonisation over the 2020s.

- **Taxpayer funding** of manufacturing deep decarbonisation projects would maintain industrial competitiveness and bring down project cost of capital.
 - Government has consulted on a Contract for Difference scheme to support both some capital and operational costs of industrial CCS projects. This, or other funding approaches, should be rolled out more widely across deep industrial decarbonisation.
 - Given the estimated costs of our scenarios set out in Chapter 3 of our *Advice report*, and that only part of industry is at risk of carbon leakage, the required exchequer support to decarbonise manufacturers at risk of carbon leakage would be around £2-3 billion per year in the early 2030s, assuming manufacturers do not face legacy policy costs on their electricity bills (see subsection (d)).
- **Border carbon tariffs**¹⁰ would raise the price of high-carbon imported goods, by ensuring that they were subject to an equivalent carbon price to that faced by UK manufacturers.
 - Under this approach, manufacturers would pay for their emissions reductions, which could then be passed through to consumers in

Taxpayer funded policies should be used in the near term to enable deep decarbonisation and avoid carbon leakage.

⁹ As companies would no longer be able to sell their free allowances if they decarbonise, which provides an incentive.

¹⁰ These are typically referred to as border carbon adjustments (BCA); however, some stakeholders also use the term BCAs to encompass the application of standards at the border, which we treat separately. Therefore, we use the border carbon tariff terminology for clarity.

higher prices without competitiveness impacts. It would also send a signal to other manufacturing countries to decarbonise their production.

- This approach, and minimum standards (below), have challenges associated with measuring the carbon intensity of imports and international trade tension.
- The EU and the new US administration have both announced plans to introduce border carbon tariffs.
- **Minimum standards** applied to imported goods (in line with domestic standards) could also enable domestic production to decarbonise without threat of being undercut by high-carbon imports.
 - Standards could be applied on producers of goods or on purchasers, and applied at the primary, intermediary or tertiary product stage.¹¹ As with border carbon tariffs, this would lead to a premium price for low-carbon goods meaning that consumers would bear the cost.
 - Standards mandating near-zero-carbon intensity may need to be introduced later than the more flexible border carbon tariffs. Other formulations of standards may have an earlier role, either through partial reductions on carbon intensity of products or production, or indirectly through other requirements, such as resource efficiency requirements. Public procurement may also have a role.

Policies to protect competitiveness are likely to need to transition from being taxpayer-funded in the near-term towards applying border carbon tariffs or minimum standards.

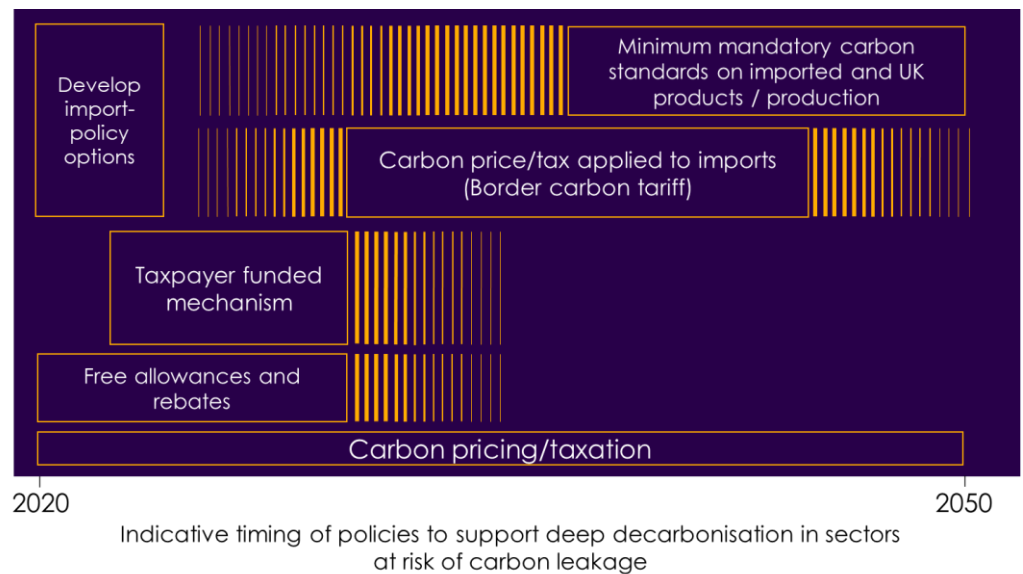
Following initial taxpayer funding, the broad pathway is likely to need to involve a transition towards border carbon tariffs or minimum standards, or border carbon tariffs followed by minimum standards (Figure 4.1).

This transition reflects the likelihood that Government would seek to pass costs through to industry and subsequently consumers, once there is an alternative to subsidy mechanisms. The timing of this transition might be delayed in some areas where other benefits of subsidy approaches (such as reducing the risk from carbon pricing) make them desirable for longer. We estimate that providing support in this way would cost the exchequer around £2-3bn per year in the early 2030s, after which taxpayer support would fall.¹²

¹¹ Primary product: This would be an unmanufactured product, consisting of a raw material. Intermediary product: A product that is manufactured or produced from a primary product intended for use in a secondary product. It can include steel or concrete, milk, or a car engine. Tertiary product: The final product for end use or consumption. In agriculture and food, this would include ice cream; in fashion a dress; in building and construction a building and in automotive manufacturing a vehicle.

¹² assuming manufacturers do not face legacy policy costs on their electricity bills (see subsection (d)).

Figure P4.1 Indicative timings of policies to achieve the combined goals of deep decarbonisation and avoiding carbon leakage



Source: CCC analysis

Notes: Dashed lines reflect uncertainty and complexity. For example, standards could represent standards of differing ambition. Policies would likely apply to different products/sectors at different times. Taxpayer funding range intended to indicate first year of support (for example, for a CfD contract, which may then last for several years).

Work should begin immediately to develop the longer-term options of applying either border carbon tariffs or minimum standards to imports of selected emissions-intensive products

Work should begin immediately to develop the longer-term options of applying either border carbon tariffs or minimum standards to imports of selected emissions-intensive products. This will provide Governments with the option to reduce the proportion of the cost of manufacturing decarbonisation that is borne by the taxpayer. With these options developed, Government will be able to decide on the appropriate mix of instruments, in consultation with the affected industrial sectors. It is particularly crucial to start work now, as many of the barriers could take substantial time to overcome.

This will require developing carbon intensity measurement standards, mandating that these are disclosed and fostering international consensus around trade policies.

To develop the longer-term options of applying either border carbon tariffs or minimum standards to imports Government should:

- **Develop carbon intensity (or broader) measurement standards** for selected industrial products and industrial processes, by working with industry and the international community.
- **Mandate disclosure** of the carbon intensity (as defined by the new measurement standards) for selected industrial products and industrial processes in the early to mid-2020s.
- **Foster international consensus** surrounding future carbon border/trade policy for products, using the UK 2021 G7 and COP presidencies. This will likely require engagement with the World Trade Organisation (WTO), to ensure future policy is developed to be WTO compliant.

While the assessment above focuses on traded¹³ manufacturing, the principles are also applicable to non-traded manufacturing at risk of carbon leakage. However, for these sectors a basic incentive for decarbonisation, such as a carbon price is required first (see subsection (d) below).

¹³ Those companies currently covered by the EU Emissions Trading Scheme

Policies that apply to the carbon intensity of imports would also likely reduce the imported element of our consumption emissions.

We note that some of the policies above are more obviously applied to imports to provide a level playing field for UK producers, but they could also be applied to UK exporters. For example, border tariffs could also involve rebates to exports from UK firms that have reduced emissions without full taxpayer support.

Policies that apply to the carbon intensity of imports would also likely reduce the imported element of our consumption emissions. Chapter 3, Section 3 of our *Advice report* sets out an indicative effect on consumption emissions under our Balanced Pathway, taking into consideration two different levels of international climate action.

d) Carbon and electricity pricing for decarbonisation

There are several gaps or weaknesses in the existing and emerging set of incentives for decarbonising manufacturing.

- There is not a clear carbon price on manufacturers in the non-traded sector (i.e. those not in scope of the existing EU ETS).
- The strength of carbon prices applying to manufacturers is typically insufficient to drive action in line with our Balanced Pathway.
- Electricity prices are well in excess of costs that would reflect supplying extra low-carbon electricity.

i) Create a clear decarbonisation signal in the non-traded sector

There is not a clear carbon price on manufacturers in the non-traded sector. The closest policy is the Climate Change Levy (CCL), which is a tax on energy use that has been levied since 2001. The main CCL rate is currently 66% higher on electricity than gas, with a higher rebate applied on electricity (92%) than gas (83%) for Climate Change Agreement (CCA) holders.¹⁴ While Government plans to equalise the tax on electricity and gas by 2025, this will still not provide an incentive for non-CCA holders to use electricity over gas.

Government should create a clear decarbonisation signal for the non-traded sector.

Government should reform overall energy and carbon pricing so that there is an incentive to switch to lower-carbon energy sources in the non-traded manufacturing sectors. Two options to achieve this are:

- Extend the future traded sector carbon pricing policy (either a UK ETS or emissions tax) to the existing non-traded sector.
- Reform the Climate Change Levy towards reflecting carbon content, so that electrification is clearly incentivised. If this approach is taken, there may be value in reviewing the role of Climate Change Agreements as the mechanism to incentivise electrical energy efficiency and protect sectors at risk of carbon leakage.

¹⁴ Applies to 43% of 'industry' energy use - BEIS (2020) Evaluation of the second Climate Change Agreements scheme.

ii) Strengthen carbon pricing

Carbon prices and taxes on manufacturers are currently below the levels that we estimate are consistent with our Balanced Net Zero Pathway.

We recommend that carbon prices and taxes on manufacturers should be strengthened, while we recognise that this may not be the only policy mechanism to support decarbonisation.

- For the traded sector, if the UK has an ETS from January 2021, this strengthening can be achieved by using our Balanced Net Zero Pathway to set the cap for the UK ETS (see Chapter 10 of the *Advice report*).
- For the non-traded sector, a tax, or equivalent, should be set well above the existing levels from the EU ETS to enable our Balanced Net Zero Pathway. This will require the non-traded sector to be covered by some form of carbon pricing, as recommended above.

All carbon pricing should be designed to include measures that protect against carbon leakage, as set out in subsection (c).

iii) Ensure cost-reflective electricity pricing

At present, industrial electricity prices are well in excess of the costs that would reflect supplying extra low-carbon electricity (e.g. from additional inexpensive extra offshore wind). This difference is a barrier to electrification in manufacturing (and other sectors - see Chapter 6 of the *Advice Report*).

We recommend that electricity pricing is reformed to reflect the much lower costs of supplying low-carbon electricity in the mid-2020s and beyond, so that electrification can play a cost-effective contribution to decarbonisation.

e) Addressing manufacturers' appetite for risk

UK manufacturers typically require investments to pay back within at least few years, shorter than required by most other businesses. This reflects a lower appetite for risk and is a barrier to investment in measures to decarbonise manufacturing.

Government should establish policies that address this lower appetite for risk. There are two clear options:

- Government could seek to provide tailored loans for manufacturers, that reduce risk to manufacturers and enable them to invest. This could involve below-market-rate loans or be delivered through the new National Infrastructure Bank. This approach may also need to address the reluctance of some manufacturers to take loans onto their balance sheets. Chapter 1 contains further recommendations on financing.
- Government could provide capital grants, potentially embedded within policies. The draft Contract for Difference for industrial CCUS proposes to include an element of capital funding. The Industrial Energy Transformation Fund is considering grants to support energy efficiency measures that have longer payback periods.

Electricity pricing should be reformed to reflect the much lower costs of supplying low-carbon electricity in the mid-2020s and beyond.

Government should establish policies that address manufacturers' low appetite for risk, either through loans or grants.

Government should establish funding mechanism(s) to support upfront and operational costs for both electrification and hydrogen use in manufacturing – this is currently a clear policy gap.

f) Funding mechanisms for deep decarbonisation measures

Electrification, use of hydrogen and application of CCS all scale up from 2025 in our Balanced Pathway for the manufacturing sector. This will require a funding mechanism or business model to enable this early deployment. However, current policies and proposals do not consider a business model to support electrification¹⁵ or the use of hydrogen and are too limited to supporting upfront costs rather than ongoing operational costs.

Government should establish funding mechanism(s) to enable both electrification and hydrogen-use in manufacturing.

- The mechanism(s) will need to support the operational costs of these measures, as well as some of the upfront costs.
- This could be achieved by extending the proposed industrial CCUS Contract for Difference, in a similar way to the Netherlands' Sustainable Energy Transition Scheme.
- The mechanism(s) should award to projects from 2022, to enable deployment from 2025.

Government should also finalise the Contract for Difference mechanism to support industrial CCS, to enable manufacturing CCS projects to be operating in 2025. Bioenergy with CCS and waste with CCS should also be considered within these mechanisms.

It is likely that funding mechanisms will be required across the different parts of manufacturing in the early stages of deployment: traded and non-traded, and sectors at (and not at) risk of carbon leakage. A transition away from initial funding should be a lot faster for sectors not at risk of carbon leakage.

The development of such mechanisms can help to drive investment in UK manufacturing, by reducing the policy risk that exists as a result of a lack of clear climate change policy for manufacturers.

g) Support for innovation and demonstration

The manufacturing and construction sector is diverse, involving a wide variety of different industrial processes, which will require different low-carbon technologies. Analysis we commissioned from Element Energy sets out many of these technologies.²⁶ Several of these technologies required for Net Zero are still at earlier stages of development and require support for development. The Government has provided some initial support through its Energy Innovation Programme.

Government should provide further support for innovation and demonstration. These demonstration projects are needed to enhance industry confidence in novel technologies, enable a better understanding of costs and requirements of different options and keep options open for different future scenarios.

Demonstration projects are needed to enhance industry confidence in novel technologies.

¹⁵ Beyond the very limited industrial application of the Non-Domestic Renewable Heat Incentive.

h) Policy to improve resource efficiency, energy efficiency and enable material substitution

Our Balanced Net Zero Pathway includes a range of resource efficiency, energy efficiency and material substitution measures. The measures can broadly be split between the following groups.

- Consumer product related measures, including increasing product longevity; increasing product utilisation and sharing; optimising product design to reduce material inputs; and increasing recycling and reuse of products.
- Construction related measures, including optimising construction designs to reduce material inputs; increasing reuse and recycling of construction materials and material substitution.
- Manufacturing energy efficiency improvement measures.

Carbon and energy incentives (subsection (d)) and policy to address manufacturers' appetite for risk (subsection (e)) can help to encourage some of these measures, but in many cases non-financial policy is required. We set out policy recommendations to encourage the three groups of measures below.

i) Consumer products

Government should extend product standards to cover how a product is made.

The Government is taking steps to improve the resource efficiency associated with products, including through the Environment Bill's new provisions. However, the Government should go further. The Government should:

- Ensure continuous improvement to product standards, building on the success of the Ecodesign regulation. Coverage should expand to include major consumer goods and extend to consider how a product is made, through resource efficiency indicators such as the level of recycled content and critical material content, as well as how repairable, durable and upgradeable a product is.
- Consider whether the forthcoming plastics tax should be expanded to cover other single-use materials.
- Work with business to develop policies to facilitate more sustainable consumer behaviour such as incentivising the use of car clubs and 'libraries of things', discouraging 'disposable' business models such as fast fashion.

ii) Construction

Government should work towards introducing a mandatory minimum whole-life carbon standard for both buildings and infrastructure.

There are currently few policies in place to improve resource efficiency and incentivise material substitution within construction of assets such as buildings and infrastructure.²⁷ Standardised approaches to calculating embodied carbon at a building or infrastructure level are largely voluntary. To improve resource efficiency and incentivise material substitution within construction the Government should:

- Work with industry to agree a standard for the 'whole-life' carbon footprint of buildings and infrastructure.
- Introduce mandatory disclosure of whole-life carbon in buildings and infrastructure to facilitate benchmarking as soon as possible.

- Following this, introduce a mandatory minimum whole-life carbon standard for both buildings and infrastructure which strengthens over time, with differentiated targets by function and usage. For homes, this standard should be included within the Future Homes Standard.

This could also provide a driver for decarbonising construction materials such as steel and cement. However, we do not think this should be the primary measure to support the initial uptake of transformative measures such as fuel-switching and CCS in these sectors. This is because steel and cement plants typically have a diverse set of customers, for which coordination would be challenging for this demand-side policy. This standard may also provide a route to decarbonising off-road mobile machinery on construction sites (see subsection (i)).

iii) Manufacturers' energy efficiency

A range of schemes currently support energy efficiency. Ambition will need to be tightened to meet our Balanced Pathway, including by strengthening energy and carbon pricing (subsection (d)) and addressing manufacturers' low appetite for risk (subsection (e)).

The Government could also consider strengthening enabling policies, such as mandating the use of Energy Management Systems. There may also be room for simplifying policy, for example by merging Streamlined Energy and Carbon Reporting (SECR) and the Energy Savings Opportunities Scheme (ESOS). Furthermore, Climate Change Agreements may require reform, after the upcoming round (see subsection (d)).

There may be room for simplifying energy efficiency policy, for example by merging SECR and ESOS.

i) Off-road mobile machinery

Policy on off-road mobile machinery appears to have largely fallen through the gaps between Government Departments and planned strategies. However, with emissions of around 12 MtCO₂e in 2018 from off-road mobile machinery across sectors¹⁶ (around half the emissions of Heavy Goods Vehicles), this area should not be ignored. This is emphasised by recent research suggesting that products of such low-carbon machinery may be an area of competitive advantage for the UK.²⁸

Policy on off-road mobile machinery appears to have largely fallen through the gaps between Government Departments and planned strategies.

We recommend that, failing its inclusion in either the Industrial Decarbonisation Strategy, Heat and Buildings Strategy or Transport Decarbonisation Strategy, it should be covered by the Net Zero Strategy.

This should set out a clear plan to develop near-zero emission off-road mobile machinery (ORMM) for applications where these are not yet available and increase deployment for ORMM applications where options are already available. The standard on embodied carbon in construction recommended in subsection (h) could be one way to increase deployment of low-carbon ORMM. The plan will also need to address the potential challenge of providing a distribution infrastructure for future fuels.

j) Infrastructure development

Electricity, hydrogen and CO₂ networks will all require development or upgrade in our Balanced Pathway. This will require actions on behalf of Government, regulators and network operators.

¹⁶ 6 MtCO₂e/year from industrial off-road mobile machinery

i) CO₂ transport and storage infrastructure

CO₂ transport and storage networks need to be developed to enable CCS across manufacturing and other sectors. Government has recognised the need to do this and has consulted on a support mechanism. Network infrastructure is likely to be focussed around a series of CO₂ terminals and cluster points (Figure 4.2).

Government should establish at least two CCS clusters in the mid-2020s, at least four by the late 2020s, and further clusters around 2030.

Government should establish at least two CCS clusters (terminals or cluster points) in the mid-2020s, at least four by the late 2020s, and further clusters around 2030, to ensure our Balanced Pathway can be met.

Our manufacturing Pathway also requires CCS to be fitted to a range of dispersed sites, particularly in the minerals sectors, such as cement and lime, with these sectors applying CCS (or potentially some CCU - Carbon Capture and Use) to all sites by 2040, with early projects starting in 2030. This may require substantial pre-planning as the transport of CO₂ will be more challenging than for sites located in clusters. It may involve trucking, shipping, trains or long pipelines, as identified by a study commissioned by BEIS.²⁹ Establishing options, such as pipelines, could have long lead-times.

Government should work with the minerals industries to develop a detailed joint plan for CO₂ transport from dispersed sites.

Given there is no likely alternative to CCUS for deep decarbonisation of these sectors and the possibility of long lead times, Government should work with the minerals industries to develop a detailed joint plan for CO₂ transport from dispersed sites.






Figure P4.2 Potential locations for cluster points and terminals for CO₂ transport and storage infrastructure

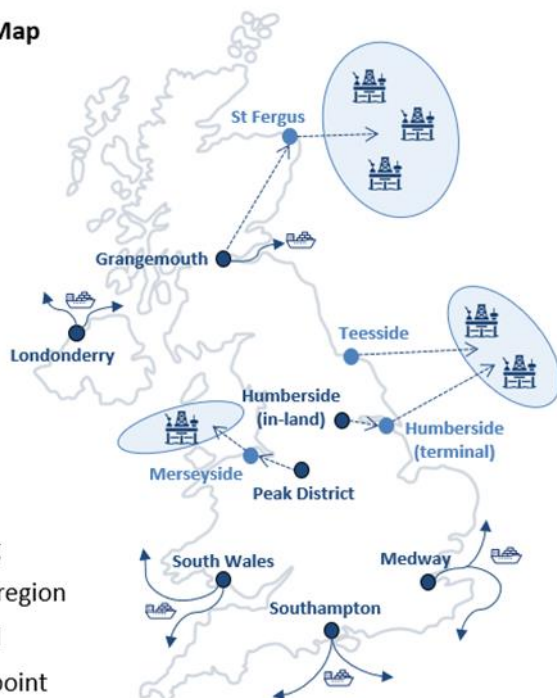


CCS Infrastructure Map

(for illustrative purposes)

Legend

-  Pipeline
-  Shipping
-  Storage region
-  Terminal
-  Cluster point



Source: Element Energy (2020) *Deep-decarbonisation pathways for UK Industry, report for the Climate Change Committee*

Government and regulators should prepare to make decisions about whether initial areas of the gas transmission and distribution networks should be converted to hydrogen.

ii) Hydrogen distribution

We anticipate that early hydrogen deployment in manufacturing in the second half of the 2020s will not be distributed through the existing gas networks (outside of trials), but rather via dedicated pipelines, or in some cases trucked. Hydrogen starts to be used via the existing gas networks (combined with dedicated new pipelines) from 2030 in our Balanced Pathway, starting near the industrial clusters.

Government and regulators should prepare to make decisions about whether initial areas of the gas transmission and distribution networks should be converted to hydrogen. These should be made on a cross-sectoral basis (see Chapter 3, Figure 3.3).

Future hydrogen (and alternative fuel) distribution plans should also consider the needs of off-road mobile machinery, which use around a fifth of the hydrogen consumed in manufacturing and construction in our Balanced Pathway. These are not typically located near clusters or with a grid connection.

iii) Electricity network upgrades

Ofgem and the network operators should make plans for a potential increase in large localised network reinforcements for manufacturers.

If a manufacturer decides to electrify its processes that currently use fossil fuels, it may require localised electricity network reinforcements. With widespread manufacturing this could necessitate a lot of localised network reinforcements. Ofgem and the network operators should prepare for this eventuality, which provides a different challenge to the larger but more evenly spread uptake of electrification of buildings and transport.

k) Target Dates

Government should set targets for UK ore-based steelmaking and cement production to reach near-zero emissions by 2035 and 2040, respectively.

Meeting the Sixth Carbon Budget will require decarbonisation actions to ramp up across the economy. In manufacturing, it will be particularly important to develop the momentum behind change. To achieve this, we recommend that the government set the following targets to indicate ambition.

- Government should target near-zero emissions from ore-based steelmaking¹⁷ in the UK by 2035. This could include CCS applied with high capture and application rates.
- Government should target near-zero direct emissions from the cement sector by 2040.¹⁸

l) Skills

The capacity of skills and supply chains needs to be increased, which will require supply chains and skills gaps to be mapped.

As a key constraint for the pace of the Balanced Pathway, the capacity of skills and supply chains needs to be increased. While this can be partially achieved through demonstration projects, additional work on mapping supply chains and future skills gaps is likely to be needed.

As part of this, engineering, procurement and construction organisations and training institutions need to be engaged and consulted on new training courses for the required upskilling. This should involve a role for the Engineering Construction Industry Training Board (ECITB) and the Government's new Green Jobs Taskforce.

¹⁷ This is typically based on using coke – a refined form of coal – in blast furnaces.

¹⁸ This excludes the negative emissions from BECCS, which would take the sector net negative.

- ¹² CCC (2020) *Policies for the Sixth Carbon Budget and Net Zero*. Available at: www.theccc.org.uk
- ¹³ Garvey, A. and Taylor, P (2020) *Industrial Decarbonisation Policies for a UK Net Zero Target*. Centre for Research into Energy Demand Solutions. Oxford, UK. ISBN 978-1-913299-05-7. <https://www.creds.ac.uk/publications/industrial-decarbonisation-policies-for-a-uk-net-zero-target>
- ¹⁴ Energy Systems Catapult (2020) *Industrial Decarbonisation: Net Zero Carbon Policies to Mitigate Carbon Leakage and Competitiveness Impacts*. A report for the Climate Change Committee.
- ¹⁵ CCC (2020) *The Potential for Product Standards to Address Industrial Emissions*.
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- ²¹ HMT (2020) *Budget 2020: Delivering on our promises to the British people*. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/871799/Budget_2020_Web_Accessible_Complete.pdf
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- ²⁴ Energy Systems Catapult (2020) *Industrial Decarbonisation: Net Zero Carbon Policies to Mitigate Carbon Leakage and Competitiveness Impacts*
- ²⁵ CCC (2020) *The Potential for Product Standards to Address Industrial Emissions*
- ²⁶ Element Energy (2020) *Deep-decarbonisation pathways for UK Industry*, report for the Climate Change Committee
- ²⁷ Aecom (2019) *Options for incorporating embodied and sequestered carbon into the building standards framework: Report prepared by Aecom for the Committee on Climate Change*
- ²⁸ Vivid Economics (2019) *Energy Innovation Needs Assessment (Sub-theme report Road transport)*
- ²⁹ BEIS (2020) *CCS deployment at dispersed industrial sites*. Element Energy for the Department for Business Energy and Industrial Strategy (BEIS).



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