C R E D S

Industrial decarbonisation policies for a UK net zero target

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Contents

Abbreviations

B2B	Business to Business
B2C	Business to Consumer
BCA	Border Carbon Adjustment
BCS	Border Carbon Standard
CAPEX	Capital expenditure
CCA	Climate Change Agreement
CCfD	Carbon Contract for Difference
CCL	Climate Change Levy
CCUS	Carbon Capture, Utilisation and Storage
CfD	Contract for Difference
CPF	Carbon Price Floor
CPS	Carbon Price Support
ECA	Enhanced Capital Allowances
EPR	Extended Producer Responsibility
ETS	Emissions Trading System
FFPS	Fossil Fuel Production and Supply
GHG	Greenhouse Gas
IP	Intellectual Property
LCA	Life Cycle Assessment
MCA	Multicriteria Analysis
MRV	Monitoring, Reporting and Verification
NRMM	Non-Road Mobile Machinery
OPEX	Operational expenditure
PPP	Public-Private Partnership
RAB	Regulated Asset Base
RDD	Research, Development and Demonstration
SECR	Streamlined Energy and Carbon Reporting
UKCS	UK Continental Shelf
WLCA	Whole Life Carbon Assessment

Executive summary

UK industrial greenhouse gas (GHG) emissions must fall by more than 90% over the next 30 years to be consistent with an economy-wide target for net zero GHG emissions by 2050. The impact of current industrial decarbonisation policies is far below what is required for this level of ambition. There is therefore an urgent need to consider how new policies might be designed and implemented to deliver wide-scale and rapid reductions in industrial emissions.

To help inform their recommendations for a 6th Carbon Budget, the Climate Change Committee (CCC) asked the University of Leeds to undertake independent research to evaluate which policies (and combinations of policies) would enable industrial decarbonisation in line with the UK's net zero target, without inducing carbon leakage. The research has focused on policies applicable to the manufacturing sector, but with some consideration also given to the policies required to decarbonise the Fossil Fuel Production and Supply and Non-Road Mobile Machinery sectors. In this report we:

- Conduct a comprehensive review of existing policies;
- Identify future policy mechanisms that address key challenges in decarbonising industry;
- Explore how combinations of policies might work together strategically in the form of 'policy packages' and how these packages might evolve over the period to 2050;
- Evaluate a series of illustrative policy packages, and consider any complementary policies required to minimise carbon leakage and deliver 'just' industrial decarbonisation.

Our findings were developed through a combination of literature review and extensive stakeholder engagement with industry, government and academic experts. Our key conclusions include the following.

Policy must address multiple challenges to decarbonisation and go beyond an overarching carbon reduction mechanism

- Sector-wide carbon policies such as pricing, subsidies or standards can provide leading signals for industrial decarbonisation by delivering an overarching incentive or regulatory framework to drive action and investment. To ensure UK competitiveness it is critical to include mechanisms that mitigate carbon leakage in the design of such policies.
- However, such overarching carbon policies alone will be insufficient to achieve net zero. Complementary policies will be required to 'fill gaps' in the incentive and penalty structures that these carbon policies provide, as well as mitigating any adverse impacts. Such policies will be needed to address challenges in accelerating innovation, deploying new infrastructure, increasing material efficiency and other areas.

There is no 'policy panacea' and policy solutions need to be flexible and adapt over time

- There is limited experience in the UK and internationally with developing and implementing policies for ambitious industrial decarbonisation. Ultimately the effectiveness of a particular policy or policy package is likely to depend both on its specific design and on the broader economic and other conditions within a country.
- Whilst there is no clear 'policy winner' in the options evaluated, for many manufacturing sectors a potentially effective approach could be identified as: a sequence of subsidisation and investment, supported by a carbon price signal, followed by increasingly stringent regulation.
- A number of the policies involving standards are reliant on credible metrics being developed, requiring methods such as Whole Life Carbon Assessments. Setting standards for embodied carbon is a significantly more complex process than that for operational efficiency standards. It is essential to have robust and defensible methodologies to conduct such assessments and the development of such data infrastructure is therefore a critical near-term action to facilitate future policy.
- Demand-side measures could also play a critical role in most policy packages, by acting on final demand for materials and products. The multiple benefits and high social acceptability of these policies provides a strong case for their implementation in the near-term.

A number of principles should guide effective policy design

- **Policy packages**: there is a need for a strategic and coordinated approach to delivering industrial decarbonisation policy for net zero, and a whole systems approach to designing 'policy packages' can help to optimise synergies between individual policies and reduce their negative spill-over effects.

- **Streamlined policy**: policy packages should deliver the required outcome in as lean a way as possible, avoiding any excessive 'layering' of policy burden, and reducing inefficiency and duplicated incentives or penalties. The cumulative impact of new and existing policies should be evaluated before implementing any changes.
- **Clear signals and incentives**: providing consistent policy signals allows industry to plan more effectively. Long-term targets for action, with clearly communicated plans for the phasing of policies, could support this.
- **Logical sequencing and built-in flexibility**: the timing of policies is critical to their effectiveness and the evolution of policies towards 2050 is a key consideration. The relevance of policies will necessarily change over time, meaning a phased and flexible approach is required in the design of long-term policy. Some policies may need to be 'front-weighted' given their longer lead times for realising mitigation benefit. Similarly, incorporating flexibility into policy design is important to allow for continuing adaptation to market responses, and newly available evidence.

There are evidently many uncertainties in planning future industrial decarbonisation policy given the current political and economic environment. This report is only able to provide an initial evidence base to inform such policy development and more detailed work will be needed to inform policy choices, not least on the impact of particular policies on specific industrial sectors. However, the urgency of the climate crisis and the need for industrial emissions reductions to be accelerated in line with the UK's net zero target demands a rapid policy response. We do not have the luxury of waiting while we design the perfect policy approach; action is needed now and we hope that this report can provide some guidance towards creating a clean and competitive future for UK industry.

1. Introduction

1.1 Context

In June 2019 the UK Government amended the Climate Change Act to legislate for a net zero greenhouse gas (GHG) emissions target for 2050 and in doing so signalled an unprecedented level of ambition for climate action. The challenge now for the Government is to develop and implement policies that will put the UK on a pathway towards this target, while minimising any adverse impacts on the economy or society. These issues are particularly acute for the industrial sector, which in 2019 was responsible for GHG emissions totalling 102 $MtCO_2e$, representing 21% of total UK emissions (CCC, 2020, p. 55). Analysis by the Climate Change Committee (CCC) suggests that under a net zero pathway, industrial emissions will need to fall over the next 30 years by at least 90% (CCC, 2019, p. 73).

Whilst GHG emissions from industry have been largely on a downward path since 1990, falling by 53% between 1990 and 2019 (CCC, 2020), industry will still face significant challenges in delivering future decarbonisation at the pace and scale needed. Historically, the offshoring of industrial production has made a significant contribution to reducing UK industrial energy use and therefore emissions (Hardt et al., 2018). As a consequence of this offshoring and a rising share of imports, the UK's overall consumption-based emissions footprint has only reduced by 15% between 1990 and 2016 (WWF, 2020). The threat that more stringent decarbonisation policies might result in future carbon leakage,[1] with the associated negative impacts on jobs and prosperity, is a very real concern. Carbon leakage is also counterproductive when considering that the purpose of the UK's net zero commitment is to contribute to a reduction in global GHG emissions.

To date, progress towards the Government's 5 yearly carbon budgets has been dominated by mitigation in the power sector, with reductions of 67% between 2008 and 2019 (CCC, 2020, p. 17).

1 Carbon leakage is the situation in which, as a result of stringent climate policies, companies move their production abroad to countries with less ambitious climate measures, which can lead to a net rise in global greenhouse gas emissions (ESC, 2020).

Further emissions reductions in the power sector alone will not be sufficient to meet future carbon budgets. Rapid and widespread reductions across all sectors of the economy are required to put the UK on a pathway to net zero emissions by 2050.

There is therefore an urgent need to examine how policies might be designed and implemented to ensure industrial GHG mitigation at the levels required by the net zero target, while avoiding carbon leakage. Furthermore, these issues need to be considered within the context of broader discussions around delivering a green economic recovery from the COVID-19 pandemic and on a just transition to climate neutrality, in which no one is left behind (Scottish Government, 2020). Any policies must also take into account the very disparate characteristics of the sectors that comprise industry and significant uncertainties about the most appropriate technologies and energy vectors to deliver industrial decarbonisation in these different sectors.

The CCC will be considering these and other issues as part of their advice to Government on the 6th Carbon Budget to be published in December 2020. To help inform their work the CCC asked the University of Leeds, as part of their activities with the Centre for Research into Energy Demand Solutions (CREDS),[2] to undertake independent research to evaluate a range of industrial decarbonisation policy options and how these might be combined to deliver the emissions reductions required, while minimising carbon leakage. This report presents the findings from the CREDS research.

1.2 What is 'industry'?

Despite the evident importance of industrial emissions to economy-wide decarbonisation, there is considerable ambiguity in what is implied by the term 'industry'. Analyses variously assume different definitions of industry, and the boundary of the sector with regards to sub-sectors is often unclear. Several classification approaches can be adopted, for example: normative classifications of industry (energy-intensive, heavy industry, manufacturing), technical classifications (Standard Industrial Classification codes and their equivalents), and conceptual typologies ('ordinal' definitions such as primary, secondary, tertiary). Increasingly, policy papers set out by the UK Government are sector-neutral, such as the 'Grand Challenge' areas of the Industrial Strategy, including 'artificial intelligence and data', 'ageing society', 'clean growth', and 'future of mobility', suggesting a more problem-oriented approach (BEIS, 2019).

In this analysis we identify three component sub-sectors to 'industry', namely: manufacturing (trade-exposed and non trade-exposed), the fossil fuel production and supply sector (FFPS; i.e. oil and gas), and the non-road mobile machinery sector (NRMM)[3] (see Figure 1).

2 See the CREDS website.

3 Non-Road Mobile Machinery (NRMM) includes 'transportable industrial equipment or vehicles which are fitted with an internal combustion engine and not intended for transporting goods or passengers on roads' (London Assembly, 2020).

This industry definition is selected for consistency with other analysis by the CCC. Our focus is on policies that are most relevant to the manufacturing sector, although we also briefly consider the needs of NRMM and FFPS, while recognising that further detailed work is required for these sectors. Figure 2 outlines the importance of emissions from these industry sectors to the UK's total GHG account.

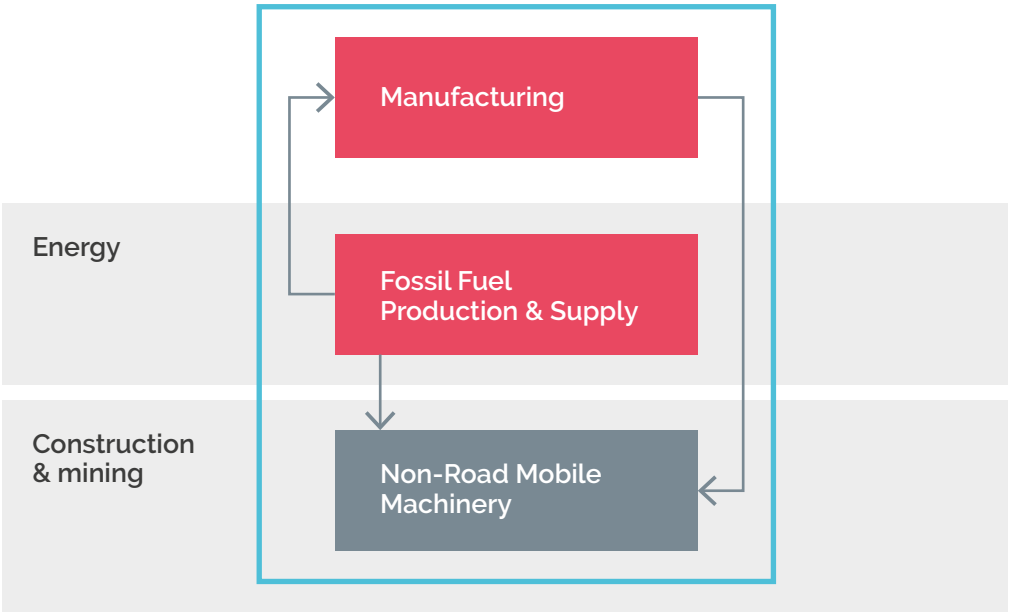


Figure 1: Scope of industry considered in this review, encompassing the manufacturing, NRMM, and FFPS sectors (blue box). Red boxes indicate sectors most at risk of carbon leakage, and arrows suggest the interdependencies between the sectors. The light grey boxes indicate the sectors to which NRMM and FFPS are conventionally allocated in official emissions statistics.

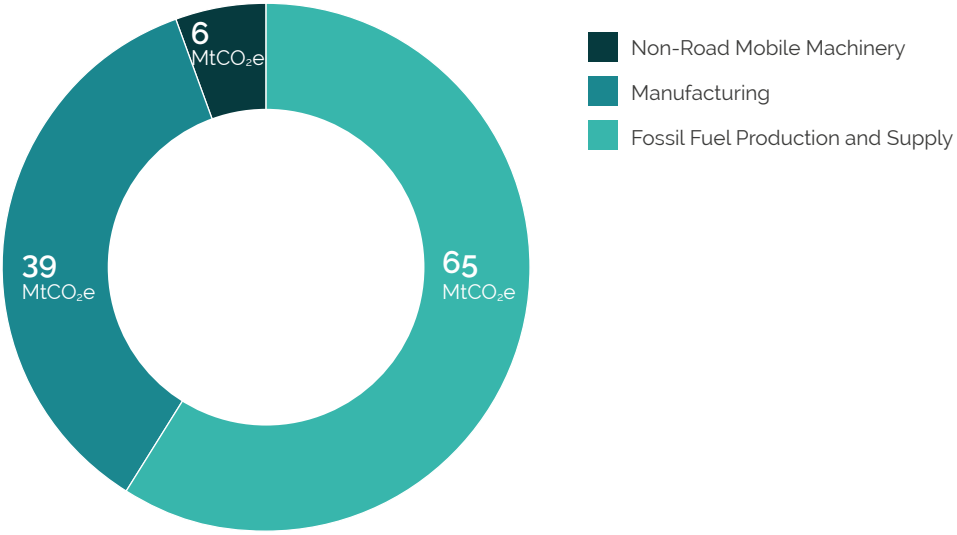


Figure 2: Greenhouse gas (GHG) emissions ($MtCO_2e$) attributable to industrial sectors in 2018 (National Atmospheric Emissions Inventory, 2020).

1.3 Research design

1.3.1 Aims and objectives

The aim of our analysis was to provide an evaluation of which policies (and combinations of policies) would enable industrial decarbonisation in line with net zero UK emissions without inducing carbon leakage.

This aim was complemented by four key objectives. These were to:

- Conduct a comprehensive review of existing policies;
- Identify future policy mechanisms that address key challenges in decarbonising industry (i.e. going beyond policies that provide an overarching carbon reduction incentive);
- Explore how combinations of policies might work together strategically in the form of 'policy packages' and how these packages might evolve over the period to 2050;
- Evaluate a series of illustrative policy packages, and consider any complementary policies required to minimise carbon leakage and deliver 'just' industrial decarbonisation.

1.3.2 Approach and methods

Quantitative evidence on the effectiveness of policy options is relatively limited, therefore in this analysis we used a combination of largely qualitative methods (see Table 1).[4]

Table 1: Summary of research methods adopted in the review.

Method	Description
1. Desk research	• Literature review of potential industrial decarbonisation policy options. • Compilation of a database of existing UK industrial decarbonisation policies.
2. Sector consultations	Consultation with key sector representatives for insight into their respective policy priorities.
3. Expert survey	Online survey distributed to approximately 30 key stakeholders to gather anonymous input on a range of policy options.
4. Policy workshops	Three interactive workshops (held in July, August and September 2020) with an expert stakeholder group, representing industries and sector organisations, government departments (BEIS, Defra, DIT, HM Treasury), and the third sector (including academia). • Workshop 1: identification of key policies for policy packages. • Workshop 2: verification of the approach to evaluate policies. • Workshop 3: feedback on policy package design and evaluation.

4 All activities were granted ethical approval by the University of Leeds Business, Environment and Social Science Faculties Research Ethics Committee (AREA FREC). Ethics reference LTSEE-113

Key inputs on the viability of policy options identified in the course of the literature review and on the approach taken in the analysis was provided by both a Working Group and Steering Group on industrial decarbonisation, convened by the CCC. After development of the analysis in collaboration with the Working Group, regular engagement with the Steering Group via consultations and broader stakeholder workshops provided important feedback on the interim results and methodology. Two further pieces of work developed by members of the Working Group provided critical input to, and intersected with, this assessment; namely an evaluation by Energy Systems Catapult of carbon policies to mitigate carbon leakage and competitiveness impacts in the industrial sector (ESC, 2020), and a review of the potential for product standards to address industrial decarbonisation (CCC, 2020a). Where possible, the terminology, definitions and evaluation criteria in this analysis are consistent with those of the other outputs of the Working Group.

1.3.2.1 Challenges for industrial decarbonisation policy

In the course of the literature review, we identified several key challenge areas for industrial decarbonisation which policy must address. Whilst providing an overarching incentive for carbon reduction is clearly of central importance, we identified that a number of related challenges, covering the complete industrial value chain, will need to be met in order to achieve net zero (Table 2). The challenges are necessarily non-exhaustive, and could for instance include the issue of addressing stranded assets.

Table 2: Summary of the industrial decarbonisation challenges identified in the review.

Challenge	Description
Overarching carbon reduction incentive	Overarching approaches including carbon pricing, standards and subsidies. Also including mechanisms for the mitigation of carbon leakage.
Deployment and coordination of infrastructure	Supporting deployment of new industrial infrastructures (e.g. CCUS/ H_2 pipelines), and encouraging integration and clustering where appropriate.
Improvements to existing technologies and assets	Improving the efficiency and performance of existing technologies and processes, encouraging upgrade/ refurbishment or early retirement where relevant.
Incentives for innovation	Supporting research, developing new 'breakthrough' technologies and fuels, and stimulating investment in their demonstration and deployment (i.e. commercialisation).
Improvements in the efficiency of material and product use	Improving the efficiency of material and product use and creating markets for low-carbon goods.
Enabling policies	Policies with a socioeconomic focus to support long-term industrial strategy, such as skills and (re)training investment, and generating low-carbon manufacturing jobs in the sectors and regions in which they are most needed.

1.3.2.2 Developing a policy evaluation framework

In light of the lack of quantitative evidence on the effectiveness of many policy options, as identified through the literature review, a qualitative evaluation approach was employed based on available evidence from the literature and expert judgment.

A comprehensive list of evaluation criteria was first developed, similar to the 'criteria tree' approach of multi-criteria analysis (MCA) (see Table 3). This was informed by the range of criteria selected for comparable reviews, such as in a UKERC Technology and Policy Assessment (TPA) (Hanna et al., 2016) and public policy literature (Transport Scotland, 2014). The initial longlist was refined in consultation with the Working and Steering Groups, identifying priority issues and providing clear definitions.

Table 3: Overview of evaluation criteria used.[5]

Group	Criteria	Description
Feasibility and deliverability	Implementation time	Approximate policy complexity, and the time required to implement the policy and achieve results.
	Technical feasibility (inc. measurability)	Requirement for new metrics and indicators, and/or monitoring, reporting, and verification (MRV) frameworks.
	Political/legal challenges	Susceptibility to political barriers and/or legal challenge, and precedent for implementation.
Cost characteristics	Cost to taxpayer	Potential cost to taxpayer, or potential for revenue generation.
	Effect on cost of capital	Certainty the policy provides to industry to invest.
	Socioeconomic distribution of cost	Whether the policy is regressive (costs are borne by industry/consumers), or progressive (costs borne by taxpayers).[6]
Carbon reduction potential	Achieving net zero	Strength of incentive to reduce emissions in line with net zero emissions by 2050.
	Production-based emissions	The policy's coverage of the UK's production-based emissions.
	Consumption-based emissions	The policy's coverage of the UK's consumption-based emissions.
Key additional challenges	Carbon leakage and competitiveness impacts	Ability to limit or mitigate carbon leakage and competitiveness impacts.

5 A number of further criteria could be included, for example the risk of the policy to taxpayer costs, the robustness of the policy to future uncertainty, and how well the policy would deal with operational expenditure (OPEX) costs in addition to capital expenditures (CAPEX). Additional considerations could include the certainty that the policy would be able to achieve the required emissions reductions, i.e. a voluntary agreement would score positively across most criteria, but may not in isolation achieve sufficient decarbonisation to align with a net zero target.

6 The policy is viewed as progressive where the costs are borne by taxpayers, since this presents an opportunity to more fairly manage the distribution of costs so that those that earn more, pay more. Imposing policy costs purely on industry could lead to UK industry becoming uncompetitive and/or unmanageable cost transfers to consumers thus affecting vulnerable groups disproportionately. However, in other cases there may be advantages in industry paying the costs (in line with the polluter pays principal) or in passing these costs through to consumers.

A guide was then developed (see Table 16, Section 2.2.4.), to ensure consistent scoring. Evidence-based scoring was used as far as possible, using case studies and available evidence from the literature. Members of the working and steering groups were consulted on the choice of final scores, including through an online survey, although there is evidently scope for further work that could help inform the scoring. To reflect these uncertainties, colour coding was used.

The different criteria can be considered of varying importance to different stakeholders; industry actors may, for example, perceive cost characteristics as more significant to policy choice than government. In textbook MCA exercises, this is where the allocation of weights is carried out through models (such as linear additive or analytic hierarchy process models) (Department for Communities and Local Government, 2009). In response to feedback from a stakeholder workshop, we have not weighted scores in this analysis. This approach can be further justified since the criteria do not represent 'mutually independent' preferences where 'the judged strength of preference for an option on one criterion will be independent of its judged strength of preference on another' (ibid, p. 22). The scoring will similarly be limited by our current understanding of how the policies function, particularly where precedent for implementing such policies is limited.

1.3.3 Scope and limitations of the analysis

The analysis aims to present a review of potential policies for ambitious industrial decarbonisation based on our current understanding of options in this area. It is not intended to provide specific 'recommendations' as to which course of policy action should be preferred, given the multiple uncertainties and trade-offs that are inherent in policy selection.

- **Section 2** of the report provides an overview of existing industrial decarbonisation policies in the UK, whilst reviewing the future policy options available to address the multiple challenges of industrial decarbonisation.
- **Section 3** outlines our approach to developing 'illustrative policy packages' and presents our evaluation.
- **Section 4** considers policy beyond the direct scope of industrial decarbonisation, but which is critical to ensuring a just industrial transition to net zero.
- **Section 5** outlines our key conclusions.

2. Industrial decarbonisation policies

2.1 The UK policy landscape

To provide context for how future policies could strengthen the ambition for industrial decarbonisation in line with a net zero target, a review of existing policies was carried out. A critical gap in the academic and grey literature on industrial decarbonisation is the existence of a comprehensive dataset on the policies that are currently in force in the UK.

Our review therefore considered currently, or recently, active UK industrial decarbonisation policies. The review aimed to bring together information on long-running policies, with a summary of funding initiatives and policy announcements contained in recent UK Government budgets. It did not aim to 'assess' or evaluate the policies, but rather to provide a brief qualitative description of each policy and a reference to where more detailed information can be found. A key uncertainty is how future policy would interface with existing policies. The policy packages described in Section 3 suggest a direction of travel from the 'baseline', but further consideration needs to be given as to how ongoing policies should evolve over time, including the extent to which they would be replaced by new policy mechanisms. Further detail on the approach to the review can be found in the Appendix (Section 6.1.).

The outcomes of the upcoming Treasury Net Zero Review, BEIS Industrial Decarbonisation Strategy, Net Zero Strategy, and provisions in the Environment Bill (HM Treasury, 2019; CCC, 2020b; Department for the Environment, Food and Rural Affairs, 2020) could provide more clarity on the future direction of travel for industrial decarbonisation policy.[7]

The following policies are structured by the decarbonisation challenge they primarily address, as outlined in Table 2 (Section 1.3.2.1).

7 The following provides a summary of upcoming UK energy and environment policy milestones (Policy Exchange, 2020).

2.1.1 Review of existing policy

2.1.1.1 Overarching carbon reduction incentive

The overarching mechanism for large-scale carbon reduction in UK industry has been the European Union Emissions Trading System (EU ETS), of which the UK has been a member since 2005 (BEIS, 2019a). The EU ETS is a cap and trade scheme in which eligible facilities buy and sell tradeable emissions allowances to cover their annual emissions, with a 'cap' set on the total emissions permitted by all allowances under the scheme. Permit trading occurs via free allocation or auctioning at the national level, or through secondary market auctions (BEIS, 2020). Guaranteeing a level of emissions in line with or below a determined 'cap' encourages decarbonisation by providing a price signal for low-carbon investment, whilst the market-based approach encourages least cost abatement (BEIS, 2019a). In the current phase of the ETS (Phase III, January 2013 to December 2020), free allocation of allowances to industrial sectors at risk of carbon leakage has reduced by 12% to drive deeper decarbonisation (BEIS, 2020).

With the UK's exit from the EU (see Box 1), a number of successor schemes have been considered by the UK Government. A proposed option is the creation of a UK ETS, either standalone or linked to the EU ETS (HM Government, 2020). A Carbon Emissions Tax has also been proposed as a backstop to ensure consistent carbon pricing (BEIS, 2020a). Recent advice from the CCC on the future of carbon pricing post-Brexit has suggested the potential for increasing the ambition and alignment of the UK's carbon pricing system in line with net zero (CCC, 2020c). Several caveats to the design of a replacement system are proposed, including: setting an appropriate level of cap in line with actual UK emissions (rather than the UK's share in the EU ETS) to avoid the floor price functioning as 'de-facto tax', and extending the sectoral coverage of the scheme prior to 2030 (ibid). Continuing with an ETS variant is viewed as a means of providing consistency, in which will otherwise prove to be a period of significant uncertainty for industry compounded by the ongoing impacts of the pandemic.

However, a Carbon Emissions Tax has also been proposed as a 'fallback policy should the UK have left the EU without a deal' (HM Revenue and Customs, 2020). Under the proposal, emitters originally reporting under the EU ETS would be required to pay a tax if their emissions were above an 'individually set emission allowance', thus providing a consistent carbon price (ibid).

The Climate Change Agreements scheme (CCA) is a system of voluntary agreements between government and industry, the second phase of which started in 2013. Firms joining the scheme commit to sector-based 'umbrella' agreements, which outline targets for energy and carbon reductions (Environment Agency, 2020). In return, firms receive a discount on their Climate Change Levy (CCL),[8] a tax on industrial energy use via electricity and fuel bills.

8 The Carbon Price Floor (CPF) upholds the price of carbon within UK electricity markets to incentivise low-carbon generation. The tax is applied to electricity generators using fossil fuels via the CCL, which eligible generators must pay at the Carbon Price Support (CPS) rate (HMRC, 2017).

These discounts can be as high as 90% in the case of electricity use by energy-intensive business (HM Government, 2020a). The scheme covered 43% of industrial energy use in 2018 (BEIS, 2020b) and represents energy cost savings of as much as £300m to industry per annum (HM Treasury and BEIS, 2020).

A recent consultation on extending the lead time of the CCAs until March 2025 (it was previously set to run until 2023) suggested strong support for the proposal;[9] it was highlighted that the continuation the scheme in its existing structure would provide 'consistency for operators during a time of economic uncertainty' (HM Treasury and BEIS, 2020). There is also a suggestion that a long-term scheme may be under consideration (ibid). Support for the agreements may stem from a number of factors which increase its viability for industry: a familiar structure and consistency in design, negotiated sector-specific commitments, and some protection from international competitiveness impacts for trade-exposed industries through reductions to energy costs (BEIS, 2020b).

However, the ongoing effectiveness of the scheme may be contingent on several unknowns: the extent to which firms 'ring-fence' CCL savings to finance efficiency improvements (ibid), the stringency of future target-setting, the potential strength of the policy signal provided by the scheme to decarbonise in line with net zero, and the remaining scope of economically feasible efficiency savings to be made. At least in a structural sense, the CCAs provide a positive case study of incentivising decarbonisation, in part acting as a form of 'sector deal' and providing a framework for negotiated progress between government and industry. However, the level of ambition in the scheme and its potential to stimulate decarbonisation in line with net zero should be explored further.

It can be seen that the UK relies on a largely market-based approach in its industry-wide carbon policy, through the combination of a trading system, sectoral voluntary agreements, and passing on carbon costs via energy prices in the CCL.

9 Although the CCAs outline targets for decarbonisation and efficiency improvements, they were designed to negotiate the costs of the Climate Change Levy and address international competitiveness concerns.

Box 1: Brexit: Opportunities and risks for industrial decarbonisation

EU legislation has been an important driver of decarbonisation across the UK energy sector, including in industry. Much of EU law is implemented through Directives, which set out a goal that all EU countries must achieve. Each individual country is then left to devise their own laws on how to reach the goal. For some issues the EU adopts regulation, which is a binding legislative act and must be applied in its entirety across all countries (European Union, 2020).

With the UK exit from the EU, the UK parliament can decide which parts of EU legislation it wishes to retain and which to repeal. Currently there is an ongoing process of policy translation towards retaining legislation for at least some of the directives relating to industrial decarbonisation. For instance, the UK has already committed to keeping the standards contained in the Ecodesign and Energy Labelling Directives (BEIS, 2020c).

However, the precise shape of the post-EU policy framework will only become clear once trade deal negotiations are concluded. A critical uncertainty is in the replacement for the UK's participation in the EU Emissions Trading Scheme. The UK has indicated its preference for a UK emissions trading scheme linked to the EU ETS. However, if an overall deal cannot be reached with the EU then the UK Government has drawn up plans to replace emissions trading with a Carbon Emissions Tax. More generally, integrating strong environmental standards into any post-Brexit trade deal could be a valuable mechanism for improving parity and protection from leakage between international industrial competitors.

Various EU bodies are also an important source of funding. For example, the UK has previously been the recipient of significant energy sector grants from the EU's structural programmes and loans from the European Investment Bank (UKERC, 2019, p. 3). Set against this, and depending on the terms of any trade deal, the UK may have more flexibility to provide its own funding to support industry, as it would no longer be subject to EU State Aid rules.

Going forward, there are questions around to what extent the UK will remain in-step with the ambition of EU policy (so called regulatory alignment), fall behind, or go even further now that it has greater freedom for independent policymaking. This is tested by the current ambition of the EU Green Deal, and the need for comparably ambitious policy at the UK level, which is not currently in evidence.

The EU's proposed implementation of a Border Carbon Adjustment, carbon pricing imports from selected sectors outside the EU at the border, could be a testbed for this type of policy and provide key insight for policy experimentation in the UK (European Commission, 2020a).

2.1.1.2 Deploying and coordinating infrastructure

The availability of low-carbon hydrogen and Carbon Capture, Use and Storage (CCUS) is likely to be critical for the deep decarbonisation of some industrial sectors. Low-carbon electricity infrastructure will also be a key need for industry, as in all economic sectors, given the potentially large increases in demand as a result of fuel switching.[10] The availability of these vectors is contingent on the development and deployment of the necessary infrastructure (for instance infrastructures with direct industrial application, such as CCUS networks, and hydrogen production and distribution facilities). Existing industrial infrastructure policy in the UK is largely oriented around funding programmes towards demonstration (Table 4). A critical development is the announcement of the Industrial Clusters Mission under the Industrial Strategy Challenge Fund (a target to establish the world's first net zero industrial cluster by 2040, and a low-carbon cluster by 2030) (BEIS, 2019b). A cluster-based approach considers the regional distribution of large energy-users, thus prioritising infrastructure delivery in regions where the largest abatement potential is concentrated (BEIS, 2017). However, there is some risk of 'picking winners', if certain sectors cannot be sited in clusters.

In addition to the Clusters Mission, key recent policies include grant funding towards CCUS innovation and deployment and the Low Carbon Hydrogen Production Fund. Further consideration could be given to the potential for integration of offshore renewables and CCUS with industrial demand, for example in the oil and gas sector, where platform electrification and reuse of existing assets for CCUS could deliver abatement potential (Oil and Gas Authority, 2020).

Table 4: Summary of recent infrastructure policy, of relevance to industrial decarbonisation.

Policy	Policy type	Lead time	Description
Industrial Clusters Mission	• Target • Direct funding	2019–2030/40	• Target to establish a net zero industrial cluster by 2040 (world first) and a low-carbon cluster by 2030. • Financed by a £170m public investment under the Industrial Strategy Challenge Fund (BEIS, 2019c).
Energy Innovation Programme	• Funding programme	2015–2021	• Promoting commercialisation of clean energy technologies and processes over the 2020s and 2030s. • Programme of funding worth £505m over 6 themes, including £100m for industrial decarbonisation and CCUS (BEIS, 2020d).
Carbon Capture Usage and Storage (CCUS)[11]			
Carbon Capture and Storage (CCS) Infrastructure Fund	• Direct funding	2020–2030	• Announced in the 2020 Budget (HM Treasury, 2020a). • Fund to implement CCS at a minimum of 2 UK sites, the first by mid-2020 and the second by 2030.

10 It is beyond the scope of this report to discuss energy policies for low-carbon electricity infrastructure, but it is undoubtedly a critical concern for industrial decarbonisation.

11 The Government has provided a response to a recent consultation on CCUS business models, which is another dimension of policy to support the development of CCUS infrastructure (BEIS, 2020e).

Policy	Policy type	Lead time	Description
CCUS Innovation Programme (Call for CCUS Innovation)	• Grant funding	2018–2021	• Grant funding worth £24m distributed to research and innovation projects aiming to reduce the cost of CCUS and accelerate its deployment (BEIS, 2020f).
Carbon Capture and Utilisation Demonstration (CCUD) innovation programme	• Grant/ competition funding • RDD	2017–2021	• Up to £20m in funding allocated to demonstration of CCUS at several UK industrial sites, aiming to achieve cost reductions of 20-45% in CCUS technologies (BEIS, 2019e). • Implemented in 3 phases.
Hydrogen production and supply			
Low Carbon Hydrogen Production Fund	• Direct funding • RDD	2020–ongoing	• Fund of a total £70m for 2 large low-carbon hydrogen production plants (Merseyside, Aberdeen), and a project integrating offshore wind (Grimsby) with electrolytic hydrogen production (BEIS and UKRI, 2020). • £18.5m is allocated from the scheme to the Industrial Fuel Switching Programme for 4 demonstration projects.
Low Carbon Hydrogen Supply Competition	• Competition funding • RDD	2018–2020	• £33m competition funding to accelerate the development of low-carbon hydrogen supply (BEIS, 2020g). • Delivered in two phases.

2.1.1.3 Improving existing technologies and assets

Energy efficiency policy in various forms has been a consistent feature of UK industrial policy since the 1970s, although a result of varying policy aims (Mallaburn and Eyre, 2013). Energy efficiency is viewed as a key strategy to decouple energy use from economic growth, by maintaining or improving economic productivity whilst reducing energy inputs. Support for energy efficiency is frequently reiterated in policy, as in the Clean Growth Strategy's target to increase business energy efficiency by a minimum 20% by 2030 (BEIS, 2018). However, there are questions around both the remaining potential for efficiency gains (particularly in energy-intensive sectors where gains have already been made to minimise energy costs), as well as the risk of inducing rebound, where efficiency gains are compromised by a corresponding increase in consumption due to the saving (Brockway et al., 2017).

A suite of energy efficiency policies are in force in the UK, as in Table 5. Existing measures are largely delivered by means of grant funding for the deployment of cost-effective efficiency technologies. Some funding for these measures is provided through the Industrial Energy Transformation Fund (BEIS, 2020h). Efficiency targets are also addressed under the CCAs.

Table 5: Summary of recent energy efficiency policy.

Policy	Policy type	Lead time	Description
Boosting access for SMEs to energy efficiency (BASEE)	• Competition funding	2019–2021	• £6m in funding for the development of business models to encourage energy efficiency measure uptake by SMEs (BEIS, 2020k). • Delivered in two phases.
Industrial Energy Efficiency Accelerator (IEEA)	• Competition funding	2019	• £13m programme to improve the availability of 'innovative' energy efficiency technologies at the near commercialisation stage (BEIS, 2020j). • Aiming to encourage private sector investment. • Delivered in 2 phases.
Industrial Heat Recovery Support (IHRS)	• Competition funding	2018–2022	• £18m competition funding to drive investment in heat recovery technologies BEIS, 2020i). • Supporting industry to identify opportunities.
Industrial Energy Transformation Fund	• Competitive grants	2018–2021	• Fund worth £315m for capital investment in energy efficiency and deep decarbonisation measures proposed by the applicant companies (BEIS, 2020h). • Only projects which 'would not happen without Government support' are to receive funding.[12]
Non-Domestic Smart Metering	• Information provision	2017—2024	• Part of the Smart Metering Implementation Programme, this targets implementation in industrial settings (BEIS, 2018a).
Energy Savings Opportunity Scheme (ESOS)	• Mandatory assessment and reporting	2014–ongoing	• Mandatory energy assessment scheme for large energy users, consisting of 4 yearly reporting (Environment Agency and BEIS, 2019).[13] • Requires the identification of 'cost-effective energy saving measures'. • Regulated by the Environment Agency, they can enforce penalties for non-compliance and publish compliance data. • Implemented by compliance periods.

2.1.1.4 Incentivising innovation

The innovation funding landscape for UK industry largely follows a competition funding approach (Table 6). Funding is typically distributed in phases, each of which may focus on a separate element of innovation including scoping, feasibility studies, demonstration at scale, and accelerating deployment, to support innovation at each commercialisation stage.

12 The IETF has a focus on accelerating the deployment of energy efficiency and other low-carbon technologies, by supporting feasibility studies in addition to delivering funding.

13 Designed to implement Article 8 (4 to 6) of the EU Energy Efficiency Directive (2012/27/EU), implemented in the UK by the ESOS Regulations 2014.

A move towards more innovative financial approaches can be observed in the development of the Clean Growth Equity Fund (BEIS, 2020l).

As perhaps one of the most visible commitments in recent years, the Industrial Strategy Challenge Fund (ISCF), announced in 2016 as part of the UK Government's Industrial Strategy, outlines significant funding for industrial decarbonisation. As one of the four 'grand challenge areas' of the Strategy, the industrial decarbonisation programme is worth £170m, with an expectation of industry match-funding of up to £261m (UKRI, 2020). Subsidiary schemes under the fund include the Industrial Clusters Mission (BEIS, 2019b), and the Transforming Foundation Industries £8m innovation competition funding (with a further £66m in partnership investment from Government) (BEIS, 2020m).

Despite these funding commitments and increasing attention being given to industrial decarbonisation, as a recent UKERC report noted, 'policy initiatives are not joined up' and 'funding for specific projects and industrial clusters should be complemented by market creation policies' (UKERC, 2019, p. 1). Similarly, although funding may be available to industry in principle, there can be key barriers in both accessing funds and justifying match-funding where this is a condition.

Table 6: Summary of recent innovation policy.

Policy	Policy type	Lead time	Description
Clean Growth Equity Fund	• Investment finance	2019–2030s/40s	• £20m Government funding to develop a 'clean technology early stage investment fund', aiming to attract further private sector funding (BEIS, 2020l). • Encouraging investment to drive commercialisation in key technologies. • Subsidiary to the Energy Innovation Programme.
Transforming Foundation Industries	• Competition funding • RDD	2019–2024	• £5m funding for RDD projects in the foundation industries (including the cement, paper, glass, ceramics, metals, and bulk chemicals sectors) (Innovate UK and UKRI, 2019). • Subsidiary of the ISCF.
Industrial Fuel Switching Competition	• Competition funding • RDD	2018–2019	• Phased funding worth £20m to support research, feasibility studies and investment in low-carbon fuel switching processes and technologies (BEIS, 2020n).
Industrial Strategy Challenge Fund	• Funding • RDD	2017–various	• Contains a number of subsidiary schemes under three workstreams: deployment, clustering, the Industrial Decarbonisation Research and Innovation Centre (IDRIC).

2.1.1.5 Improving the efficiency of material and product use

Whilst there has been considerable emphasis on policies promoting the efficient use of energy, there is less evidence for consideration of the efficiency of material and product use.

Resource and material efficiency can be achieved on both the production and consumption side; that is, through both efficient design and manufacture (e.g. using modular design, and improving fabrication yields), and by reducing final demand for the end product or material (e.g. by improving longevity). There is therefore a need for a range of both demand pull and push measures. Improvements to material use have an estimated mitigation potential of 200 $MtCO_2e$ by the end of the 5th carbon budget period (i.e. 2032) (Green Alliance, 2018).

The existing focus on operational efficiency of final products and materials is clear in Table 7, largely through EU driven initiatives such as the Ecodesign and Energy Labelling Directives (BEIS and Office for Product Safety and Standards, 2017; BEIS, 2018b). There is evident scope for extending such policies to include material use and embodied carbon (Scott et al., 2017), and applying these new sources of material and product data to demand-side policies such as purchasing standards.

Table 7: Summary of recent policy towards improving the efficiency of material and product use.

Policy	Policy type	Lead time	Description
Plastic Packaging Tax	• Tax	2022–	• The proposed Plastic Packaging Tax (currently under consultation), will be applied to relevant imported or manufactured packaging with under 30% recycled plastic content (HMRC, 2020a).
Energy Information Regulations	• Regulation[14]	2011–ongoing	• Regulation requiring product suppliers to provide standardised performance data for labelling (BEIS and OPSS, 2017).
Government Buying Standards	• Purchasing guidelines/ standard	2011–ongoing	• Sustainable procurement guidelines for the public sector, designed with input from industry (Defra, 2017a). • The rules are mandatory for central government departments.

14 Implementing legislation for the Energy Labelling Directive (2010/30/EU).

Policy	Policy type	Lead time	Description
Ecodesign for Energy-Related Products Regulations	• Regulation[15]	2010–ongoing	• Regulation for operational emissions setting mandatory minimum requirements for product energy efficiency, particularly electrical products and appliances (Scott et al., 2017; BEIS, 2018b). • A recent CREDS response to the BEIS Call for Evidence on energy-related products suggested that an 'effective and cost-effective' approach in the UK post-Brexit is in the 'enhanced enforcement' of these regulations, and 'using existing regulations as a basis for additional UK-specific policy action' (Brocklehurst et al., 2020).
Producer Responsibility Obligations (Packaging Waste) Regulations	• Regulation[16]	1997–ongoing	• The regulations oblige packaging producers to recover and recycle waste, in alignment with targets established via the Packaging Directive (Defra, 2017).

2.1.1.6 Sectoral approaches

There are relatively few sector-specific policies in the UK, and funding appears increasingly sector-neutral, instead targeting generic user groups such as 'energy-intensive industries'. Whilst there is an Offshore Wind Sector Deal, there are no analogues to this for the manufacturing, NRMM, or FFPS sectors (BEIS, 2019f). As a result the CCAs mark the de facto sector-level approach. A notable exception is the recent Clean Steel Fund, worth £250m, focused on the implementation of new technologies and processes, in parallel to improving skills and growth opportunities in the sector (BEIS, 2019g).

2.2 Prospective net zero policies

A comprehensive literature review was undertaken to determine what policy mechanisms could be employed in addition to those in the baseline for the UK, in order to achieve net zero.

Business-as-usual policymaking remains far below what is required for net zero consistent industrial emissions. The CCC's recent Progress Report highlighted the 'policy gap between expected emissions and required reductions' according to official projections (BEIS, 2019h), and considered industrial decarbonisation policy to date as 'piecemeal and slow' (CCC, 2020, p. 19). By the end of the 5th carbon budget in 2032, CCC analysis indicates that the gap between government projections for total UK GHG emissions and an indicative path to the UK's net zero target could be as much as 100 $MtCO_2e$ (ibid).[17]

15 Implementing legislation for the Ecodesign Directive (2009/125/EC).

16 The Producer Responsibility Obligations (Packaging Waste) (Amendment) Regulations 2017 are implementing legislation for the original EU Packaging and Packaging Waste Directive (94/62/EC).

17 Note that this is true of total UK emissions, not only emissions from industry.

Tables 8 to 13 present key policies identified through literature review and engagement with industry, ordered by the mechanism type (since some policies could address more than one decarbonisation 'challenge').[18] The categories considered include: regulation, pricing, subsidies, finance, information, and voluntary. They are broken down to subcategories where applicable. There is evidently scope for some policies to fall within more than one category. International evidence of the policy mechanisms is also highlighted.

This is followed by a consideration of sectoral approaches for manufacturing, FFPS and NRMM.

2.2.1 Available policy mechanisms

2.2.1.1 Regulation

Whilst mandatory emissions targets are possible, a key form of regulation currently debated is the use of production and purchasing standards. Standards may be applied to producers or purchasers, and can be differentiated by whether they are voluntary or mandatory, the product stage to which they are applied (primary, intermediary or final products), and the type of obligation the standard imposes (CCC, 2020a). The obligation may take the form of direct regulation (on producers, purchasers, or developers), self-regulation (through compliance standards governed between sector bodies and government), or flexible regulation (an incentives/penalties framework that can be linked to existing pricing regimes) (ibid).

Approaches to mitigate the leakage associated with standards include Border Carbon Standards (BCSs), as discussed in Box 2.

Table 8: Typology of regulatory policies.

Policy	Description
Standards	
Production standard: Carbon disclosure	• Carbon disclosure is likely to be a component of any standard to facilitate monitoring. Carbon disclosure standards involve reporting the embodied emissions of a product, according to a set Whole Life Carbon Assessment (WLCA) methodology (typically managed by a standards body) (ibid).
Production standard: Carbon cap	• Standards have previously focused on operational emissions, for instance the UK's **Ecodesign for Energy-Related Products Regulations and Market Transformation Programme** (IEA, 2017; BEIS, 2018b). • Production standards with a carbon cap on embodied emissions, would capture the life-cycle impacts of products and materials, and could function to 'phaseout' emissions-intensive goods from the market. A Border Carbon Standard could function as a carbon leakage containment mechanism for the domestic product standard, where the same product requirements are imposed on imported goods at the border. • **Example: product standards for embodied carbon have been notably advanced in the construction sector, for example in their integration to building standards frameworks (AECOM, 2019; Zero Waste Scotland, 2020).**

18 The categories of mechanism were chosen with reference to OECD and IEA typologies. We recognise there may be other appropriate systems for categorisation (Warwick, 2013; IEA, 2020).

Policy	Description
Production standard: Non-carbon specification	• A non-carbon product standard could involve setting requirements for the content of recycled material in selected goods, or specifying other measures to lower the indirect embodied carbon content of the good (e.g. CCUS obligations) (CCC, 2020a). • **Example: the EU Circular Economy Action Plan sets out a 'sustainable product policy framework' considering initiatives to 'increase the recycled content in products' (European Commission, 2020).**
Purchasing standard	• Purchasing standards require the purchaser (public and/or private) to comply with regulation on the type of materials and products they acquire. • Purchasing standards may initially take the form of voluntary 'guidelines', before moving to a mandatory standard. The **UK Government Buying Standards** apply mandatory sustainability guidelines to central government purchasing, whilst acting as voluntary but encouraged guidance for the broader public sector (Defra, 2017a). • **Example: the Buy Clean California Act imposes a carbon cap on public procurement requirements within the state, by setting 'maximum acceptable' Global Warming Potentials (GWPs) for selected construction materials. Environmental Product Declarations must indicate lower than benchmarked embodied emissions to be eligible for state procurement (State of California, 2020; RICS, 2020).**
Energy performance standards	• This is a type of operational emissions standard, governing limits for the energy efficiency of products. • Examples include the **EU Minimum Energy Performance Standards** under the Ecodesign Regulations, which covered 41% of EU emissions in 2010 (Sonnenschein et al., 2019). In the **Top Runner scheme (Japan)** the most efficient products act as a benchmark for products in the succeeding year (Siderius and Nakagami, 2013).
Demand-side interventions	
Extended Producer Responsibility instruments	• Extended Producer Responsibility (EPR) schemes can reduce material demand by improving recycling and recovery rates. • EPR can involve product take-back requirements, advance disposal fees (ADFs), deposit refund systems (DRS), and is a principle of several EU waste directives (Pouikli, 2020). • For instance, **Advance Disposal Fees** internalise the cost of end-of-life treatment to the cost of the good (Neuhoff et al., 2018). • Other policy options to improve the longevity of products include reparability requirements, such as the **Right to Repair legislation** under the Ecodesign framework, and as is in progress in 20 US states (EC, 2019; Harrabin, 2019).
Building and planning regulations	• Regulation can incentivise or mandate low-carbon construction approaches in building design or retrofit. Building regulations may be implemented as a standard or may be in place as guidelines for industry best practice. • Building and planning regulation may be interlinked, as in the **Greater London Authority's guidance on Whole Life-Cycle Carbon Assessments** as part of its statutory spatial development strategy (Greater London Authority, 2020). Developers are required to assess the embodied as well as operational emissions of a project, and identify how these might be mitigated. • Planning regulation could be supportive of industrial decarbonisation on a regional basis, for instance in the development of industrial clusters and 'eco-innovation' parks. For example, in the UK **business rate reliefs** are applied as rebates when firms are located within **Enterprise Zones** (HM Government, 2020b).

2.2.1.2 Pricing instruments

Carbon pricing mechanisms are considered to be effective market-based approaches to internalising emissions costs and driving 'cost-effective mitigation' (Vivid Economics, 2019). However, pricing alone is seen as insufficient to address 'non-price barriers', and there are key concerns around setting a price level appropriate to drive ambitious decarbonisation (ibid).

Table 9: Typology of pricing policies.

Policy	Description
Carbon pricing mechanisms	
Carbon tax	• Carbon taxes 'place a set price per unit of emissions to help firms internalise the costs of emissions and face incentives for emissions reductions' (ibid). • Any carbon tax would need to evolve over time, and the use of tax revenues would be a key feature of its socio-political acceptability (Burke et al., 2019). Hypothecation of revenues towards reinvestment in low-carbon projects and policies is sometimes suggested as a means of achieving this (ibid). • **Example: British Columbia, a province of Canada, implemented a steadily rising carbon tax in 2008, covering 70% of its GHG emissions, with a revenue recycling mechanism directed to low-income households and industry at risk of carbon leakage (ibid). The tax is credited with emissions reductions of between 5 and 15%, suggesting the potential of a well-designed and publicly endorsed taxation regime (ibid).**
Emissions trading system: National / standalone	• Emissions trading systems are cap and trade schemes where eligible facilities trade emissions allowances according to the alignment of their emissions with predetermined annual 'caps'. • Carbon leakage mechanisms associated with ETS systems include the allocation of free allowances to trade-exposed industries. Methods of awarding allowances vary, and can involve either grandfathering, sectoral benchmarking, or output-based allocation (ESC, 2020).
Emissions trading system: Linked	• An option for the design of a UK ETS is a linkage with the existing EU ETS market. Linked emissions trading systems are considered to be more stable (Vivid Economics, 2019), so this is a favoured approach pending the outcomes of UK trade negotiations. • **Example: precedent for linked ETS systems is in the case of Switzerland, which implemented a Linking Agreement with the EU in 2020, effectively joining the two carbon markets (EC, 2019a).**
Tax mechanisms	
Accelerated depreciation	• Accelerated depreciation is a taxation approach aiming to incentivise investment in low-carbon assets, by deducting tax in the early stages of an asset's lifetime (Larkin, 2014). • **Example: in Peru, the Accelerated Depreciation Benefits apply a 20% depreciation for technologies in the renewables sector, and the technique has also been used as a green recovery mechanism (IEA, 2013).**
Material pricing mechanisms	• A Green Alliance report proposed either a **virgin material tax** and **material price stabilisation mechanism** in order to support the creation of value in the UK's secondary materials market (Green Alliance, 2018). • A material tax could encourage material recovery and reuse, by adding value to virgin material prices which can typically be low (ibid). A price stabilisation mechanism would act as a compensatory pricing system to uphold stable prices for virgin materials to better incentivise recycling, recovery and reuse (ibid). This could in effect act as a subsidy.

Policy	Description
Tax reliefs	• Tax reliefs can be delivered via rebates or credits, and directed towards specific decarbonisation measures, for instance specific RDD reliefs. They can also be applied at different levels, for example the product or technology level (capital allowances), or at the firm level (via business rates, VAT or corporation tax reliefs). • Existing corporation tax reliefs include R&D relief, marginal relief (a 'ringfenced' relief for profits from UKCS oil and gas), and capital allowances (HM Government, 2020c). • Capital allowances can be used to encourage investment in efficient or low-carbon technologies and products, by writing the cost of the investment against firms' taxable income (HMRC, 2018). The **UK's Enhanced Capital Allowances scheme (ECAs)** ran from 2001 to 2020, and permitted tax allowances for the purchase of products on an annually updated **Energy Technology List (ETL)** (ibid). • Tax reliefs could also be applied to the use of materials, for instance in **reductions to VAT for materials with lower embodied emissions** or which include a level of 'reprocessed material' (Green Alliance, 2018a). • **Business rate reliefs** could be used to incentivise the development of certain service-based business models, improving material efficiency and final demand for products (for instance, businesses operating in the hire and leasing, 'collaborative consumption' and product longevity space) (Zero Waste Scotland, 2020a)

Box 2: Mechanisms to minimise carbon leakage

Whilst a range of mechanisms to mitigate carbon leakage exist, Border Carbon Adjustments (BCAs) are currently receiving significant scrutiny.

However, there is considerable ambiguity in the literature in defining BCA mechanisms. Here we define BCAs (also known as Carbon Border Adjustments, CBAs) as the application of a price mechanism or regulation to imported goods at the border, on the basis of their carbon content (Sakai and Barrett, 2016). Variants include Border Carbon Standards, and Border Carbon Tariffs, and represent a form of embodied carbon standard and taxation mechanism respectively. BCAs are viewed as an equalisation measure, extending domestic standards to imported goods (ibid). There is considerable debate over the viability of implementing BCAs in the context of global trade law, and whether they would represent an effective anti-leakage policy.[19] The alignment of the BCA measure with the choice of broader domestic pricing or regulatory regime is a critical factor determining how effective it may be as a carbon leakage control mechanism.

A number of further mechanisms exist, and a recent report by Energy Systems Catapult examined the impact of carbon policies on competitiveness and carbon leakage (ESC, 2020). Mechanisms must be built into carbon policies to mitigate the risk of carbon leakage, and these mechanisms will necessarily vary by the carbon policy under consideration.

19 For instance, in the case of a domestic carbon price coupled with a Border Carbon Standard, whilst both imports and domestic production would be required to meet the standard, only domestic producers would be paying the carbon price in addition.

A process of subsidy based carbon policy, transitioning to the implementation of standards in the long-term, was viewed as a possible policy pipeline to manage leakage. The report also differentiates between the short-term risks to competitiveness from carbon policy, and the long-term potential for investment leakage.

Table 10 provides a summary of available leakage mechanisms according to the primary carbon policy implemented.

Table 10: Summary of leakage mechanisms according to carbon policy approaches (derived from ESC, 2020).

Carbon policy approach	Policy	Leakage mechanism	Description
Pricing	ETS	Cap and trade free allocation of allowances	The key mechanism to prevent leakage associated with ETS schemes is the allocation of free allowances to trade-exposed industry. There are various methods for allowance allocation, including: grandfathering; sectoral benchmarking; output-based allocation. • Grandfathering allocates allowances to industry based on historical emissions. It is a simpler approach more suited to the initial stages of an ETS. • Sectoral benchmarking involves allocation based on 'historical production and a product-specific benchmark of emission intensity' for the sector in question (ibid). • Output-based allocation is based on both the product-specific benchmark and actual production levels.
	Carbon tax	Exemption	Carbon leakage from a taxation approach may be managed through rebates or exemptions. Exemptions reduce or eliminate the cost of the carbon price to firms (ibid). The exemption may cover any percentage of the carbon price.
		Tax rebate	Rebates may either be direct (a subsidy), or indirect (a reduction in other tax commitments, e.g. VAT).
Regulation	BCA		See discussion above. This may also be considered a form of pricing (rather than regulation) to control leakage (when the BCA is a tariff).
Subsidy	Public procurement; Carbon Contracts for Difference (CCfD); direct funding		Subsidy policies (such as those listed) could be considered as mechanisms to reduce the risk of carbon leakage (if they are applied to those sectors and areas of industry most affected by carbon policy costs, and effectively counteract these costs). For example, procurement practices favourable to low-carbon production could effectively subsidise industry if public sector demand constitutes a key source of demand for the sector in question. If procurement had a strong enough demand pull effect to drive a new revenue stream for industry, it could be considered a form of leakage prevention.

2.2.1.3 Subsidies

Subsidies are a means of directly funding industrial decarbonisation measures, but can encounter state aid and acceptability issues depending how and where they are applied. For example, the elimination of subsidies for the fossil fuel sector is viewed as a critical target for decarbonisation, particularly at a time when global oil prices are historically low (Burke et al., 2020).

There are questions of definition in what constitutes a subsidy, for instance tax reliefs are often considered a form of subsidisation. The World Trade Organisation (WTO) defines a subsidy as a 'financial contribution by a government or any public body [...] which confers a benefit' (WTO, 2020).

Table 11: Typology of subsidisation policies.

Policy	Description
Carbon Contracts for Difference (CCfD)	Contracts for Difference (CfD) are considered 'investable' market instruments, encouraging large scale capital investments in low-carbon technologies and production by providing a guarantee of a stable price per unit of output (CCC, 2020, p. 95). CfDs are currently used to develop low-carbon electricity generation capacity in the UK, particularly offshore wind auctions. Participants in CfD schemes are paid a predetermined 'strike price' for the unit of output they deliver; over the period of the agreement, if the strike price falls below the reference (wholesale) price participants pay the difference whereas if the strike price is higher than wholesale prices participants receive a compensatory payment (BEIS, 2020o). A Carbon CfD would consider the unit of output delivered as the quantity of CO_2 avoided against a reference case, as in **proposed designs of CCfDs for CCS** using a functional unit of 'capture units' (Pöyry Management Consulting, 2016). CCfDs could also provide a stable carbon price for producers of low-carbon materials, where there currently is no such price (Sartor and Bataille, 2019).
Direct funding	Funding can be delivered directly to industry in the form of grants or competitions, and may be generally preferred to loans given the latter is considered a 'debt instrument' in business accounting. There is particular precedent for innovation funding for UK industry, often delivered via competitive grants targeted at different stages of the commercialisation process.
Early replacement, retirement, repurposing incentives	Incentives or compensations could be used for the early replacement, retiring, or repurposing of key assets or technologies before the end of their lifetime, where the net mitigation potential of new technologies is positive. This may be particularly appropriate in the UK where the age of capital stocks in industry tend to be older, and it is therefore key to time incentives in alignment with industrial investment cycles (IEA, 2020).

2.2.1.4 Financial instruments

Certain mechanisms could be considered a pricing mechanism (for instance, regulated returns), but in this context, they are treated as an investment mechanism for incentivising expenditure on large capital assets.

Table 12: Typology of financial policies.

Policy	Description
Instruments for investment	
Equity funds	Equity funds are a form of stock fund (as opposed to bond funds), that can be used to finance the capital costs of projects. The **EU's Taxonomy for Sustainable Finance**, implemented in 2020, is a recent example of attempts to direct 'capital flows towards sustainable investments' (EUR-Lex, 2020).
Export finance	Extended export finance mechanisms such as overseas investment insurance and loan guarantees could support UK industries seeking to export low-carbon technologies and products overseas (UK Export Finance, 2013). This could be a key measure in support of the UK's Industrial Strategy.
Green bonds	Green bonds are debt instruments designed to 'raise the necessary capital for a project that contributes to a low-carbon […] economy', and may take the form of 'asset backed securities' (ABS) or 'treasury-style bonds' (Corfee-Morlot et al., 2012). ABS bonds are linked to a specific project, whilst the capital in 'treasury-style' bonds is distributed across a 'portfolio of green projects' (ibid). Transition bonds pose another form of debt instrument issued to industries considered as 'brown' (rather than industries under the typical remit of 'green bonds') with the aim of driving decarbonisation – although there is ongoing debate around their intent and effectiveness.[20] **Example: the recently announced EU Green Bond Standard (GBS) is a voluntary standard to improve the quality and uptake of green bonds in the EU (EC, 2020b). It has been indicated that the UK will issue its first Sovereign Green Bonds in 2021, alongside the development of a 'green taxonomy' for sustainable finance (HM Treasury, 2020b).**
Loans	Soft loans (i.e. on favourable terms) could incentivise deployment of capital-intensive technologies. Conditional loans (loans in return for a specified improvement on behalf of industry) could also be developed, in extension of the debate on selective industry bailouts in times of recession.
Public Investment Banks	Public Investment Banks can be used to provide 'long-term strategic finance to high risk and capital intensive projects, crowding in future business investment' (Mazzucato, 2017). **Example: the UK Green Investment Bank (GIB), established in 2012, was a public investment bank targeting green infrastructure investment and aiming to leverage private sector funding. A total £2.8bn of direct investment and £8bn private investment had been raised in 2016, but despite this success it was subsequently privatised (Mazzucato and Macfarlane, 2017).**

20 That is, some argue that transition bonds could be seen as 'greenwashing' on the part of polluting industries (Gross and Stubbington, 2020).

Policy	Description
Risk reduction mechanisms	
Loan guarantees; credit lines	Loan guarantees, or 'credit lines', provide 'risk-sharing' mechanisms between industry and government to improve confidence and underwrite risk in making large capital investments (Corfee-Morlot et al., 2012).
Partial risk guarantees	Partial risk guarantees provide debt-servicing protection for private investors against a fraction of the loan amount. They are designed to 'balance risk allocation between government and private investors' and have commonly been used under the World Bank's Guarantees Programme for developing countries (World Bank, 2020). **Example: India's Partial Risk Guarantee Fund for Energy Efficiency (PRGFEE) covers 50% of the value of loans to participating financial institutions (PFIs) on energy efficiency projects (IEA, 2019).**
Regulated returns	Regulated return or Regulated Asset Base (RAB) models of investment are often considered a form of public-private partnership (PPP) (Makovšek and Veryard, 2016). RAB approaches underwrite the risk of investment in large capital projects by 'providing regulated returns to investors' and reducing 'the cost of raising private finance', as is under consultation for the UK nuclear sector (BEIS, 2019i).
Alternative business models	
Public ownership	Public ownership poses a finance model for capital-intensive projects. However, there is some suggestion that without private equity in large projects the incentive to 'outperform on efficiency' is reduced or lost (Helm, 2009).
Public-Private Partnerships	Public-Private Partnerships (PPPs) are a form of project financing and risk management, in a contractual agreement between government and industry. PPPs are commonly discussed for their potential application to infrastructure projects (Makovšek and Veryard, 2016). Sector deals could be considered a form of PPP.

2.2.1.5 Information-based tools

Information-based policies may attempt to address asymmetries in information between industry and government, between companies, or between industry and consumers. Lack of information on the part of government around the relative feasibility and cost of different decarbonisation measures can be a key barrier to designing targeted policy.

Knowledge sharing between companies can facilitate industrial symbiosis and identify market opportunities. Providing more product information to consumers can drive informed purchasing, especially where consumer interest in low-carbon goods is high.

Table 13: Typology of information-based policies.

Policy	Description
Knowledge sharing	Knowledge sharing can enable industry to identify appropriate sector-specific mitigation measures. It may also promote investor confidence (DECC/BIS, 2015, p. 93). 'Road-mapping' and planning activities can also be highly valuable in driving stakeholder engagement within and across sectors. **Example: although in the energy sector, the Carbon Trust Offshore Wind Accelerator (OWA) is an effective public-private innovation programme encouraging collaboration to reduce cost, address market barriers and develop industry standards. The OWA has reduced the cost of energy from a typical offshore wind project by 15% in 10 years (Carbon Trust, 2020).**
Support for IP protection; patent development	Support to provide safeguards for intellectual property (IP) and develop patents is a key mechanism to provide assurance to firms investing in innovation (Corfee-Morlot et al., 2012).
Demand-side interventions	
Data infrastructure	In order to identify opportunities for resource and material efficiency savings across the supply chain, data infrastructure in the form of reliable, robust, frequently updated data flows and indicators are required (Norman et al., 2020). A **National Materials Datahub** to be developed by the Office for National Statistics (ONS) has been proposed in order to track materials across the value chain in 'near real time' (Green Alliance, 2019). Delivery of this proposal or comparable data infrastructure for material efficiency could be a valuable policy approach. Digitalisation more broadly could be of significant value in achieving net zero; by improving data collection on manufacturing processes and products through smart monitoring and other data analytic approaches there is potential to optimise performance in terms of both energy and material efficiency. Digitalisation will increasingly be a key step in cutting costs and remaining competitive (Green Alliance, 2020). **Example: the Core Resource for Industrial Symbiosis Practitioners (CRISP), an online portal collating resource data from participants, underpinned the UK's National Industrial Symbiosis Programme (NISP) (Mirata, 2004). This highlights the role of appropriate data infrastructure to support material demand management.**
Industrial symbiosis schemes	The Ellen MacArthur Foundation defines industrial symbiosis as 'a local partnership where, partners provide, share and reuse resources to create shared value' (Ellen MacArthur Foundation, 2020). They highlight the case of the **Kalundborg Symbiosis project (Denmark)**, a public-private partnership delivering savings of €14m per annum to members (ibid). **Example: the UK National Industrial Symbiosis Programme (NISP) (2005-2014) was a Defra-funded voluntary agreement identifying material flows between participating firms. It saved 7.9 million tonnes of raw materials and created savings for members of £131m from 2005 to 2009 (EC, 2009).**

Policy	Description
Labelling protocols	Operational energy performance labelling is currently legislated under the **Energy Labelling Directive**, but product labelling could valuably be extended to cover embodied carbon content. Labelling informs consumer demand for products, and successful schemes require standardisation over a range of products for comparability. Embodied emissions labelling is currently implemented mostly on a company-by-company basis, for example in **Quorn's use of labelling on its products (Quorn Foods, 2020). Denmark has also considered implementing carbon footprint labelling for food products (Quackenbush, 2018).**

2.2.1.6 Voluntary agreements

Voluntary agreements are a form of negotiated agreement between industry and government, on a company or sector basis. Negotiated voluntary commitments often include a linked incentive such as a reduction on an existing business rate or levy, or else a form of positive incentive. A key example is the UK's CCAs, linked to the CCL. A comparable approach is the Long-Term Agreements (LTAs) scheme for energy efficiency improvements in the Netherlands; in the LTAs, required final energy savings are specified at the firm-level and the government identifies how it can remove barriers to the firm delivering the energy savings (IEA, 2019a). The scheme has been attributed with an estimated 25-50% of efficiency gains in the manufacturing sector (Rietbergen et al., 2002). However, there is scope for considering voluntary agreements which could act over a longer time horizon to improve the security of policy signals and the strength of industry commitments. Many of the policies listed in the preceding section could have voluntary variants.

Box 3: International dimensions of decarbonisation

Some policies would require or be enhanced by processes of international negotiation and/or collaboration. Some domestic policies would have significant impacts on the UK's export markets, and potentially put the UK at competitive disadvantage. Conversely, processes of international negotiation may be required for policies seeking to level the international playing field in terms of carbon leakage and competition. There are several international dimensions to UK industrial decarbonisation policy:

- **State aid**: such provisions are in place at the international level to avoid distorting competition between states by use of subsidies and other preferential measures. Although the future applicability of EU state aid rules post-Brexit is as yet unclear, the UK may have more freedom over its use of subsidies. However, it would still be required to comply with WTO level state aid rules, although these rules have a tighter definition of what constitutes a 'subsidy' and require demonstration of 'actual harm' to competition to be applicable (Institute for Government, 2020).

- **Negotiation**: contentious policy that could affect international trade could be challenged by WTO members. This is considered likely for mechanisms such as BCAs, where risks include the effects on developing and exporting nations, and the potential for retaliatory tariffs if the measure is viewed as a form of protectionism (Holmes et al., 2011; Fouré et al., 2016). The design of the BCA is the key factor in the 'compatibility' of the measure with WTO law (Sakai and Barrett, 2016).
- **Ambition**: as with the UK's legislation of a net zero target, there is potential for the UK to maintain its climate leadership role with a strong industrial decarbonisation strategy. In the lead up to the UK's COP26 presidency, upscaling the ambition of the UK's Nationally Determined Contribution (NDC) under the Paris Agreement would signal a radical level of ambition on the global stage. With the UK's departure from the EU, there is need to maintain a comparable level of ambition. For example, the EU's Green Deal policies suggest an agenda-setting and experimental level of ambition in terms of decarbonisation policy.

International cooperation could benefit UK industrial decarbonisation, and by extension the global mitigation effort, in several ways:

- **Sharing expertise and costs**: collaborative international innovation could reduce the cost burden of RDD and large capital projects. For instance, as in the approach taken in the Mission Innovation initiative. Cost and technology sharing initiatives would widen the evidence base for novel technologies, thus increasing confidence to invest and accelerating deployment (IEA, 2020b).
- **Innovation and technology transfers**: sharing technologies and expertise with nations with more emissions-intensive industrial production is a way of contributing towards decarbonisation at the global level.
- **Leveraging better quality standards**: the inclusion of embodied emissions in product and purchasing standards, and their application to international trade could be an important step in driving reductions to consumption-based emissions. Agreement on international standards for embodied carbon disclosure would ensure a degree of consistency in the reporting methodology, provide greater confidence in any caps set, and contribute towards reducing leakage (CCC, 2020a).
- **Harmonised policy approaches**: this is particularly important for products with strong export markets.
- **Linkages to international carbon markets**: linking a prospective UK ETS to an international scheme (e.g. the EU ETS) is seen as a means of guaranteeing price stability, and would necessitate further international collaboration (Vivid Economics, 2019).

2.2.2 Addressing industrial decarbonisation challenges

Table 14 first indicates how the policies address each challenge area (as identified in Table 2), an exercise we carried out to map which policies might fit together in a package. Much of the effect on the demand-side will depend on the inclusion of Whole Life Carbon Assessment (WLCA) and embodied approaches into the policy design.

There are many ways to implement the outlined policies, which will impact their effectiveness. To reflect this, in the table we have indicated where the impact of a policy on a challenge would be dependent on the specific policy design. Whilst this would be true in most cases, we have identified here where it would make particular difference. A tick suggests where the policy would contribute to the decarbonisation challenge.

Table 14: Mapping policy options against industrial decarbonisation challenges.

Key	
✓	Contributes to achieving the challenge
	No effect on challenge
	Weak effect on challenge
	Moderate effect on challenge
	Strong effect on challenge
	Conditional effect on challenge

Policy type	Policy subcategory	Policy	Decarbonisation challenges: Overarching carbon reduction incentive	Deployment and coordination of infrastructure	Improvements to existing technologies and assets	Incentives for innovation	Improvements in efficiency of material and product use
Regulation	Standards	Production standard: Carbon disclosure	✓		✓		✓
		Production standard: Carbon cap	✓	✓	✓	✓	✓
		Production standard: Non-carbon specification	✓	✓	✓	✓	✓
		Purchasing standard	✓	✓	✓	✓	✓
		Energy performance standards	✓	✓	✓	✓	
	Demand-side interventions	Extended Producer Responsibility instruments	✓	✓	✓	✓	✓
		Building and planning regulations	✓	✓	✓	✓	✓

Policy type	Policy subcategory	Policy	Decarbonisation challenges				
			Overarching carbon reduction incentive	Deployment and coordination of infrastructure	Improvements to existing technologies and assets	Incentives for innovation	Improvements in efficiency of material and product use
Pricing	Carbon pricing mechanisms	Carbon tax	✓	✓	✓	✓	✓
		Emissions trading system: National/ standalone	✓	✓	✓	✓	✓
		Emissions trading system: Linked	✓	✓	✓	✓	✓
	Tax mechanisms	Accelerated depreciation	✓	✓	✓	✓	✓
		Material pricing mechanisms	✓				✓
		Tax reliefs	✓	✓	✓	✓	✓
Subsidies		Carbon Contracts for Difference (CCfDs)	✓	✓	✓	✓	✓
		Direct funding	✓	✓	✓	✓	✓
		Early replacement, retirement, repurposing incentives	✓	✓	✓	✓	✓
Financial instruments	Instruments for investment	Equity funds	✓	✓	✓	✓	✓
		Export finance	✓	✓	✓	✓	✓
		Green bonds	✓	✓	✓	✓	✓
		Loans	✓	✓	✓	✓	✓
		Public Investment Banks	✓	✓	✓	✓	✓
	Risk reduction mechanisms	Loan guarantees; credit lines	✓	✓	✓	✓	✓
		Partial risk guarantees	✓	✓	✓	✓	✓
		Regulated returns	✓	✓			
	Alternative business models	Public ownership	✓	✓	✓	✓	✓
		Public-Private Partnerships	✓	✓	✓	✓	✓
Information-based tools		Knowledge sharing			✓	✓	✓
		Support for IP protection; patent development			✓	✓	✓
	Demand-side interventions	Data infrastructure					✓
		Industrial symbiosis schemes					✓
		Labelling protocols					✓
Voluntary		Voluntary agreements	✓	✓	✓	✓	✓

2.2.3 Sectoral approaches

2.2.3.1 Manufacturing

The heterogeneity of the manufacturing sector limits the application of blanket policy approaches. The manufacturing sector in the UK represents 20% of industrial emissions (ONS, 2020), but sub-sectors differ in the degree of their exposure to trade, competitiveness risks and carbon leakage.

General challenges for manufacturing sub-sectors include decarbonisation at lowest cost, the degree to which a low-carbon premium can be incorporated in final products, and the risk of how far costs may be transferred across the value chain to consumers. This cost pass-through to consumers may be more limited in manufactured products, than for instance in the energy sector. Where costs are transferred business to business (B2B), there is need to consider how flexible clients might be in terms of alternative procurement and the danger of purchasing leakage. Other barriers include the availability of deep decarbonisation technologies and fuels, since radical decarbonisation in many sectors is reliant on the availability of hydrogen and CCUS, and improving the economic viability of capital-intensive mitigation technologies.

Table 15 outlines a series of principles for future policy design of particular application to the manufacturing sector. These were identified through consultation with the Steering Group in the form of workshops.

Table 15: Overview of principles for industrial policy design.

Principle	Issue	Solution(s)
Streamlined policy	Policies should aim not to impose disproportionate administrative burden on industry, particularly in terms of the cumulative burden of multiple policies. This is particularly problematic for energy-intensive industries facing several sources of policy costs. The potential for 'double regulation', and overlapping and competing policy priorities must be avoided. This can be obscured when the policy costs and administration are applied to different parts of the industry's operations. Since unmanageable energy costs could drive carbon leakage, the resultant energy costs as a result of multiple decarbonisation policies should be evaluated.	Evaluation of the cumulative impact of policies should be carried out, across a company's operations. For example, in policy impact assessments, Government should evaluate the cumulative burden resulting from the design of any new policy, considering the additional value of that policy to the existing policy landscape. Varied delivery mechanisms may best avoid the cumulative policy burden on industry, particularly with regards to small operators (i.e. there are choices around the extent to which the measure is paid for via taxation or through other pricing routes). Support could be targeted to managing energy costs throughout any transition period, where appropriate.

Principle	Issue	Solution(s)
Clear signals and incentives	In light of uneven policy signals in the recent past, industry may be unwilling to act and invest.	Strong cross-party, cross-departmental, and cross-governmental commitments to industrial decarbonisation, and policies with longer lead times could be useful approaches. Clear policy with defined targets for long-term action would act on the perceived risk of investing. Timelines for policy implementation could be shared with industry to allow space for planning and even anticipatory action.
Logical sequencing and built-in flexibility	Some decarbonisation measures have long lead times for commercialisation, and large capital costs. There is potential for unintended policy effects and variable market response.	Action to de-risk and invest in technologies and fuels with long lead times for development should be a priority, and 'front-weighting' such investment could be appropriate. Flexible policy design through phased structures (e.g. in rounds, competitions, setting periodic review points) would be better able to respond to changing evidence (e.g. new cost data and feasibility analyses) and action taken by industry to decarbonise. Continuous consultation with industry would help to monitor effectiveness. Where policy is adaptive it may usefully generate information to improve learning for market actors and regulators.
Matching supply and demand	Demand-driving policies (e.g. public procurement) have varying influence per sector. There are key questions around how demand reducing policies (e.g. material efficiency) can realise added value for industrial sectors.	Procurement strategies should be configured on a sector-specific basis. Demand-driving policy shouldn't precede the available supply of the low-carbon material or product in the UK. Material efficiency can add value to UK industry by reducing dependence on imports and upscaling the ability of UK industry to meet domestic demand. There is a key role for material efficiency in the UK's industrial strategy.
Outcome-driven policy	There is a possible risk of policy 'picking winners' (technologies, fuels, sectors) and engendering lock-in to specific decarbonisation pathways. This may be unavoidable in some cases, particularly for early-stage RDD.	It was identified that it could be more appropriate to specify desired policy outcomes than the measures required to meet those targets. This would allow industry to identify the most viable solutions for their particular sector.

Although Section 2.1 largely considered UK policies applied to the manufacturing sector in general, there are additional policy considerations for the FFPS and NRMM sectors. Policy is often differentiated by emitter size, but there is a need to recognise sector-specific requirements. Boxes 4 and 5 provide a summary of policy perspectives on the FFPS and NRMM sectors respectively, informed by stakeholder workshops and literature review.

Box 4: Fossil Fuel Production and Supply

Upstream oil and gas operations accounted for 4% of UK GHG emissions in 2018 (Oil and Gas UK, 2020, p. 12), representing a key mitigation target for net zero. Key activities to decarbonise the sector in the UK involve improving efficiency, reducing methane flaring, assessing opportunities for integration with renewable generation, and decommissioning emissions-intensive facilities (OGUK, 2019). Concerns for the sector are focused on carbon leakage and the impact of decarbonisation on employment across the value chain.

Concern has been expressed over the nature of the North Sea Transition Deal, a review into the 'UK offshore oil and gas licensing regime' (BEIS, 2020p). Oil and Gas UK, the trade association for the offshore oil and gas sector, recommend collaboration with government on a sector deal for implementing integration opportunities (OGUK, 2020a). A critical need is viewed as the accessibility and integration of key infrastructure such as hydrogen and CCUS. Integration encompasses platform electrification (through networking with offshore renewables), offshore gas use for electricity generation, 'sharing infrastructure' with offshore renewables, and repurposing offshore infrastructures for CCUS and hydrogen applications (OGA, 2019).

The first phase of the Energy Integration Project, 'a scoping study […] to consider the technical feasibility of oil and gas assets, combined with renewable sources, to enable the transition to a low-carbon economy', was recently completed (ibid). Building on existing work identifying opportunities for integration and developing targeted policies to implement integration projects could be a key area for future focus.

Box 5: Non-Road Mobile Machinery

NRMM constitutes a relatively small proportion of UK emissions, at 6.4 $MtCO_2e$ in 2018 (NAEI, 2020).[21] However it is typically excluded from assessments of industrial decarbonisation, and is structurally different from the 'manufacturing' sector in several ways, meaning a number of sector-specific characteristics must be taken into account in the framing of relevant policy. As identified in the introduction (Section 1.2), further work is required to outline these sector-level policy needs.

The sector is characterised by high capital costs, equipment with long lifetimes, and a strong international dimension.[22] As such, the impact of any policy on the export market for NRMM must be taken into account. Similarly, the decarbonisation measure will be dependent on the NRMM equipment in question, of which there are many types and applications, often determined by the site type and purpose. Key strategies to decarbonise the sector include improving operational efficiency, optimising equipment design, and using alternative fuel sources (CECE and CEMA, 2018).

21 Data is for 'industrial off-road mobile machinery'.

22 Equipment may often be sold on early in its lifetime to international customers, reducing the effective life of the equipment in the UK.

Operating costs in the NRMM sector are dominated by fuel costs, meaning efforts to reduce fuel consumption are a priority. This also confers commercial advantage, driving corporate action to continuously improve the performance of NRMM equipment; for instance in the use of smart productivity tools marketed by NRMM manufacturers, increasing fuel and material efficiency through automation and tracking (CAT, 2020; Komatsu, 2020).

Two policy dimensions apply to the NRMM sector: the management of operational emissions from NRMM equipment, and its embodied emissions. It has been suggested that NRMM regulation to date has been oriented to air pollution reduction rather than emissions mitigation, for instance in regulation covering pollutant emissions rather than CO_2 (Bellona, 2020). A number of policy suggestions are outlined in the literature, including:

- Regulating CO_2 emissions in addition to pollutant emissions (IEA Advanced Motor Fuels Technology Collaboration Programme, 2018; Bellona, 2020).
- Implementing demand-driving mechanisms for low/no emission equipment (i.e. alternative fuelled vehicles), for instance via public procurement tools (Bellona, 2020).
- Phasing out conventional fuelled NRMM equipment. Given the length of equipment lifetimes however, appropriate incentives would need to be in place to support the transition (ibid). Low emissions equipment is also estimated to cost 20-30% more than current equipment, meaning appropriate price incentives must be in place to support demand for alternative vehicles and reduce costs in the long-run (ibid).
- Variable fuel taxation, mandatory fuel blend targets, and support for retrofitting have also been posed as possible policy solutions (IEA Advanced Motor Fuels Technology Collaboration Programme, 2018).

To address the embodied emissions of NRMM manufacture, where appropriate, incentives should be in place to encourage replacement of low-performing equipment before the end of its lifetime, where there is a clear net mitigation benefit. Early retirement incentives could be appropriate in this case. A further policy need is in improving the access and availability of decarbonised fuel, and similarly to support the development of alternative fuel vehicles capable of operating in the NRMM sector.

Other feasible policies towards NRMM decarbonisation include planning regulations and zoning to set limit values on emissions from NRMM equipment in construction, mandatory assessment and reporting standards, and mandatory public sector contractor reporting requirements. The London Low Emission Zone for NRMM (London Assembly, 2020) sets specific pollutant emissions limits for various subcategories of NRMM equipment, and requires site users to report via an online register. Extensions to such schemes to cover CO_2 emissions would need to account for the variable type and use of NRMM equipment. Replication of the scheme in other Local Authority regions, and reductions to limit values over time could encourage continuous improvement in line with industry best practice and the availability of appropriate alternative equipment.

2.2.4 Policy options evaluation

Since we identified that there is limited empirical evidence on the effectiveness of individual decarbonisation policies, we conducted a qualitative appraisal of the relative strengths and weaknesses of the policy mechanisms discussed above. We designed and distributed an online survey to members of the CCC Steering Group for input on how policies in the review could be evaluated (see Appendix, Section 6.2.). In the survey we grouped policies by the challenge they addressed, and by their policy instrument type. In the following evaluation, we consider the effect of individual policies by broad instrument type (according to the structure of Section 2.2.1). This was informed by the responses to the survey, but may differ given the extended range of evaluation criteria considered in the current assessment. The policies are not assessed for their specific implications for individual sectors.

Table 16 provides a scoring guide of typical responses for each evaluation criterion (identified in Table 3, Section 1.3.2.2.), to aid consistency in the scoring approach.[23]

Table 16: Scoring guide for assessing policies (and policy packages) against the evaluation criteria.

Criteria	Strong negative	Negative	Positive	Strong positive
Implementation time	• Highly complex. • Long lead times for implementation. • Mitigation benefits realised after 15+ years.	• Complex, but with precedent. • Delivery in the medium-term. • Mitigation benefits realised in the next 10-15 years.	• Minimal additional policy effort. • Delivery in the near-term. • Mitigation benefits realised in the next 5 years.	• Adjusts existing policy processes. • Short lead time for delivery. • Mitigation benefits realised in the next 2 years.
Technical feasibility (inc. measurability)	• Requires significant new data and/or metrics. • Significant uncertainties in the MRV methodology.	• New data required, metrics reasonably well established. • Some uncertainties in MRV methodology.	• Some new data required. • Metrics and MRV methodologies are well established.	• Existing data/ metrics can be used. • Well established MRV methodologies.
Political/legal challenges	• Likelihood of significant political and/or legal opposition or challenge.	• Likelihood of some opposition. • Unlikely to receive legal challenge.	• Political support in place. • No precedent for legal challenge.	• Significant political support. • No clear basis for legal challenge.
Cost to taxpayer	• Significant costs to taxpayers.	• Some cost to taxpayers.	• Potential to generate revenue.	• Potential to generate significant revenue.

23 The scoring guide is aligned with that used in ESC, 2020.

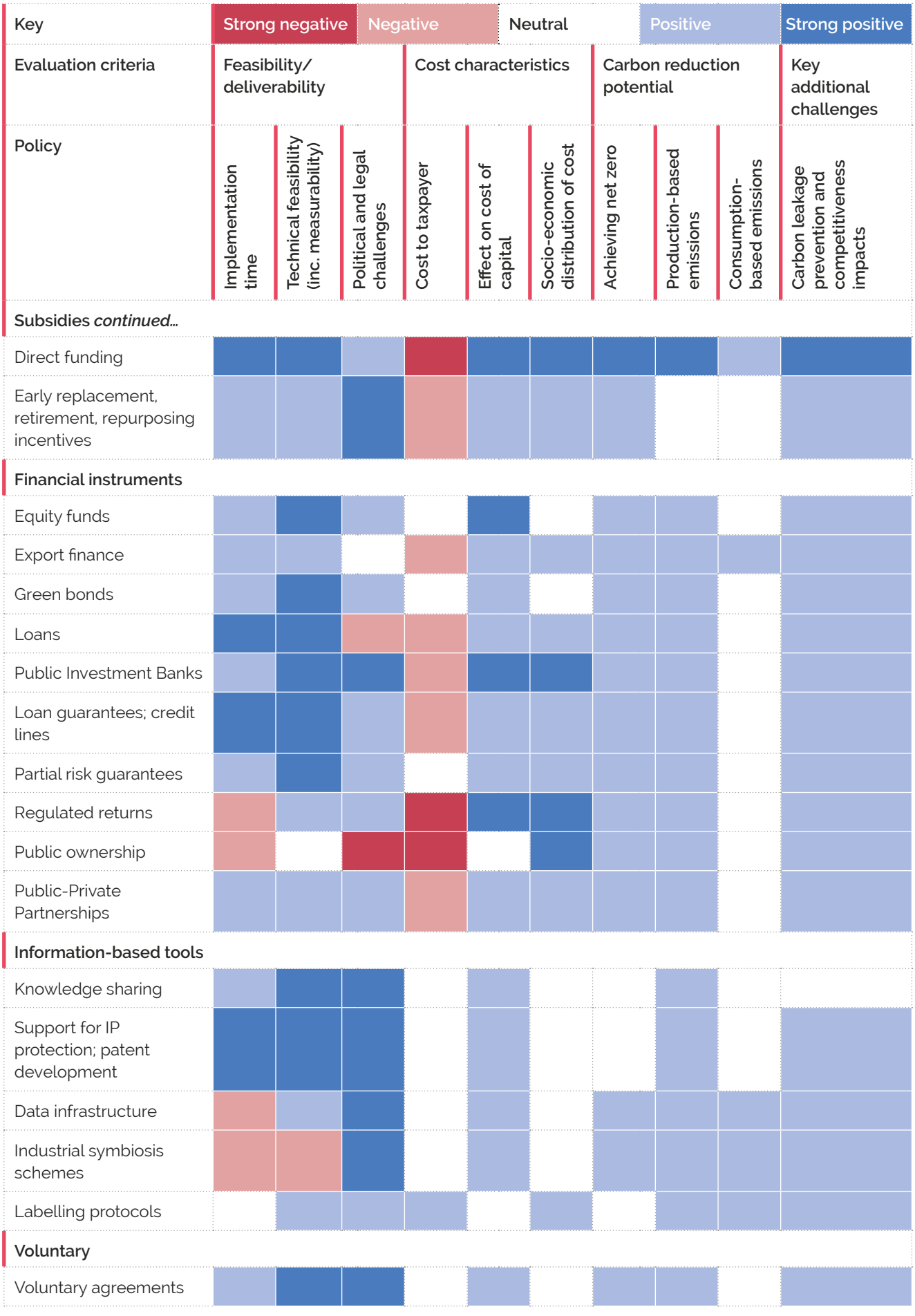
Criteria	Strong negative	Negative	Positive	Strong positive
Effect on cost of capital	• Creates highly uncertain signals. • Significantly affects willingness of industry to invest in capital costs.	• Creates weak signals. • Affects industry willingness to invest in capital costs.	• Creates moderate signals. • Moderate incentive to invest in capital costs.	• Creates clear signals. • Strong incentives to invest in capital costs.
Socioeconomic distribution of cost	• Highly regressive distribution of costs. • Costs borne entirely by industry/ consumers.	• Somewhat regressive distribution of costs. • Costs borne mostly by industry/ consumers.	• Reasonably progressive distribution of costs. • Costs mostly borne by taxpayers.[24]	• Highly progressive distribution of costs. • Costs borne entirely by taxpayers.
Achieving net zero	• Insufficient incentives for net zero consistent mitigation by 2050.	• Weak incentives for net zero consistent mitigation by 2050.	• Some incentives for net zero consistent mitigation by 2050.	• Strong incentives for net zero consistent mitigation by 2050.
Production-based emissions	• Does not address major production-based emissions sources from UK industry.	• Only addresses some major production-based emissions sources from UK industry.	• Addresses most major production-based emissions sources from UK industry.	• Addresses all major production-based emissions sources from UK industry.
Consumption-based emissions	• Significantly increases the UK's consumption-based account. • Strongly encourages imports from emissions-intensive regions.	• Increases the UK's consumption-based account. • Encourages imports from emissions-intensive regions.	• Reduces the UK's consumption-based account. • Discourages imports from emissions-intensive regions.	• Significantly reduces the UK's consumption-based account. • Strongly discourages imports from emissions-intensive regions.
Carbon leakage and competitive-ness impacts	• Significantly damages the competitiveness of UK industries in international and domestic markets. • Induces carbon leakage in a number of sectors.	• Damages the competitiveness of UK industries in international and domestic markets. • Induces carbon leakage in certain sectors.	• Improves the competitiveness of UK industries in certain sectors and markets. • Limits the carbon leakage of UK industry.	• Improves the competitiveness of UK industries in most sectors and in international and domestic markets. • Actively mitigates the carbon leakage of UK industry

24 Where policy costs are borne by taxpayers there is a degree of control over distributional outcomes. When applied almost entirely to either industry or consumers the negative distributional outcomes could be more difficult to mitigate. General taxation approaches to funding carbon policy have been suggested as more equitable (Owen and Barrett, 2020).

Table 17: Indicative performance matrix scoring policy options against evaluation criteria.

Key	Strong negative	Negative	Neutral	Positive	Strong positive

Evaluation criteria	Feasibility/ deliverability			Cost characteristics			Carbon reduction potential			Key additional challenges
Policy	Implementation time	Technical feasibility (inc. measurability)	Political and legal challenges	Cost to taxpayer	Effect on cost of capital	Socio-economic distribution of cost	Achieving net zero	Production-based emissions	Consumption-based emissions	Carbon leakage prevention and competitiveness impacts
Regulation										
Production standard: Carbon disclosure										
Production standard: Carbon cap										
Production standard: Non-carbon specification										
Purchasing standard										
Energy performance standards										
Extended Producer Responsibility instruments										
Building and planning regulations										
Pricing										
Carbon tax										
Emissions trading system: National/ standalone										
Emissions trading system: Linked										
Accelerated depreciation										
Material pricing mechanisms										
Tax reliefs										
Subsidies										
Carbon Contracts for Difference (CCfDs)										


Key
Strong negative
Negative
Neutral
Positive
Strong positive
Evaluation criteria
Feasibility/ deliverability
Cost characteristics
Carbon reduction potential
Key additional challenges
Policy
Implementation time
Technical feasibility (inc. measurability)
Political and legal challenges
Cost to taxpayer
Effect on cost of capital
Socio-economic distribution of cost
Achieving net zero
Production-based emissions
Consumption-based emissions
Carbon leakage prevention and competitiveness impacts
Subsidies continued...
Direct funding
Early replacement, retirement, repurposing incentives
Financial instruments
Equity funds
Export finance
Green bonds
Loans
Public Investment Banks
Loan guarantees; credit lines
Partial risk guarantees
Regulated returns
Public ownership
Public-Private Partnerships
Information-based tools
Knowledge sharing
Support for IP protection; patent development
Data infrastructure
Industrial symbiosis schemes
Labelling protocols
Voluntary
Voluntary agreements

The scoring of standards assumes the incorporation of a carbon leakage mechanism (e.g. BCS), or else uniform implementation across domestic and imported goods by some means. The policy could otherwise cause carbon leakage. Equity funds could have variable impact on 'cost to taxpayer' and other cost characteristics, according to the degree of private to public investment. This is a clear case of where policy design would have direct impact on the policy's effect. In the case of funding regimes (e.g. financial instruments) there could be political challenge around the allocation of funds, particularly if it is seen to 'pick winners'.

Certain caveats to the effectiveness of the above policies were identified in the stakeholder survey. The following provides a summary of key industry concerns regarding specific policy types.

Regulation:

- Disclosure is sometimes considered a weaker driver of decarbonisation, unless coupled with standards or applied to companies not otherwise covered by policies with a strong reporting requirement (e.g. the CCAs, EU ETS). Disclosure is only considered a useful policy where there are readily identifiable options for improving performance, which are also economically viable. The survey revealed a general sense that existing disclosure policy was sufficient, or else could be extended (e.g. broadening eligibility criteria for the Streamlined Energy Carbon Reporting framework) (BEIS, 2018c). This is not likely to be true of whole life carbon disclosure however, where existing reporting is fairly weak and voluntary.
- Standards were considered a valuable policy when appropriately sequenced, that is, if they are applied once significant barriers to decarbonisation are removed or once key decarbonisation technologies become commercially available.
- Similarly, applying standards to a few key products before widening the scope of their application was considered appropriate. Voluntary standards were considered a weak mechanism unless there was a market premium for a low-carbon good.
- Demand-side instruments (e.g. EPR) were not considered to provide sufficient incentive towards decarbonisation in isolation, but could work well in complement to other policies.
- Regulation was considered as more favourable once certain barriers to decarbonisation had been removed by other policy, for instance the availability of capital to invest in low-carbon technologies.

Pricing:

- The current ETS scheme was considered to be highly uncertain, affecting the ability of industry to plan ahead.
- A further concern was the potential risk for price disparities between any standalone ETS and the EU ETS, which could create competitiveness issues.
- An ETS was on the whole considered favourably in comparison to a carbon tax, given the ability of the policy to determine the level of emissions at a national scale.

Subsidies:

- CCfDs were considered an important near-term policy, which could be particularly viable for large, first-of-a-kind projects. However, a need to address the competition between different materials and sectors was identified, and it was noted that CCfDs applied to products can be more difficult to manage than those applied for electricity generation.
- Support was indicated for replicating the dedicated sectoral approach to innovation in the steel industry, as demonstrated by the Clean Steel Fund.

Financial:

- The need for strong support for initial infrastructure demonstration projects was highlighted; investment mechanisms and subsidies were seen as important to overcome the lack of market incentive to develop infrastructures with industrial applications.
- Loans were less preferred given their appearance on company balance sheets, and acting as a debt instrument.

Information:

- Business-to-consumer (B2C) rather than business-to-business (B2B) labelling was considered more effective.

The survey also highlighted that there would likely be a need for most of the policy options outlined, given the heterogeneity of industry. It was also suggested that setting appropriate policy targets, particularly on embodied emissions (e.g. a consumption-based carbon budget), should be a precursor to designing policies around embodied emissions (e.g. through whole-life carbon disclosure and standard-setting). Although a consumption-based target does not suggest the policies you need to address the UK's carbon footprint, it could set a level of ambition and expectation about future policy. A consumption-based target would emphasise the importance of UK mitigation in global perspective, and effectively account for carbon leakage risks.

3. Policy packages towards net zero

3.1 Constructing policy packages

In practice, combinations of policies that collectively address the various industrial decarbonisation challenges (Table 2) will be needed to deliver emissions reductions. Developing a 'policy strategy' in which policies work collectively to create effective incentives towards decarbonisation could be a valuable approach. We define a 'policy package' as a group of policy instruments which strategically drive decarbonisation by acting across the industrial challenge areas. These policies should work together, both complementing each other and mitigating any drawbacks that may arise if a policy was implemented in isolation. Therefore, there should be some underlying logic tying together the different policies, as opposed to piecemeal implementation tied to specific short-term political needs.

A series of core aims that each package would try to address were identified. They provided a guide to the construction of the packages, but the impact of the packages on these areas would be contingent on the specific design of individual policies. The packages would hypothetically aim to:

- **Act on each key decarbonisation challenge** (as previously identified);
- **Address key market failures** to stimulate decarbonisation;
- **Mitigate the risk of carbon leakage** in trade-exposed sectors;
- **Provide incentives to all critical decarbonisation measures** (e.g. energy efficiency, fuel switching, CCUS, resource and material efficiency);
- **Distribute policy costs reasonably, and even progressively**, across industrial, government and other public actors;
- **Avoid policy inefficiency**, aiming to introduce additionality beyond existing policies.

Carbon policies (e.g. regulation, pricing, or subsidies) are likely to provide leading signals for industrial decarbonisation, by providing an overarching regulatory or incentives framework to drive action and investment.

Including mechanisms that mitigate carbon leakage in the design of such policies is critical to ensure UK competitiveness. Complementary policies are required to 'fill gaps' in the incentive and penalty structures the carbon policies provide, as well as addressing specific and sectoral market failures the carbon policies are not well suited to reach. We also considered that in every case a series of 'enabling policies' would be required; enabling policies include skills and training investment to support an appropriate jobs strategy towards decarbonised manufacturing. This also extends to policies to encourage the deployment of industrial infrastructures, such as CCUS networks and provision of green hydrogen supply. Enabling policies are considered as structurally different to carbon and complementary policies, given they are a necessary part of any package. We consider socioeconomic policies further in Section 4. Table 18 outlines these constituent elements of a policy package.

Carbon pricing alone is insufficient to achieve net zero, without complementary policies for innovation, infrastructure and other long-sighted challenges (Neuhoff et al., 2019). Reflexively, policies for innovation, infrastructure etc. are not capable of achieving net zero without an accompanying carbon price, costing the climate externality (or else the use of regulatory policy) (Bowen, 2011).

The concept of 'policy packages' is drawn from and builds on the 'policy mix' literature, and other key studies (Rogge and Reichardt, 2016; Bataille et al., 2018; Neuhoff et al., 2018, 2019). Such work typically identifies both a selection of key policies as well as a set of guiding principles for the integration of industrial decarbonisation policies. Our work aims to provide an illustrative sense of how packages could be constructed, but is necessarily conducted at a high-level to manage complexity. Further future work could involve a more detailed assessment of the relative feasibility of each policy and package option, and implications for specific sectors.

Table 18: Elements in a strategic 'policy package'.

1. Overarching carbon policies	• Including appropriate sector-specific mechanisms to control carbon leakage
2. Complementary policies	• Policies improving the performance of existing technologies and assets • Policies driving the development and deployment of new technologies and fuels • Policies improving the efficiency of material and product use
3. Enabling policies	• Policies to support a low-carbon industrial jobs strategy • Policies to drive the deployment and coordination of industrial infrastructures

3.1.1 Policy principles

By considering 'policy packages' rather than discrete policy mechanisms, it is possible to build strategic oversight into policy planning for net zero. We develop a series of illustrative policy packages to suggest how this approach might work.

In constructing the packages we attempt to take into consideration the principles outlined in Table 15 (Section 2.2.3.1.), though how the packages comply with the principles would be a question of more detailed policy design. It is clear that there is no one 'perfect' policy package, hence our use of the term 'illustrative'. All policy packages will have strengths and weaknesses and have varying impacts on different sections of society (i.e. taxpayers, industry, consumers). The potential number of different policy packages is clearly also very large. Therefore in our work we have developed a small number of policy packages that aim to illustrate examples from the range of possibilities and which each provide an internally consistent logic for how policy for net zero industry might unfold towards 2050. The packages aim not to be prescriptive, but to suggest a direction of travel for industrial decarbonisation.

The packages outlined in Section 3.2 are framed around each of six key overarching carbon policies, considering what additional support in the form of complementary policies is required in order to mitigate the negative effects of the carbon reduction incentive/penalty, and/or enhance its performance and action on other industrial challenge areas. The additional policies were chosen by considering how effectively they provide incentives in the other challenge areas to complement the main carbon reduction policy. The packages also take into consideration where particular policies are more/less relevant to certain broad sectors – for example, a subsidy-based approach would be inappropriate for the FFPS sector. An important feature of the packages is that they are not static over time. Rather, we implemented a dynamic design, where policies could be delivered in rounds or competitions, or where a policy may change in its scope or application over time to maintain its effectiveness. This allows both a degree of flexibility whilst maintaining consistent policy signals and a familiar administrative interface.

The scoring of the packages was informed by the policy options evaluation undertaken in the previous section, and by discussion in the Steering Group workshops. The scoring of individual policies will differ from the scores for policy packages, since the packages aim to take account of policy interactions.

3.2 Illustrative policy packages

Table 19 provides an overview of the framing of each of the 6 illustrative policy packages. The subsequent sections outline the policy content of the packages according to the different decarbonisation challenges. This is followed by an initial qualitative evaluation of the packages against the criteria in Table 16.

Each package could feasibly be varied in several directions and contain elements of the other packages, as required by the political and policy environment. In every case however, policies should be in place to address each decarbonisation challenge, ensuring there are no policy gaps. The packages do not represent 6 definitive choices to achieve net zero for industrial decarbonisation and achieve the aims outlined above, but suggest possible storylines of change intended to stimulate discussion.

Table 19: Overview of the 6 illustrative policy packages.

Package	Description	Policy required in all cases			
		Socioeconomic policies	Material and product efficiency policy	Infrastructure policy	Support for innovation across commercialisation stages
1. Production standards and strong innovation	• Phased embodied disclosure and standards across all sectors, alongside strong innovation support to reduce costs of compliance with the standard. • Manufacturing standards on producers (mandatory minimum requirements) are the overarching carbon reduction framework. • A Border Carbon Standard (BCS) applied to selected sectors (e.g. trade-exposed manufacturing and FFPS) could be a control on carbon leakage. • The package balances a stringent regulatory approach with complementary policies supporting innovation.				
2. Purchaser standards and public procurement	• Strong consumption-focused and demand-driving actions, involving standards on purchasers as well as public procurement. • Standards would increase in stringency and scope over time, adapting to market response. • Application of private purchasing standards to retailers would level the playing field between international and domestic products.				
3. Carbon tax	• In this package a carbon tax is applied across industry, with targeted support for innovation and demand-side measures.				
4. Emissions trading system	• This package considers an enhanced Emissions Trading Scheme, without specifying a linked or standalone design given that the viability of either approach will be a result of trade negotiations. • Free allocation mechanisms, reducing allowances over time, would be in place where appropriate to mitigate carbon leakage. • Innovation and financial instruments are deployed for at-risk sectors, weighted to the near-term to promote reduced costs of compliance.				
5. Parallel tax and ETS	• This package considers a parallel ETS and tax system, differentiating the application of the pricing scheme by emitter size. • Smaller emitters out of scope for ETS eligibility would be covered under a carbon tax system, lowering administrative complexity, whilst large emitters would be addressed by the ETS. • Hybrid pricing instruments would be contained in each pricing policy (e.g. price floors, support rates and auction reserve prices) to regulate the carbon price. • Incorporation of appropriate carbon leakage mechanisms within the pricing schemes is assumed.				
6. Industrial subsidies and regulated improvement	• Driven by Carbon Contracts for Difference (CCfDs) for industry alongside regulated improvement to existing technologies. • A separate embodied standard and BCA would be applied to the FFPS sector, given the inadvisability of a subsidy approach here. • Further targeted innovation support would be targeted at the trade-exposed sectors to provide further protection against carbon leakage. • Whilst backstop carbon regulation or pricing would need to be in place in any case alongside the CCfD, over time the use of CCfDs could be phased out as costs and risk reduce.				

3.2.1 Overarching carbon reduction incentive

The main policy approaches to provide incentives for carbon reduction include regulation (standards), pricing (tax, ETS), or subsidies (direct funding, CfDs). Such carbon policies are likely to underlie any policy package, in providing an overarching framework for decarbonisation and managing absolute emissions levels. It is assumed that in every case there would be an appropriate mechanism in place to mitigate the risk of carbon leakage resulting from the policy; different mechanisms may be more or less relevant for different sectors (see Box 2).

Regulation

Package 1 considers the use of a carbon standard on producers, a mandatory minimum requirement). This could be sequenced by first encouraging voluntary disclosure and uptake of a provisional standard in the period where a mandatory standard is being designed. This could be followed by a transition to mandatory disclosure and standards. Mandatory reporting should extend to those companies not currently addressed under the Streamlined Energy and Carbon Reporting framework (BEIS, 2018c). By signaling a phased approach in the deployment of standards over time and a schedule for the increased stringency of those standards, this gives time for industry planning and adaptation, potentially creating anticipatory policy effect in pre-emptive action against regulation. A period of initial disclosure would also give time for a proportionate and robust assessment framework for the standard to be developed. Over time there would be need for periodic review of the level of the standard, effectiveness, eligibility etc., depending on market response. A BCS could be employed to protect vulnerable sectors. At the EU level they are prioritising specific sectors, and given the politically challenging nature of BCA mechanisms, applying it to the fewest sectors as possible could be a valid approach.

Package 2 considers the use of public and private purchasing standards. Public procurement guidelines could be enhanced in the near-term, in extension of the Government Buying Standards. Over time, the guidelines could be converted to mandatory public purchasing standards as the availability of low-carbon materials and products on the market expands. This would also give scope for the development and standardisation of WLCA data and MRV. Purchasing standards of increasing stringency could be applied to the private sector as mandatory minimum requirements, an obligation on wholesale and retail trade. This would be an effective target for the standard by levelising the risks of international competition and carbon leakage, by applying across both domestic and international goods.

Pricing

Package 3 involves a wide-ranging carbon tax approach. Carbon taxation regimes are more socially and politically acceptable where there is a clear long-term design strategy, communication, and revenues are hypothecated (Vivid Economics, 2019). To manage the risk of carbon leakage, indirect tax rebates could be applied to the trade-exposed sectors; indirect tax rebates (e.g. VAT reductions) can be more effective than exemptions as they preserve the price incentive of the tax, and can even function as a subsidy if companies reduce emissions beyond the price point of the tax (i.e. companies can keep the rebate without paying the tax).

Border Carbon Tariffs pose another mechanism to control carbon leakage in combination with a carbon tax, but may be more politically problematic. If the carbon tax is set at an appropriate initial and later adjusted price, this could provide sufficient incentive to improve the performance of existing technologies and assets.

Package 4 considers the development of a UK ETS. This would require careful design to mitigate leakage and extend its current scope and ambition to provide incentives aligned with net zero. In designing an ETS to mitigate carbon leakage in trade-exposed sectors there are number of available mechanisms to allocate free allowances, including auctioning, grandfathering, benchmarking and output-based allocation (ESC, 2020). Grandfathering is generally considered a simplistic means of allocating allowances unsuited to more developed ETS schemes, and the other approaches differ in the degree to which they incentivise decarbonisation. For example, there is a critical risk that free allowances can act as a revenue source where companies reduce emissions beyond their allocation. Allocation mechanisms have varied benefits and risks; discussion of this and specific sectoral allocation methods are beyond the scope of this report. An appropriately designed allocation is assumed to be in place in this package.

Package 5 considers the use of a parallel tax and ETS pricing strategy, where the application of each is determined by the emitter size. This addresses a previous concern that smaller emitters' cumulative contribution was being missed by the existing ETS-driven pricing regime. A combination of indirect tax rebates and an appropriate cap-and-trade allowance allocation mechanism could be put in place to protect against carbon leakage.

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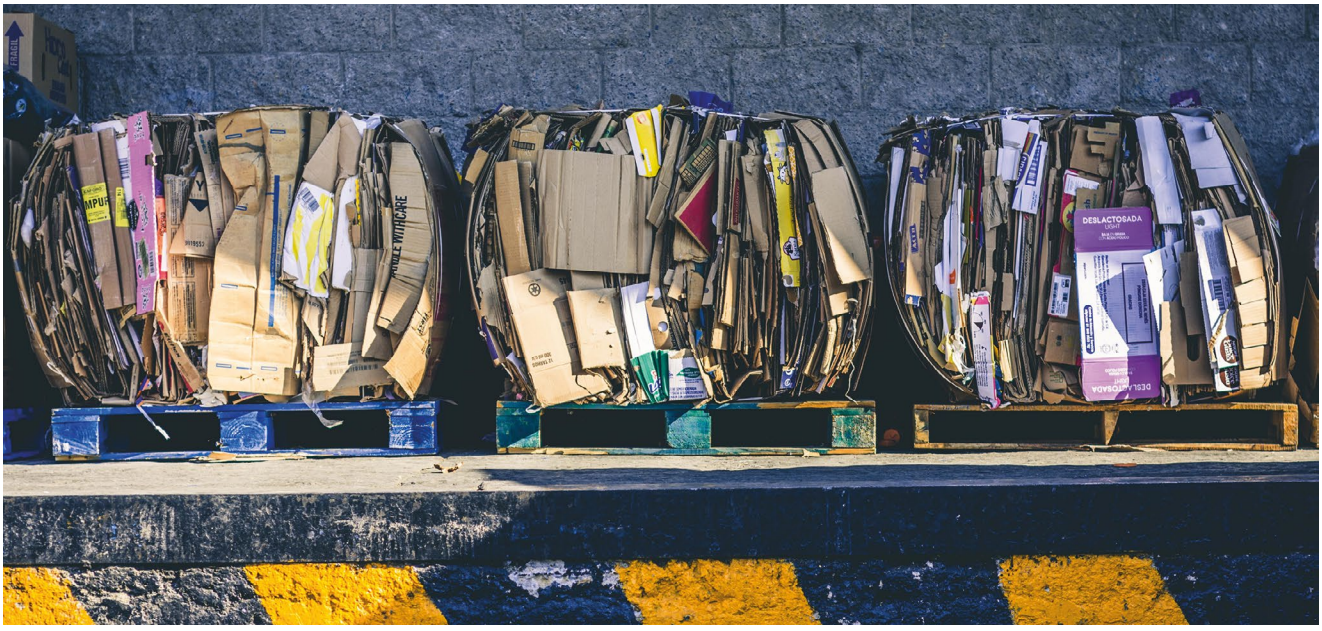
Subsidies

Package 6 is driven by a subsidisation approach via a Carbon Contract for Difference (CCfD). A CCfD would consider the unit of output delivered as the quantity of CO_2 avoided against a reference case, as in proposed designs of CfDs for CCS using a functional unit of 'capture units' (Pöyry Management Consulting, 2016). A CCfD provides an investable market instrument to drive large-scale capital investment and reduce risk. CCfDs could be phased on a project-basis. Periodic review of the CCfD would be required to assess effectiveness and the transparency of the auction process to ensure fair competition between sectors and/or target technologies. The length of contract will be dependent on the balance between capital and operational costs, and whether the CCfD provides sufficient incentive to pay off the initial capital costs of large projects. A backstop carbon price signal or regulation would need to be in place behind the CCfD subsidisation approach, and the use of CCfDs could be phased out over time as the costs and risks associated with decarbonisation technologies reduce.

3.2.2 Deploying and coordinating infrastructure

In every policy package case there would be the need for incentives to develop infrastructure, as capital and risk-intensive assets which would have widespread industrial application. The main options for infrastructure include: new ownership models, for instance public private partnerships or full public ownership; financial mechanisms such as equity funds, green bonds, and public investment banks; and mechanisms to reduce the risk of large infrastructure investments, such as regulated returns, loan and partial risk guarantees. The relevance of each instrument would be dependent on the type of infrastructure being developed.

Other supportive policy could include schemes to develop industrial symbiosis opportunities, and planning regulation, both of which could facilitate the growth of industrial clusters. Favourable business rates could also draw in companies to clusters to grow 'eco-innovation' parks.



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3.2.3 Improving existing technologies and assets

In cases where there is a strong pricing approach (**packages 3-5**), the existing incentive to improve the performance of existing technologies and assets may be sufficient where the improvements are economically viable. To encourage efficiency where the carbon price or regulation is not sufficient a range of further policies could be deployed.

In **packages 1 and 2**, using production and purchasing standards respectively, front-weighted grants and subsidies (potentially in the form of tax reliefs via capital allowances) for target technology types could be used. The early use of subsidies could migrate to a combination of subsidy and differential tax depending on the state of the technologies in place, to drive market transformation and continuous improvement over time. The use of replacement and conversion incentives may be appropriate in the long-term towards 2050. Setting a backstop date for mandatory phase out could be an appropriate additional policy, to ensure there is a specific time horizon by which technologies are brought up to speed.

In **package 6**, using a CCfD approach, a series of regulatory policies may be appropriate in balance to the subsidization approach of the carbon policy. Mandatory reporting (perhaps in extension of the SECR framework) is generally viewed as providing a weak incentive to improve. Supplementing a mandatory reporting requirement with a mechanism by which government supports the removal of barriers to implementing efficiency opportunities could be appropriate. This could follow a model similar to the Netherlands' Long-Term Agreements (Rietbergen et al., 2002) scheme involving negotiated agreements with government support to remove barriers. Mandatory phaseouts or early scrappage could be enforced as backstops or targets towards 2050, comparable to the 2035 end to sales of ICE vehicles (Department for Transport and Office for Low Emission Vehicles, 2020). Setting long-term targets would give a clear lead time for market transformation. A key issue would be the MRV processes underpinning the selection of technologies and assets.

3.2.4 Incentivising innovation

Approaches to encouraging innovation largely involve subsidisation or funding, through a number of mechanisms. Innovation policy is required in every policy package case, and will likely need to be delivered as a priority given the lead times for the commercialisation of many technologies.

In **packages 1–5**, given the use of regulation and pricing (which can be revenue-generating) in the overarching carbon policy, innovation support could be delivered via direct funding (grants and competitions), as a preferred means of industry accessing finance. Competition structured funding would give a flexible, phased approach over the time horizon to 2050. The phased and competitive system allows for fair competition and relative neutrality between the sectors, technologies and fuels receiving funding. Other supports for innovation including financial instruments such as the development of public investment funds, government guarantees for loans and actions to underwrite large capital risks could be appropriate.

Complementary policy in the form of sector deals would signal specific support to the sectors. Prioritising the early implementation of innovation policies could be disproportionately effective. This similarly brings down the cost of compliance as increasingly stringent regulation is implemented towards 2050. Upfront investment would remove barriers to demonstration, and develop the evidence base on the market opportunity for capital-intensive technologies, ultimately driving private action and investment.

In **package 2**, priority could be given to the commercialisation of those materials and products which align with the scope of the purchasing standard, in ensuring low-carbon goods for which there is highest demand are brought to market faster. This would support domestic industry by allowing public procurement to purchase within the UK as increasingly low-carbon goods are produced there.

In the case of **package 6** (CCfD), investment mechanisms of lower cost to government may be more appropriate given the capital outlay and risk in guaranteeing prices within the CCfD. In this case, loan and partial risk guarantees, as well as tax relief mechanisms (RDD reliefs) could be appropriate. Although debt instruments are less favourable to industry given their appearance on company balance sheets, given the overarching subsidization approach of the CfD, this could be a justifiable approach.

In all cases, IP protections and exercises in knowledge sharing between industry and government would be valuable to encourage confidence in both private and public investment.

3.2.5 Improving the efficiency of material and product use

Policies to address material and product efficiency would be appropriate in every policy package case and there may be a similar range of policies suitable for each package. Those suggested in Figure 3 represent a small selection.

A phased approach of transitioning from voluntary public procurement guidelines (as is currently the case), to mandatory standards applied to both the public and private sectors (retailers, wholesalers) could be valuable. As it applies to the private sector, this could effectively be an extension of existing Ecodesign requirements, and incorporate embodied carbon obligations.

The Government Buying Standards currently dominate the public procurement approach in the UK, but apply only to purchasing within central government (Defra, 2017a). Broadening the application of such buying standards could be effective. As a defined standard, which is periodically updated over time, this could be effective as more and more products and materials with lower embodied carbon content over their lifetime come onto the market. Innovative public procurement could also be prioritised for products at early commercialisation stages (Uyarra et al., 2020).

It would be important to develop procurement guidelines or standards on a sectoral basis, given the variable influence of government purchasing power in different sectors, and by extension the influence of government buying power on driving consumption of low-carbon goods produced by those sectors.

Complementary policies informing and acting on final demand could include product labelling (i.e. embodied carbon content), which would be more effective when considering B2C sales. Other approaches valuable in any policy future include the deployment of EPR initiatives; this can include advanced disposal fees, right to repair, deposit refund and product take-back schemes (Pouikli, 2020). EPR initiatives such as right to repair and advance disposal fees could be integrated to the existing Ecodesign regulation, as is being advanced at the EU level (ibid). EPR initiatives would be complementary to purchasing standards by reducing the emissions associated with the end-use products by consumers.

A suite of policies beyond product standards alone are required to incentivise resource and material efficiency. Such policies should be in place in any policy future, and early action on material efficiency has a disproportionate effect on the UK's cumulative emissions given that emissions intensity will be higher in the near-term. Alternative business models, digitalisation, and sector-level partnerships present innovative approaches to addressing these concerns and could be further supported and embedded in policy.

3.3 Policy package timelines

Figure 3 provides an illustration of how the policy packages discussed in Section 3.2 could be phased and evolve over time. The need to consider the development of policies over time to 2050, and to consider what the appropriate sequencing of policies would be, was identified in the stakeholder workshops as a key recommendation in the design of policy. For instance, in several cases, support for innovation policy, subsidies and voluntary standards are introduced before regulation such as mandatory standards to enable reductions to the costs of compliance, reducing the risk of carbon leakage resulting from unmanageable policy costs.

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		Policy package	Illustrative policies						
Decarbonisation challenge	Carbon reduction	1. Production standard	Voluntary disclosure & standard	Mandatory disclosure, voluntary standard	Mandatory disclosure & standard	Periodic review of levels and scope of standard, potential for increased stringency depending on market response			
		2. Purchasing standard	Enhanced & extended public procurement			Public procurement standards (developed on a sector-specific basis): reviewed according to availability of the product / material			
					Purchasing standard (mandatory minimum requirement): Increasing scope and stringency over time				
		3. Carbon tax		Carbon tax with hypothecated revenue and periodic review of tax rate and eligibility criteria					
		4. ETS		UK Emissions Trading System (linked or standalone), with periodic expansion of eligibility and review of free allowance allocation method					
		5. Parallel tax/ETS		UK ETS for large emitters (periodic review of eligibility criteria and review of free allowance allocation method					
					Carbon tax for smaller emitters (periodic review of tax rate and eligibility)				
		6. CCfD	Carbon CfD rounds		Phased by technology type / sector (periodic review of effectiveness)				
	Improving performance	1–5	Subsidies for key technologies		Hybrid subsidisation & differential tax approach	Technology tax with periodic review of eligibility criteria			
		6	Extensions to mandatory reporting requirements						
			Differential price supports (tax / tax reliefs)			Early retirement / replacement / repurposing incentives	Mandated phaseout targets		
	Innovation	1–5	Direct funding, front-loading investment (grants, competitions)						
			Finance-based approaches, long-term funding (equity funds, green bonds, public investment banks)						
			Development of sector deals (with periodic renegotiation and review)						
		6	Debt instruments to reduce risk of private investment (loan and particle risk guarantees)						
	Demand-side	1–6	EPR initiatives: periodic review for increased application and ambition						
		2–6	Mandatory whole-life carbon disclosure		Mandatory disclosure and B2C labelling protocols				
		1, 3–6	Extended & enhanced public procurement guidelines			Public / private purchasing standards: periodic review for increased stringency and scope			
			2020	2025	2030	2035	2040	2045	2050

Fig. 3. Illustration of timelines for the implementation and evolution of policy packages.

3.4 Comparative evaluation of the packages

Tables 20-22 outline the scores allocated to the illustrative policy packages against the evaluation criteria. This is a qualitative evaluation based on a limited evidence base, and it is therefore feasible that the scores could be allocated differently. The exact function of the policies and packages will also be dependent on their implementation, namely their stringency, carbon price assumptions, amongst other factors. As a result is impossible to fully account for the possible range of policy scores depending on design conditions, but the following provides an introductory discussion to this debate on how to both construct and evaluate groups of policies.

Table 20: Indicative policy package scoring matrix: feasibility and deliverability criteria. Annotations comment on assumptions in the packages which influenced the scoring.

Key	Strong negative	Negative	Neutral	Positive	Strong positive
Evaluation criteria	**Feasibility and deliverability**				
Policy	**Implementation time**		**Technical feasibility (inc. measurability)**		**Political and legal challenges**
1. Production standards and strong innovation	Standards could be delivered in the medium-term, innovation in the near-term.		Production standards could require new data and metrics, but innovation support would be technically streamlined to deliver.		Standards could encounter political and/or legal challenge (particularly Border Carbon Standards) and there is less precedent for their use.
2. Purchaser standards and public procurement	Standards could be developed in the medium-term, but public procurement guidelines could be more readily developed.		There would be a key need for robust MRV and metrics for WLCA.		As an equalising measure, the purchaser standards may encounter less challenge than production standards.
3. Carbon tax	A carbon tax is already under consideration as a backstop policy.		Data, monitoring, and metrics would broadly be in place for the delivery of a carbon tax.		International precedent for an economy-wide carbon tax approach. Contention over the carbon price could be likely.
4. Emissions trading system	ETS schemes have policy precedent in the UK and a UK ETS is already under consideration.		ETS schemes can be administratively complex, particularly in allocating allowances according to output-based allocation (as in later stages of the EU ETS).		An ETS is unlikely to result in challenge given precedent for such policies.
5. Parallel tax and ETS	A tax and ETS could be implemented in the near-term.		Both overarching policies have precedent for implementation, although the complexity of a parallel scheme would need to be managed.		Complexity and the difficulties of defining eligibility could result in some challenge.
6. Industrial subsidies and regulated improvement	The design requirements of a CCfD would delay delivery of mitigation benefits to the medium-term.		There could be a degree of complexity in the design of CCfDs for decarbonisation where there is little precedent.		A subsidisation approach would be broadly favourable if appropriately targeted.

Table 21: Indicative policy package scoring matrix: cost characteristics criteria.

Key	Strong negative	Negative	Neutral	Positive	Strong positive
Evaluation criteria	Cost characteristics				
Policy	Cost to taxpayer		Effect on cost of capital		Socioeconomic distribution of cost
1. Production standards and strong innovation	The delivery of innovation support would provisionally come at taxpayer cost.		Innovation policies could improve confidence to invest if appropriately targeted.		Given the cost to taxpayers from innovation funding the distribution of cost could feasibly be managed by Government. As standards are applied to producers there is potentially less cost pass-through to consumer groups.
2. Purchaser standards and public procurement	Policy cost of purchaser standards to taxpayer is uncertain, but public procurement could incur initial taxpayer expense.		Effect on the cost of capital would depend on the extent that procurement policy could incentivise low-carbon transitions/investment in different sectors, for instance there could be a split in the demand for low-carbon and other goods within businesses.		Public procurement costs could possibly be managed by Government.
3. Carbon tax	Potential to generate taxpayer revenue, but a range of policies would need to be in place to counter carbon leakage, reducing the overall cost benefit.		Uncertainty over the volatility of the carbon price could reduce confidence to invest, but targeted support for innovation etc. to the most at-risk sectors could encourage investment on the other hand.		Although the potential for cost transfers to consumers would be hard to predict, there is potential for hypothecation of tax revenues to counter the negative distributional effects.
4. Emissions trading system	As for a carbon tax, there is potential to generate revenue, but a range of policies would need to be in place to counter carbon leakage, reducing the overall cost benefit. For instance strong support for innovation and investment funds.		Uncertainty in the allocation approach could temper confidence to invest, but familiarity with an ETS scheme could provide some certainty.		It could be harder to control the distribution of cost across the system given the complexity of an ETS scheme. Innovation and investment funding approach costs could be managed as they would be controlled by Government.
5. Parallel tax and ETS	Potential for revenue generation, but also costs resulting from compensatory policies.		Mechanisms to regulate the carbon price would be contained in the package, but there could be uncertainty around the complexity of the parallel schemes.		The distribution of cost may be difficult to manage.
6. Industrial subsidies and regulated improvement	A subsidisation approach could be cumulatively costly to the taxpayer and there is some degree of risk.		A subsidy-based approach would provide a strong degree of certainty to invest (albeit in selected technologies/fuels).		There would be uncertainty in whether revenues from regulated improvement could cover the large costs of a subsidy approach. The risks of a CCfD approach could be high.

Table 22: Indicative policy package scoring matrix: carbon reduction potential and key additional challenges criteria.

Key	Strong negative	Negative	Neutral	Positive	Strong positive
Policy	**Achieving net zero**	**Production-based emissions**		**Consumption-based emissions**	**Carbon leakage prevention and competitiveness impacts**
1. Production standards and strong innovation	Standards represent a fairly stringent regulatory approach, and coupled with strong support for innovation could help reduce the costs of capital-intensive decarbonisation technologies in the medium-term.	Standards could effectively cover most industrial emissions sources, but innovation policy would have more targeted application than the standards approach.		Use of a Border Carbon Standard could reduce the footprint of the UK's industrial imports.	Use of a Border Carbon Standard could reduce imports of emissions-intensive goods if appropriately designed. Innovation would support UK industrial strategy and potentially drive greater private investment inflows.
2. Purchaser standards and public procurement	There could be uncertainty in whether demand creation would be sufficient to drive deep decarbonisation.	Purchasing standards could have reasonable coverage of industrial emissions. Procurement coverage could be more limited.		Purchasing standards would not differentiate between domestic/ imported goods, driving consumption of lower carbon domestic products and materials.	Private purchasing standards could equalise the application of policy between international and domestic products, potentially reducing leakage.
3. Carbon tax	The ability of the tax to achieve net zero would be highly dependent on the set carbon price and its change over time.	A carbon tax could widely be applied to most UK industrial emissions sources.		Effect on consumption-based emissions would be dependent on the leakage mechanisms in place. A Border Carbon Tariff could apply the tax scheme to imported goods.	The leakage impact of a carbon tax would be highly variable, according to the assumed leakage prevention mechanism in place.
4. Emissions trading system	ETSs represent a familiar approach, so there is reasonable confidence that an enhanced scheme with complementary policies could achieve net zero.	ETS schemes with complementary policy would address most production-based emission sources.		The package is unlikely to substantially address consumption-based emissions, unless demand-side measures in the package are strong.	Carbon leakage could be managed through mechanisms within the ETS as well as funding support for the most at-risk sectors.

Key	Strong negative	Negative	Neutral	Positive	Strong positive

Policy	Achieving net zero	Production-based emissions	Consumption-based emissions	Carbon leakage prevention and competitiveness impacts
5. Parallel tax and ETS	The comprehensive pricing approach could create some certainty of decarbonisation in line with net zero.	The package would cover most production-based emissions sources, as well as capturing the cumulative emissions of smaller emitters.	The package would require strong demand-side action to address consumption-based emissions.	There is a risk of creating intra-sectoral distortion with the parallel approach, and where companies sit at the eligibility boundary.
6. Industrial subsidies and regulated improvement	Ability of the subsidy to drive decarbonisation is uncertain. Backstop carbon regulation/ pricing would need to be in place.	A subsidy approach could achieve reasonable coverage of production-based emissions.	A purchasing standard in the medium-term could address consumption-based emissions.	Subsidies would work indirectly to reduce the risk of leakage and engender domestic competition if fairly designed. An embodied production standard in the FFPS sector and BCA would limit sectoral leakage.

Table 23: Strengths and weaknesses of the illustrative policy packages.

Package	Strengths	Weaknesses
1. Production standards and strong innovation	• Flexible approach through use of phased policy, avoiding lock-in. • Balance of regulation and incentives. • Effective in setting levels for emissions reductions in line with net zero.	• Border carbon standards could be politically and legally challenging. • Risk of picking winners in the design of subsidies/ phaseouts. • Complexity of standards design. • Lead time required for the development of standards.
2. Purchaser standards and public procurement	• Creates market incentives for low-carbon products. • Addresses emissions embodied in imports, creating a level playing-field.	• Setting appropriate levels for purchasing standards. • Public purchasing power is more significant in some sectors than others. • Could transfer costs to consumers. • Critical need for robust MRV methodologies and metrics for embodied carbon. • Could require an international standard on whole life carbon.

Package	Strengths	Weaknesses
3. Carbon tax	• Streamlined approach with a wide-ranging carbon policy. • Potentially high socio-political acceptability where revenues are clearly hypothecated (Burke et al., 2019).	• Determining effective rates of taxation. • Leakage/ competitiveness impacts, which may demand a Border Carbon Tariff. • May be more difficult to control absolute emissions levels at a national scale (Vivid Economics, 2019). • Reliance on a pricing approach may not be sufficient to drive demonstration for first-of-a-kind technologies and facilities.
4. Emissions trading system	• Precedent and methodological frameworks exist for this approach. • Effective in setting a cap on emissions levels across industry (ibid).	• Complexity of managing sectoral effects/rates/ allowance allocation. • Need for complementary policy to support the transition as free allocations of allowances reduce.
5. Parallel tax and ETS	• Comprehensive coverage of industrial emissions. • Providing strong incentives to decarbonise. • Capturing the cumulative emissions of smaller emitters.	• Administrative complexity of managing schemes simultaneously and effectively. • Risk of creating intra-sectoral distortions when sectors contain different size emitters. • Risk of creating competitiveness issues where companies sit at the eligibility boundary between the tax and ETS.
6. Industrial subsidies and regulated improvement	• Fosters competition through a wide-ranging CfD approach. • Regulation could be more targeted at the technology level.	• Treatment of the FFPS sector is complex. • Subsidisation approaches could be cumulatively costly to government and taxpayers. • Need for a strong accompanying carbon price to drive reductions.

4. Enabling a just industrial transition

There are both opportunities and risks associated with industrial decarbonisation. The 'just transition' debate responds to the idea that whilst decarbonisation presents significant opportunities, it comes at opportunity cost to some sections of society and certain regions. Key risks include global competitiveness issues and carbon leakage, and the impact this has on employment. Jobs in emissions-intensive sectors are regionally distributed, therefore risks may be spatially uneven, working against the government's 'levelling up' agenda (HM Government, 2019).

However, there are also opportunities allied to the transition, such as the potential for new skilled jobs and the regeneration of areas still suffering from deindustrialisation. To manage the risks and capture the benefits of industrial decarbonisation, policies must be in place acting beyond energy and emissions to support a socially sustainable transition. Much work on just transitions has addressed the energy sector, particularly oil and gas, but further thought should be given to the impacts of decarbonisation on strategic manufacturing sectors. Scotland's Just Transition Commission provides valuable recommendations on transition planning to promote investment in key industrial skills and act on sector-specific risks and opportunities (Scottish Government, 2020a).

Many of the policies proposed to stimulate a green recovery (Box 6) could also support long-term employment in low-carbon sectors.

Box 6: Green industrial recovery from the COVID-19 pandemic

Lockdown measures in response to the Covid-19 pandemic have caused considerable damage to economies around the world. In the UK, GDP fell by around 20% during Quarter 2 (April to June) 2020, compared with Quarter 1 (January to March) 2020 (ONS, 2020a). However, the lockdown also brought short-term environmental benefits; daily global CO_2 emissions decreased by 17% by early April 2020 compared with mean 2019 levels (Le Quéré et al., 2020), but as economies have opened up again these reductions have largely been reversed. Many experts have therefore been calling on governments to implement a green recovery to ensure that decisions made to rebuild the economy simultaneously work towards our climate change goals.

The CCC has highlighted a number of principles that should guide any such recovery package in the UK, including using climate investments to support economic recovery and jobs, embedding fairness as a core principle and ensuring the recovery does not lock-in GHG emissions or increase risk (CCC, 2020d). Key areas for investment that have high potential on both economic multiplier and climate impact metrics include: clean physical infrastructure, building efficiency retrofits and clean research and development (Hepburn et al., 2020). There have also been calls to ensure that any Government support for high carbon industries are contingent on them addressing environmental concerns.

Some suggest the importance of setting a 'strong carbon price' during the recovery period, to compensate for the historically low oil prices over the course of the pandemic (Burke et al., 2020). Countercyclical public investment could also pose an appropriate instrument (Deleidi et al., 2019).

Reflecting these priorities, the UK Government has committed to delivering a green recovery. In July 2020, it announced an initial £350 million worth of investment focused on the industrial sector. This investment includes:

- £139 million to cut emissions in heavy industry by supporting the transition from natural gas to clean hydrogen, and scaling up carbon capture and storage technology.
- £149 million to drive the use of innovative materials in heavy industry, including projects to reuse waste ash in the glass and ceramics industry and for the development of recyclable steel.
- £26 million to support advanced new building techniques in order to reduce build costs and carbon emissions in the construction industry.
- £10 million for state of the art construction technologies, which will go towards 19 projects focused on improving productivity and building quality (HM Government, 2020d).

These investments can provide an important foundation on which future policy packages could build, however the extent to which these commitments are a 'recycling' of earlier announced funds is unclear. The UK Government has also recently announced a Green Jobs Taskforce, aiming to create 2 million green jobs by 2030 (BEIS and DfE, 2020).

In our review, we identified what enabling socioeconomic policies would be required to support industrial decarbonisation. In every policy future there will be a need for training, retraining, and a jobs strategy that provides appropriate skills for net zero industry. Supporting jobs across sector supply chains would underpin the UK's industrial strategy, avoiding both jobs leakage and dependence on international expertise. It is important that policy in this area has a long-term outlook, as developing a low-carbon skills base is an investment (Jagger et al., 2013). Table 24 provides a summary of these 'enabling policies'.

Table 24: Summary of enabling policies to support a just industrial transition (informed by HM Government, 2011).

Policy	Description
Apprenticeship schemes	Funding for low-carbon apprenticeships. This could also address the decline in apprenticeship uptake rates (Henehan, 2020).
Industry qualifications and standards	Developing industry standards for green skills certification to improve skill transferability between sectors.
Investment in training centres	Funding for training schemes and centres oriented around key low-carbon skills, for different levels of the education system (e.g. FE, HE).
Licensing and accreditation for key technological skills	A technique to standardise skills in deployment and use of key low-carbon technologies (Jagger et al., 2013).
Retraining and upskilling subsidies	Providing incentives to develop workers' transferable skills and move between industries.
Skills demand mapping	Scoping exercises with industry and sectors to guide future jobs and training strategy where new skills are required, or additional training would add value.
STEM funding	Awareness-raising activities and funding to encourage study of STEM disciplines oriented to industrial decarbonisation. Improving the visibility of careers in this area.

To ensure that future jobs strategy is 'just' and capitalises on the opportunity to address social and spatial inequalities in the UK, a number of principles could be followed. For instance, identifying large regional employers, or sectors where there is a strongly regional concentration of jobs, and directing support to those areas. Similarly, assessing where there is most risk of 'stranded skills', where skills from certain sectors are less transferable to other industries.

5. Conclusions

Reaching net zero emissions in the UK requires radical reductions in industrial emissions. The range of existing policies are not of sufficient scale or ambition to achieve these reductions, and there is a clear need for additional action. To address this policy deficit for net zero, an ambitious suite of policies needs to be in place. A number of challenges beyond providing an overarching carbon incentive must be addressed, for instance supporting the development of infrastructure, encouraging all stages of innovation, and promoting material and product efficiency. Policy must address existing market failures, whilst avoiding the risk of carbon leakage, which would work against mitigation of greenhouse gases on a global scale. Other considerations include the progressive distribution of policy costs and promoting a just transition. A range of appropriate policy mechanisms can, and should be, developed that work effectively together in support of these challenges. However, it remains that the eventual alignment of the UK with a net zero target will be dependent on action taken across the economy.

A key research gap the report aimed to address is the lack of a comprehensive dataset on existing industrial decarbonisation policies in the UK. There could be value in maintaining and extending this dataset to facilitate future assessment by industry, academia, Government and the third sector.

Policy packages were identified as a potentially valuable approach in the course of the review, in recognition of the fact there is no effective 'one-size-fits-all' approach to policy. Whilst it would be difficult to identify the 'winning' policy package, since this is dependent on the criteria for what is considered 'best', we have attempted to illuminate through the illustrative policy packages some directions of travel for future policy. These packages were developed with a focus on the manufacturing sector, and further work is required to identify policies specific to the needs of the NRMM and FFPS sectors. We have provided an indication of how illustrative policy packages could be assembled and how they would work to address each industrial decarbonisation challenge. Whether the policy packages are consistent with net zero industrial emissions or not will depend on their design and implementation, including the stringency of regulation and the level of carbon pricing amongst other factors.

Although we have provided indicative scoring of policy options and packages, policy is ultimately a choice by government and a reflection of its priorities. The impact that any policy will have in practice (both positive and negative) will necessarily depend on its specific design and the wide policy environment in which it is situated, but a number of key issues were identified in the course of the review:

- **For many manufacturing sectors a potentially effective approach could be identified as: a sequence of subsidisation and investment, supported by a carbon price signal, followed by increasingly stringent regulation**. Consideration would need to be given to the 'milestones' for starting and stopping incentives, and introducing regulation, as well as the funding mechanisms for subsidisation approaches.
- **Standards on production and/or purchasing offer a sophisticated mechanism for promoting decarbonisation whilst protecting against carbon leakage** (when effectively designed). The development of embodied standards will require robust and standardised assessment of whole life carbon, and they may therefore take a number of years to be put in place. In the interim, measures to reduce the cost of capital and promote investment would remove industrial barriers to decarbonisation, and ultimately lower costs of compliance when regulation comes into force. Precursor policies acting on the demand-side via procurement for example could signal ambition and allow for anticipatory policy action, provided policy pipelines are clearly communicated with industry.
- **A number of policies and policy packages are reliant on standardised metrics being developed to conduct whole life carbon assessments**. For instance, setting standards for embodied carbon is a significantly more complex process than that for operational efficiency standards. It is essential to have robust and defensible methodologies to conduct such assessments. The development of such data infrastructure is therefore a critical near-term action to enable ambitious future policy.
- **Sector-specific agreements such as sector deals or negotiated agreements (e.g. CCAs) appeared to receive strong industry buy-in**. Enhanced and extended agreements in a similar model could be a valuable future approach. Whilst agreements in this model are considered favourably by industry, they are dependent on voluntary action and could therefore be of limited effectiveness if not appropriately tracked or of sufficient ambition.
- **This highlights that some existing policies are considered favourably**, and that new policy could in some cases build on existing policy frameworks.
- **A range of demand-side measures could play a critical role in most policy cases, by acting on final demand for materials and products**. The multiple benefits and high social acceptability of such policies provides a strong incentive to implement them in the near-term (Green Alliance, 2018b). Similarly, their disproportionate impact on cumulative emissions by reducing demand when emissions intensity is highest in the near-term, is another clear case for their early implementation.

Whilst it is hard to advance any one policy option as the 'most effective', we note several principles for effective policy design.

- **Streamlined policy**: the leanest possible policy packages should be in place that deliver the desired outcome, avoiding excessive 'layering' of policy burden where policies are applied to different areas of an industry's operations, and minimising administrative burden, complexity, and duplicated incentives or penalties. The total impact of policy packages on any given industrial sector should be evaluated.
- **Clear signals and incentives**: policy should aim to provide clear long-term signals to industry to allow for planning and adaptation. Setting backstop long-term targets, with clearly communicated plans for phasing policies could better inform industry planning. Timelines for implementation should be shared with industry.
- **Logical sequencing and built-in flexibility**: the timing of policies is critical to their effectiveness and the evolution of policies towards 2050 should be considered. For example, demand-driving policies should be sequenced to create markets for the supply of low-carbon materials or products produced in the UK. Investment should be prioritised for decarbonisation measures with longer lead times. Building in flexibility to policy design will be important, in which regular evaluation of progress and continuous engagement with industry informs successive phases of a policy to adapt to market response. Similarly, a sector-neutral approach may be appropriate where a framework for 'outcomes' is set rather than a predetermined choice of 'winning' fuels and technologies.

There are evidently many uncertainties in planning future industrial policy given the current political and economic environment. However, the urgency of the climate crisis and the UK's net zero legislation demands a rapid and strategic policy approach, in which reducing GHG emissions from industry, while maintaining UK competitiveness, will play a crucial role.

6. Appendix

6.1 Developing a database of existing policies

In order to establish the necessary context for the development of future policies for industrial decarbonisation in line with net zero, a review of existing policies was carried out. The review considered currently or recently active industrial decarbonisation policies in the UK, as well as those with suggested Government commitment. The lack of a comprehensive database of UK industrial decarbonisation policies in the literature is a critical gap, which the present review attempts to correct.

The full policy database can be downloaded as a separate file alongside the report (xlsx file 40 KB, may not be suitable for users of assistive technology).

The typology for policy status was loosely based on that used by BEIS Updated Energy and Emissions Projections (UEEPs), which classify a limited subset of policies according to the following status categories: expired, implemented, adopted, and planned (BEIS, 2019h). We modify this system to: active, adopted, due to expire, prospective (see Table A1).

Table A1: Policy typology in the database.

Policy status categories	Description
Active	Policies currently in force
Adopted	Government has committed to the policy (may also be under consultation)
Due to expire	Active policies which have a specified end date
Prospective	Speculative policy options considered by Government to public knowledge but without clear Government approval

We considered expired policy as out of scope, given legacy savings are unlikely to pose significant ongoing contributions to mitigation. We add prospective policies to the typology in respect of known policies which have not received clear Government approval, but which are at least under consultation. Policies explicitly acting on the energy supply sector were considered out of scope.

Among the key sources consulted to compile the policy database, the UEEPs (ibid) are limited to those policies with quantifiable effect on the UK's energy demand and greenhouse gas (GHG) emissions. This may preclude policies such as funding and investment, from which there is limited directly measurable effect on mitigation. Other key sources included the IEA policy database (IEA, 2020), Climate Change Committee Progress Reports (for instance CCC, 2020), UK Government Budgets (HM Treasury, 2020), the database of Climate Change Laws of the World (Grantham Research Institute, 2020), and a CREDS report on industrial energy datasets (Norman et al., 2020).

Detail on the longitudinal design of the policies (e.g. the structure of delivery, any changes to eligibility or stringency signposted) was captured amongst other descriptive criteria (see Table A2). Where policies (particularly funding) are subsidiary to other initiatives, the linkages are made clear.

Table A2: Criteria used to evaluate baseline policies.

Criteria	Description
Policy type	Description of the policy mechanism according to high-level categories (e.g. regulation).
Policy mechanism	Further description of the policy (e.g. standard).
Status	According to Table A1.
Date introduced	When policy was implemented, or announced.
Lead time	End year for the policy.
Related legislation	Relevant legislation to enforce the policy (or translate from EU directives).
Linkages to other policies	Relationship with other policies and schemes (e.g. the Climate Change Agreements feed into the Climate Change Levy).
Jurisdiction (and/ or regulator/delivery partner)	Body or organisation responsible for implementing, regulating and delivering the policy.
Application to industry	How the policy applies to industry (i.e. sectoral coverage).
Policy stages	How the policy is delivered (e.g. in rounds or competitions).
Policy evolution	Whether the policy is expected to change in time (e.g. in terms of eligibility criteria or stringency).

6.2 Policy options survey

Table A3 presents the aggregated results from a provisional policy scoring exercise conducted through an anonymous online survey. The survey was distributed to 28 expert stakeholders from the CCC Working and Steering Groups on industrial decarbonisation. The survey was conducted between July and August 2020. 10 responses were recorded, some of which represented joint responses from industry sectors. The policy groupings and evaluation criteria are slightly different to those in Table 17 of the main report, reflecting an earlier approach to the analysis. However, the survey results helped to inform the scoring shown in Table 17.

The survey asked respondents to score a series of policies grouped by the industrial decarbonisation challenge they address, according to a series of evaluation criteria. The challenges included: carbon reduction, deploying and coordinating infrastructure, improving existing technologies and assets, incentivising innovation, demand-side action, and enabling policies (as discussed in Table 2 of the main report). The evaluation criteria that were considered included: feasibility and deliverability, cost-effectiveness, production-based emissions coverage, competitiveness risks, and spill-over effects. Scores could be input from a 5-point scale from -2 to +2. A second question then asked when stakeholders would consider a particular policy should be implemented, whether a) now (before 2024); b) later (after 2024); or c) not at all. The results from this question are synthesised in Figure A1 and helped to inform the timelines for the policy packages shown in Figure 3. Comment boxes were also provided for further qualitative input on any of the policies. Survey responses were anonymised, synthesised and presented back to the CCC Steering Group at workshop 2.

Table A3: High-level summary of policy survey results against selected evaluation criteria.

Key	Strong negative	Negative	Neutral	Positive	Strong positive

Challenge	Policy group	Scores against evaluation criteria					Avg. score	Std. Dev
		Feasibility and deliverability	Cost-effectiveness	Emissions coverage (production-based)	Risks: Competitiveness	Spill-over effects		
Carbon reduction	Mandatory disclosure							0.8
	Carbon Contract for Difference (CCfD)							1.4
	Standards							1.3
	Emissions trading system							1.3
	Disclosure and standards							1.2
	Carbon tax and ETS (differentiated by emitter size)							1.1
	Carbon tax							1.0
Infrastructure	Direct subsidisation approach							1.2
	Public ownership							1.4
	Governance approach							1.0
Improvement	Incentivising improvement							1.0
	Hybrid approach							0.9
	Regulating improvement							1.1
Innovation	Structural supports							0.8
	Financing and de-risking							1.0
	Incremental supports							0.6
Demand-side	Information-based tools							1.0
	Regulatory approaches							0.9
	Hybrid approach							1.0
	Creating/shaping markets							1.2

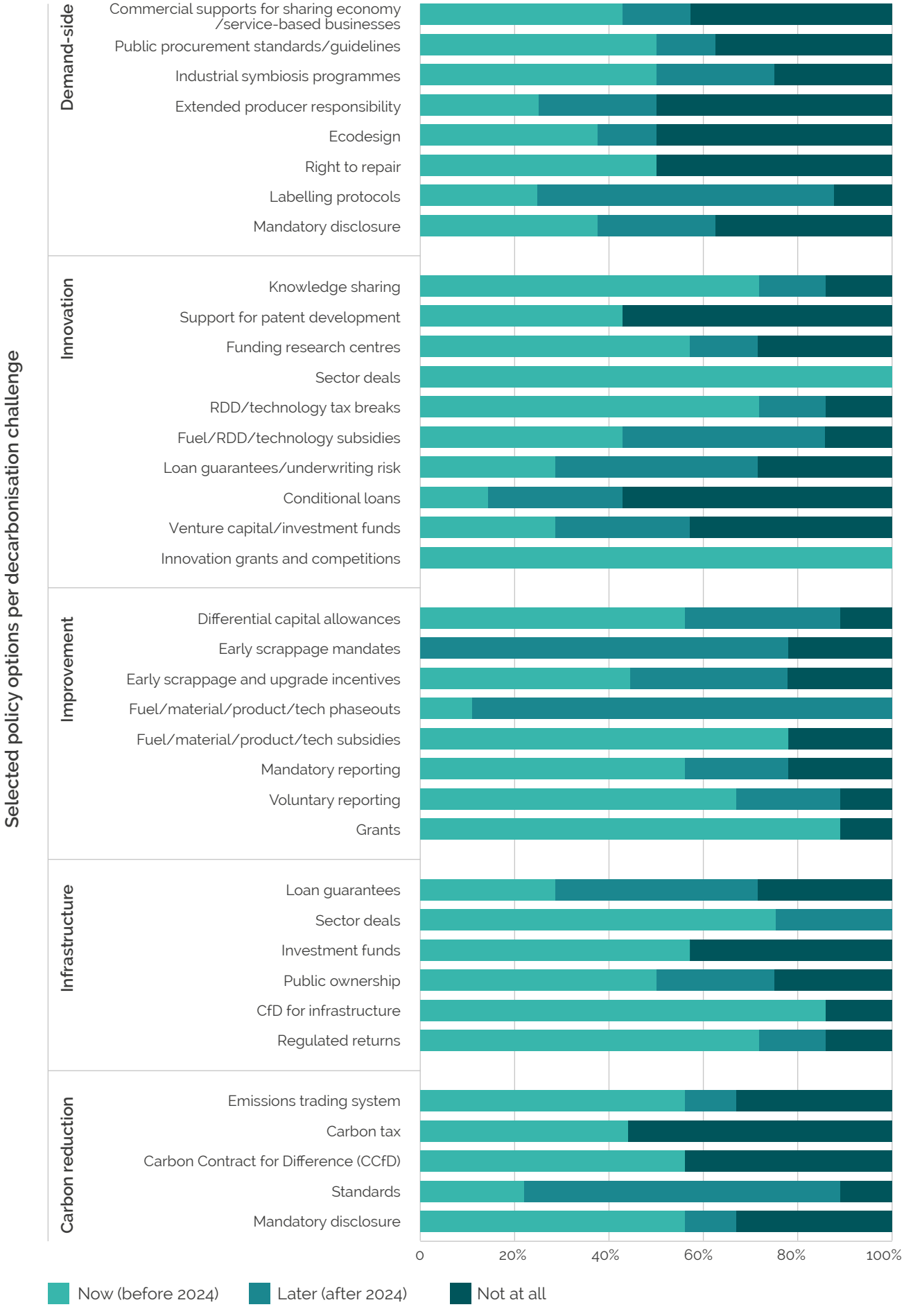

Figure A1. Summary of survey responses on when selected policies would be best implemented.

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8. Glossary

Table 25: Glossary of key terms used in the report.

Term	Definition
Border Carbon Adjustments	Border Carbon Adjustments (BCAs; also known as Carbon Border Adjustments, CBAs) involve the application of a price mechanism to imported goods at the border, on the basis of their carbon content (Sakai and Barrett, 2016). Variants include Border Carbon Standards, and Border Carbon Tariffs, and represent an embodied carbon standard and taxation mechanism respectively, as means of applying the price.
Carbon leakage	This describes a potential effect of carbon policy; if it is applied to domestic industry in the absence of comparable policy on the international market, the obligation for domestic firms to abate can lead to offshoring emissions to other world regions and competitiveness issues. It can undermine climate ambition by resulting in net growth in emissions in other regions.
Carbon policy	Carbon policy is a general description of mechanisms which drive greenhouse gas mitigation, and can take the form of regulation, subsidies, or pricing.
Competitiveness	The 'capacity and ability of a firm or sector to gain and maintain a profitable, sustainable market share relative to rivals' (Kansy et al., 2020). Competitiveness impacts may be felt at a domestic/ intra-national level, or may be international.
Consumption-based emissions	A consumption-based accounting approach is where 'emissions are allocated according to the country of the consumer, usually based on final consumption' (Barrett et al., 2013).
Just transition	Achieving net zero will involve the wholesale transformation of national economies and the forms of employment underpinning them. The concept of a 'just transition' emphasises the need to 'plan, invest and implement a transition to environmentally and socially sustainable jobs, sectors and economies' (Scottish Government, 2020b).
Policy package	A group of policy instruments which strategically drive emissions reductions, by acting on different challenges to industrial decarbonisation (e.g. the development of infrastructure, encouraging innovation etc.). The concept is draw from, and comparable to, the 'policy mix' literature (Rogge and Reichardt, 2016; Bataille et al., 2018; Neuhoff et al., 2018, 2019). The literature typically identifies key policies as well as guiding principles for the integration of different policies to a coherent 'package'.
Production-based emissions	A production-based emissions accounting approach includes all GHG emissions occurring under a particular national jurisdiction (Barrett et al., 2013).

9. Project team

This report was produced by the Centre for Research into Energy Demand Solutions (CREDS). CREDS is a UKRI funded research centre established in 2018, involving more than 80 academics across 13 UK academic institutions. The centre aims to understand the role of energy demand in achieving a low-carbon transition, with 3 sector and 3 cross-cutting themes (buildings, materials and products, transport and mobility; and digital society, flexibility, and policy and governance, respectively), as well as specific challenges on the decarbonisation of heat and fuel and transport poverty. The material and products theme is led by Professor John Barrett at the University of Leeds, considering the role of industrial energy demand, energy efficiency, and the energy embodied in materials and products. The project team consisted of:

- **Alice Garvey**: Alice is an EPSRC funded PhD researcher at the University of Leeds and part of the CREDS 'materials and products' theme, with research interests in UK industrial strategy, regional decarbonisation, and just transitions.
- **Peter Taylor**: Peter is Chair in Sustainable Energy Systems at the University of Leeds and a member of a number of high-profile RCUK research centres including CREDS, the UK Energy Research Centre, the Centre for Climate Change Economics and Policy and the Supergen Energy Networks Hub.

About CREDS

The Centre for Research into Energy Demand Solutions (CREDS) was established as part of the UK Research and Innovation's Energy Programme in April 2018, with funding of £19.5M over 5 years. Its mission is to make the UK a leader in understanding the changes in energy demand needed for the transition to a secure and affordable, low carbon energy system. CREDS has a team of over 100 people based at 15 UK universities.

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