Annex: The Future of Carbon Pricing

1) Carbon pricing in the UK

Since 2005, the UK has been a member of the EU's Emissions Trading System (EU ETS), widely recognised as a flagship emissions trading policy around the world. Prior to this, the UK had its own, voluntary, emissions trading scheme. The EU ETS covers emissions from power stations, large industrial facilities and flights between EU countries (known as the 'traded' sectors). In addition to the EU ETS, the Climate Change Levy[1] is applied to fuel combustion in power stations and industrial facilities. The UK's carbon budgets cover emissions from all sectors of the economy, not only the sectors traded in the ETS.

In principle, all sectors of the economy can be exposed to carbon pricing. In the UK at present, carbon pricing is applied more widely than the sectors covered by the EU ETS.

Across the UK policies with objectives that are broader than climate change mitigation can be judged to indirectly reflect a carbon price (Figure 1) and are applied, to varying extents, in the surface transport and waste sectors, and to energy use in commercial and residential buildings.[2] However, some sectors do not face a carbon price at all, or face reduced tax rates that are judged by some to be, in effect, negative carbon prices.[3] For example, fuel duty is not levied on aviation fuel, meaning that international flights that go beyond EU borders do not face a carbon price or fuel taxation. Similarly, fuel for certain uses – such as red diesel for tractors or home heating – faces a reduced rate of VAT, and the carbon component of fuel duty is not explicitly set. In developing policy to meet the UK's net-zero target by 2050, more explicit carbon pricing may need to be introduced into these sectors.

There are different ways to apply carbon pricing. For example, emissions can be priced directly, at the point of combustion, or fuels could face a carbon price based on their carbon content. Separately, policies and regulations can be aligned to a carbon price level, without pricing carbon directly.[4]

- **Emissions trading.** Operators of power stations, industrial facilities and intra-EU aviation are currently required to purchase allowances to cover their emissions under the EU's Emissions Trading System. Emissions trading could be extended to other emitting sectors.
- **Taxing carbon:**
  - **Upstream:** Carbon could be taxed on fuels (at the point of production or import), and on direct sources of emissions from industry, waste and agriculture (alongside complementary measures to stimulate efficiency and investment). Fuels are currently taxed this way in the power and industrial sectors under the Climate Change Levy (and Carbon Price Support).

[1] This includes the Carbon Price Support (CPS).
[2] ESC (2019) *Rethinking decarbonisation incentives.*
[3] Institute for Fiscal Studies (2013) *Energy use policies and carbon pricing in the UK*. Where reduced tax rates are applied to fossil fuels, this is sometimes referred to as fossil fuel subsidies.
[4] Energy Systems Catapult (2019) *Rethinking Decarbonisation Incentives*.

  - **Downstream:** Applying a carbon tax on goods and services at the point of consumption, maximising consumer-visibility (through carbon labelling) and taking account of full lifecycle emissions for both imported and domestic production.

- **Ensuring policies effectively price carbon.** Currently, impact assessments for Government policies measure the emissions impact of the policy as part of a broader cost benefit analysis.[5] In future, these assessments need to ensure that carbon is priced in line with the UK's new 2050 target, and that policy is consistent with moving towards a net-zero economy.
- **Standards and regulations** can be set for the carbon intensity of fuel or products, as an alternative to direct carbon pricing. These standards could tighten over time, consistent with reducing economy-wide emissions to net-zero by 2050.

Figure 1. Current carbon policies for each sector and policy gaps.

Sector		Current Carbon Policy	Gaps
Power Generation		EU Emissions Trading System Carbon Price Support Low Carbon Subsidies (e.g. CfD, FiTs, ROCs)	-
Transport	**Road**	Fuel Duty Vehicle Excise Duty	Carbon component of fuel duty is not explicitly set.
	Air	EU Emissions Trading System Air Passenger Duty	No VAT on fuel or tickets.
	Rail	Fuel Duty	Carbon component of fuel duty is not explicitly set (for non-electrified rail).
Industry		EU Emissions Trading System Climate Change Levy Climate Change Agreements Low Carbon Policy Costs (Electricity)	Currently receives significant compensation.
Buildings	**Business & Public**	Climate Change Levy Climate Change Agreements Low Carbon Policy Costs (Electricity)	Climate Change Levy rates for gas are currently low.
	Residential	Low Carbon Policy Costs (Electricity) Low Carbon Subsidies (e.g. RHI)	No existing carbon price for gas and a reduced VAT rate for both gas and electricity.
AFOLU		-	No existing carbon price and fuel duty is very low on red diesel.
Waste		Landfill Tax	-

Source: ESC (2019) *Rethinking decarbonisation incentives.*

[5] Using the Government's *Green Book* carbon values.

2) Principles and experience of carbon pricing around the world, and implications for the UK

Economic theory suggests that carbon pricing is a key tool in driving the transition to a low-carbon economy. Carbon prices should be strong and rise over time, with increasing coverage across the economy.

Moving towards a low-carbon economy could present competitiveness challenges in some sectors, but will also present opportunities to others. Businesses that produce energy and carbon-intensive products that compete in international markets may face competiveness challenges if they are exposed to significant costs not faced by international competitors. If that results in changing the location of production to other countries ("offshoring" or "carbon leakage") it would be undesirable for the economy and potentially for global emissions. Any carbon pricing scheme should maintain the UK's industrial competitiveness.

In principle, all sectors of the economy can be exposed to carbon pricing. Indeed some schemes around the world have broader scopes than the EU ETS, including sectors such as surface transport, upstream fossil fuels and forestry.

Carbon pricing schemes are becoming increasingly ubiquitous globally, with 28 emissions trading schemes and carbon taxation in more than 29 jurisdictions being implemented or scheduled to be implemented around the world.[6] Carbon pricing now covers 25% of global emissions. However, economic theory and real world experience also demonstrate that whilst carbon pricing is an important policy instrument for driving decarbonisation, in itself it is likely to be insufficient.[7] Evidence suggests that there is a requirement for supplementary policies, standards and regulations to overcome barriers such as investment in early stage innovation (e.g. support for offshore wind, or greenhouse gas removal technologies), capital-intensive facilities (e.g. CfDs in power, support for industrial decarbonisation), or non-price barriers. We have previously set out the range of policy requirements for the UK.[8] These supplementary policies will interact with carbon prices in each sector, suggesting a need for some differentiation of carbon prices across the economy.

The UK's choices

Exit from the European Union implies at least four possible scenarios for carbon pricing in the UK, and a choice between trading of carbon allowances of limited quantity and taxing carbon at a set price. The Government's intention is for a scheme to be up and running by 2021. Both types of scheme have advantages and disadvantages, summarised below and in Table 1.

- **Linking a UK ETS to the EU ETS** is the Government's current preference for a scheme:
  - This would offer access to a liquid market in emissions allowances, incentivising decarbonisation at lowest cost across Europe. The EU's Market Stability Reserve is likely to enable price visibility. Additionally, if there were common emissions trading

[6] Vivid Economics (2019) *Advice on the UK's future carbon pricing policy*.

[7] In support of the Committee's advice, we commissioned Vivid Economics to provide more detail on principles of carbon pricing, experience of carbon pricing around the world and an assessment of the carbon pricing options facing the UK. Vivid Economics' work represents the conclusions of Vivid Economics alone and not the conclusions of the Committee.

[8] CCC (2019) *Reducing UK emissions: 2019 Progress Report to Parliament*.

arrangements with a large (and geographically close) trading partner this would reduce the risk of carbon leakage.

  - However, unless and until the EU adopts a net-zero target and amends the EU ETS, the scheme is less aligned to the UK's net-zero target, implying a greater role for supplementary policies in the UK. Additionally, under this scheme it is likely that the UK will need to mirror the EU ETS scheme as closely as possible. Therefore there may be limited room for expanding the sectoral coverage of any scheme in the near term, and the UK may have limited input on governance arrangements.

- In case a linking agreement with the EU cannot be reached, **a standalone UK ETS** could be an option:
  - A standalone UK ETS may offer more policy autonomy than a linked ETS, and the opportunity to align the scheme more directly to the UK's current emissions, net-zero ambition and directly to carbon budgets.
  - However, the scheme risks low liquidity in the long-term unless sectoral coverage is expanded. The system would require robust rules and governance around price or quantity of permits to ensure that a sensible price prevails, particularly given likely volatility in the early years of a new scheme. Furthermore, expansion of a UK scheme could impact the possibility of securing linking agreements to other schemes, as experience suggests linking of differentiated schemes can be a complex and lengthy process.
- Implementation of a UK **carbon tax** is the Government's fall back position in the case of leaving the EU without a deal:
  - A carbon tax offers less complexity than trading schemes, and lower administrative costs, potentially expanding the range of actors and sectors to which it can be applied in the near-term. A strong and rising tax that offers stability and visibility will give greater price certainty than an emissions trading scheme, though less certainty over the quantity of emissions.
  - However, experience with the Carbon Price Support and Fuel Duty Escalator suggests that effective governance arrangements around a carbon tax would be required in order to ensure price visibility. Additionally, as taxes do not set a limit on quantity, a greater role may be required of other policy instruments if a tax under delivers.
- Remaining a member of the **EU ETS** would maintain current arrangements.

We agree with the Government's preference for a linked UK-EU ETS in the case of UK exit. This maintains key benefits of membership of the EU scheme, most notably access to a wider market and addressing competitiveness issues by maintaining a level playing field across the EU.

Table 1. Advantages and disadvantages of emissions trading and carbon taxation options facing the UK

Scenario	Advantages	Disadvantages
Linked UK ETS	• Status quo • Addresses competitiveness issues • Liquid market	• Limited UK input • Greater need for supplementary policies • Not currently aligned to net-zero
Standalone UK ETS	• Policy autonomy: possibility of increasing scope of coverage, aligning to net-zero (and potentially carbon budgets) • Certainty of quantity of emissions abatement	• Risk of low liquidity • Need to set up new arrangements (price visibility, competitiveness)
Carbon tax	• Potential for greater price certainty • Administrative simplicity • Possibility of increasing scope of coverage, aligning to net-zero	• Risk of tax changing at each fiscal event • Uncertain quantity of abatement

Source: CCC analysis based on Vivid Economics (2019) *The Future of Carbon Pricing in the UK*.

Rules, governance and competitiveness

In order to be effective, the ultimate outcome of any scheme should be a strong carbon price that rises over time. In practice, given the large uncertainties around future emissions and abatement opportunities, designing a new scheme risks an inefficient price or quantity outcome.

Evidence of schemes around the world identify the key components of an effective carbon pricing scheme:

- The **rules and mechanisms** associated with the scheme need to be robust to big economic shifts and other uncertainty:
  - Price visibility should be the key outcome of the scheme. However, given uncertainty over future emissions – particularly due to changes in fuel prices, economic output and technological change – it is difficult to set the quantity or price of any scheme at the 'right' level. There is a risk that the carbon price is set or emerges at an inefficient level, implying adjustments need to be made over time.
  - Experience of carbon pricing around the world to date shows that almost all carbon pricing schemes have introduced price and/or quantity stability mechanisms in order to correct for this (e.g. EU ETS and Market Stability Reserve, UK Carbon Price Support, Auction Reserve Prices in California).
  - In any scheme, review mechanisms should be built in, and wider policies will need to take into account the level of carbon price.
- **Competitiveness and carbon leakage** must be addressed. This is likely to be a particular issue in the case of a UK only schemes:

- The UK has reduced emissions by 40% from 1990 to 2018 while the economy grew by nearly 75% and manufacturing economic output has been maintained.
- Since 2001, most manufacturing emissions have been subject to the Climate Change Levy, and since 2005, have been part of the EU's Emissions Trading System. Following some delays in introduction, industrial sectors deemed by the Government 'at most risk of carbon leakage' now receive compensations and exemptions from the costs of low-carbon policies. These can reduce the impact of low-carbon policies on electricity prices by up to 80%. For these firms low-carbon policy adds less than 10% to the electricity price, which adds less than 2% to operating costs in the case of steel. Within this, carbon pricing itself is an even smaller proportion.
    - The majority of manufacturing sectors have a Climate Change Agreement (CCA) and therefore receive a 90% discount from the levy, and metallurgical/mineralogical processes are exempt from CCL.
    - Under the EU ETS, free allocation of EU ETS allowances (EUAs) to industry has been important in maintaining industrial competiveness, whilst still providing an incentive to reduce emissions due to the opportunity cost of the allowance.
        - During Phases I and II (2005-2012), most allowances in all Member States were given out for free based on historical GHG emissions.
        - From Phase III (2013 onwards) a benchmarking approach was introduced for the free allocation of allowances. The total amount of free allocation each installation should receive is determined by product-related GHG emission benchmarks, set at the average emission level of the 10% most efficient installations within each sector. Evidence suggests this has driven some industrial decarbonisation.
    - Carbon pricing also increases the costs of fossil fuelled electricity generation. In the UK electricity intensive firms in sectors deemed "most at risk" of carbon leakage received compensation up to 80% of this impact.
- As a result of these measures, the impact of low-carbon policies on energy prices has not had a major impact on the competitiveness of UK manufacturing to date.[9] Cost compensation and exemptions should remain so long as there are differences in low-carbon policy costs between the UK and elsewhere. The Government should ensure businesses can plan on the basis that this will be the case, while keeping the precise coverage, level and conditionality of the compensation and exemptions under review.
- Industrial competiveness can be maintained without free allocation of permits. Longer term, the Government should consider policies to ensure a level playing field with other countries while encouraging action to reduce emissions. Other possibilities include border tariff adjustments that put a charge on imports based on their carbon content, or developing standards that incentivise the purchase of lower carbon products.

[9] CCC (2017) *Energy prices and bills.*

3) Setting the UK's emissions cap

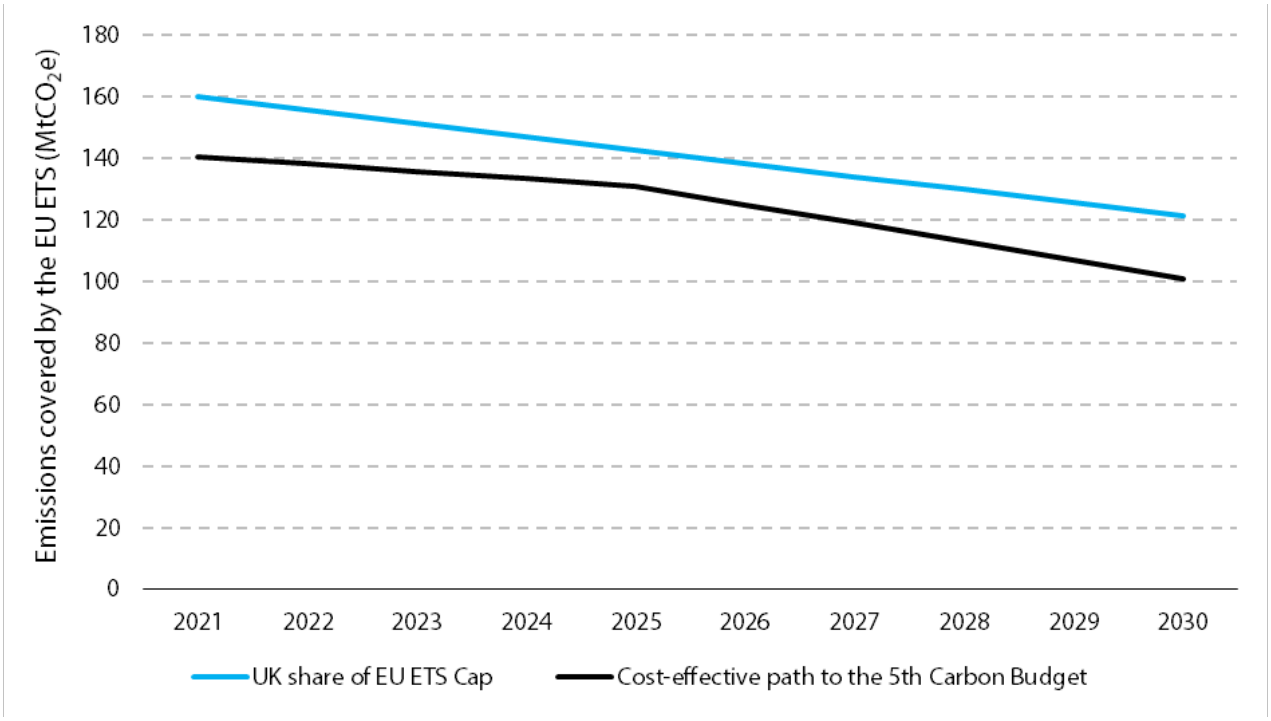
The EU ETS is a 'cap and trade' emissions trading system that requires participants to provide allowances (EUAs) for greenhouse gas emissions within a system-wide cap. Allowances are distributed via auctions or free allocation, and are traded at a value that reflects abatement opportunities in the system. The third phase of the EU ETS runs between 2013 and 2020, with the fourth phase extending between 2021 and 2030. The cap of the scheme declines towards an emissions reduction target by 2030 of 43% below 2005 levels for all covered emissions.

The UK's allocation of EUAs is currently based on outputs of EU modelling (which takes into account other factors such as economic activity, past emissions and equity considerations). For sectors currently covered by emissions trading, the UK is already decarbonising more quickly than other EU countries, meaning the UK's emissions are lower than its share of the EU ETS cap. If this remains the case during the 2020s, there is a risk that other EU countries will buy UK allowances to continue polluting (a net gain to UK Treasury) rather than reducing overall EU emissions.

- At the time of the 5th Carbon Budget recommendation the UK's projected shared of the cap for Phase IV of the EU ETS was expected to be around 120 $MtCO_2e$ in 2030. In the 5th Carbon Budget we estimated this was around 31 $MtCO_2e$ higher than the actual emissions we would expect from the UK's traded sector over this period in order to comply with the 5th Carbon Budget (Figure 2).[10] The Government's carbon pricing consultation also notes this issue.[11]
- In 2018, the UK auctioned around 100 $MtCO_2e$ of allowances. At an EU ETS price of €15/tCO_2 (£13/tCO_2) this is equivalent to revenue of around £1.6 billion/year. Around 75% of these allowances are sold to UK firms. The remainder is sold to Europe (or banked for future compliance), raising around £0.4 billion/year in revenue. EU ETS allowances have since risen in price, to around €30/tCO_2.

[10] CCC (2015) *The Fifth Carbon Budget Table 6.1*.
[11] BEIS (2019) *The Future of Carbon Pricing*.

Figure 2. The UK's share of the EU ETS cap



Source: CCC analysis based on CCC (2015) *The Fifth Carbon Budget*, and BEIS (2019) *BEIS Carbon Pricing Model*.

Setting UK emissions caps provides opportunities for reconsideration of the rate of decarbonisation of sectors covered by carbon pricing schemes and better-alignment to carbon budget periods. Emissions caps that rise significantly above the cost-effective path to the 2050 target – such as the UK's current share of the EU ETS cap – are an inefficient way of abating emissions and meeting carbon budgets. A lower cap in the 2020s would be more in line with expected UK emissions over the fourth and fifth carbon budget periods and allow policy instruments to be better aligned to the UK's decarbonisation trajectory.

The Committee is in the process of preparing its advice on the sixth carbon budget, covering the period between 2033-2037 and detail on the cost-effective pathway to reach both this period and the 2050 target. We will publish this advice in 2020. We recommend that the UK's emissions trading cap be aligned to the sixth carbon budget advice as soon as possible after publication.

A lower UK cap could have implications for the EU ETS free allocation process that protects competitiveness. Government should ensure that under a tighter cap, this mechanism does not lead to carbon leakage.

As carbon budgets are currently set based on a projections of the UK's share of the EU ETS cap, there is a specific risk that the accounting rules for the EU ETS can undermine the integrity of carbon budgets, as noted in the fifth carbon budget advice.[12] When setting a UK cap, these risks will need to be avoided. For example, for existing carbon budgets, if the UK ends up with a smaller share of the EU ETS cap than assumed in our analysis, then the budget could be met with less effort from the rest of the economy, and vice versa. This was an issue for the second carbon budget. As such, we have previously recommended that carbon budgets be set based on

[12] CCC (2015) *The Fifth Carbon Budget*.

expected emissions over the carbon budget period, and not the traded sector cap. We will revisit this advice as part of our work on the sixth carbon budget.

4) Other key considerations for the future of UK carbon pricing

Impact of carbon pricing on consumers

The costs of carbon pricing can be passed through to the fuel bills that consumers pay, and the products they purchase. Our 2017 *Energy Prices and Bills* report considered the impact of low-carbon policies on residential, industrial and commercial consumers.[13] This concluded that low-carbon policies currently make up a small proportion (less than 10%) of energy bills for the majority of consumers, and have been outweighed by savings from energy efficiency policy. Within this, the carbon price makes up a small proportion of overall costs. This is likely to increase to 2030, though there will be opportunities for further energy efficiency to offset this increase:

- **Carbon pricing on power.** Of a total estimated dual-fuel household bill of around £1,160 in 2016, low-carbon policies made up around £105 (9%). Within this, carbon taxation accounted for around £30 (or 2.5%) of the overall bill, and spread evenly across electricity prices. Energy efficient product standards have enabled average household electricity consumption to fall by 17% between 2008 and 2016, saving around £100 per year on a household's electricity bill, offsetting the bill impact of low-carbon policies, including carbon prices.[14] In 2016 we estimated that further energy efficiency opportunities would be available to households up to 2030 (and beyond), the majority (85%) of which is available from replacing appliances, lights and boilers at the end of their lives with the latest equivalent models.
- **Impact on prices of consumer products.** If all of the costs of low-carbon policies were passed on to consumers through higher product prices this would add 3 pence to an average £10 basket of goods and services in 2016 and would add 6 pence by 2030. Within this, the impact of currently projected carbon prices is a small proportion. In reality, low-carbon policy costs are not fully passed through to consumers. Additionally, where firms can cut costs through energy efficiency or other measures, price impacts will be reduced.

Carbon pricing raises funds for the Exchequer (e.g. around £3.3 billion in 2018).[15] In principle, these revenues could be allocated to specific decarbonisation objectives, such as carbon capture and storage or industrial decarbonisation. However, in reality, revenues from the current carbon pricing regime are unlikely to be sufficient to cover the costs of decarbonisation across all sectors, so further supplementary policies will be required (see section 5).

Expansion of carbon pricing to other sectors (e.g. transport, domestic gas) could increase overall revenue from carbon pricing, but would also impact household bills. However there would also be opportunities to redistribute some carbon pricing revenue to households through carbon tax and dividend schemes (as is done in British Colombia for example, and has been suggested for the UK[16]), or develop policy instruments to incentivise decarbonisation that do not directly pass the cost of carbon through to consumers.

[13] CCC (2017) *Energy Prices and Bills*.
[14] In addition to this, we estimate reduced household gas consumption to have saved around £200 per year on household bills over this period. See CCC (2017) *Energy Prices and Bills – impacts of meeting carbon budgets*: *Annex*.
[15] Including EU ETS auction revenues, CPS and CCL.
[16] See Grantham (2019) *How to price carbon to reach net-zero emissions in the UK*.

Impact on devolved administrations

The EU ETS in the UK covers installations in England, Wales, Scotland and Northern Ireland. Additionally, power generators in all nations – except Northern Ireland – pay the Carbon Price Support (CPS) rates of the CCL.

Northern Irish power generators are exempt from paying the CPS, as this would create a distortion between Northern Irish and Irish power generators within the Irish Single Electricity Market (I-SEM). Under a linked scheme these arrangements would be maintained. The UK Government's preference is to have a harmonised carbon price in the I-SEM. However, there is a risk that separate schemes could lead to a carbon price differential. Options are available to address this, were it to arise.[17]

Current UK fourth and fifth carbon budgets are aligned to outdated Scottish and Welsh climate targets, as Scotland has recently set a net-zero target for 2045, and Wales has committed to updating its long-term targets in light of the CCC's recent advice. The CCC's sixth carbon budget advice will be aligned to the recently updated targets.

Aviation

Aviation is an international sector and is covered by international agreements regulating emissions. Intra-EU flights are covered by the EU ETS, and some but not all international flights will be covered by CORSIA (a global offsetting scheme agreed through the International Civil Aviation Organisation). These policies are currently less ambitious than is needed to be consistent with the UK's net-zero target and with the Paris Agreement.

In the UK, carbon budgets cover emissions from domestic flights. The Government has stated that the 2050 net-zero target must cover all sectors of the economy, including emissions from international flights.

In a future UK carbon pricing system, the appropriate approach for aviation will depend on the wider approach to carbon pricing:[18]

- In a UK ETS that is linked to the EU ETS it makes sense for this to cover UK-EU flights, in line with the EU approach.
- In a standalone UK ETS, it makes sense for this to align to the coverage of UK carbon budgets (i.e. currently domestic flights only).
- In a carbon tax Government has stated that, in the event of a no-deal Brexit, this will exclude emissions from aviation. However, if this were to be a more permanent option coverage of aviation would be appropriate, either through a carbon tax or equivalent supporting policies.

In either trading option, the UK cap for aviation should align to the sixth carbon budget pathway.

The Committee will publish further advice on the policy approach to aviation under a net-zero target later in 2019.

[17] See Box 16 of Vivid Economics (2019) *The Future of Carbon Pricing in the UK*.
[18] For example, we note the Government has issued a call-for-evidence on the role of carbon offsetting in transport, including aviation (DFT (2019) *Carbon offsetting in transport – A call for evidence*).

5) Carbon pricing for net-zero

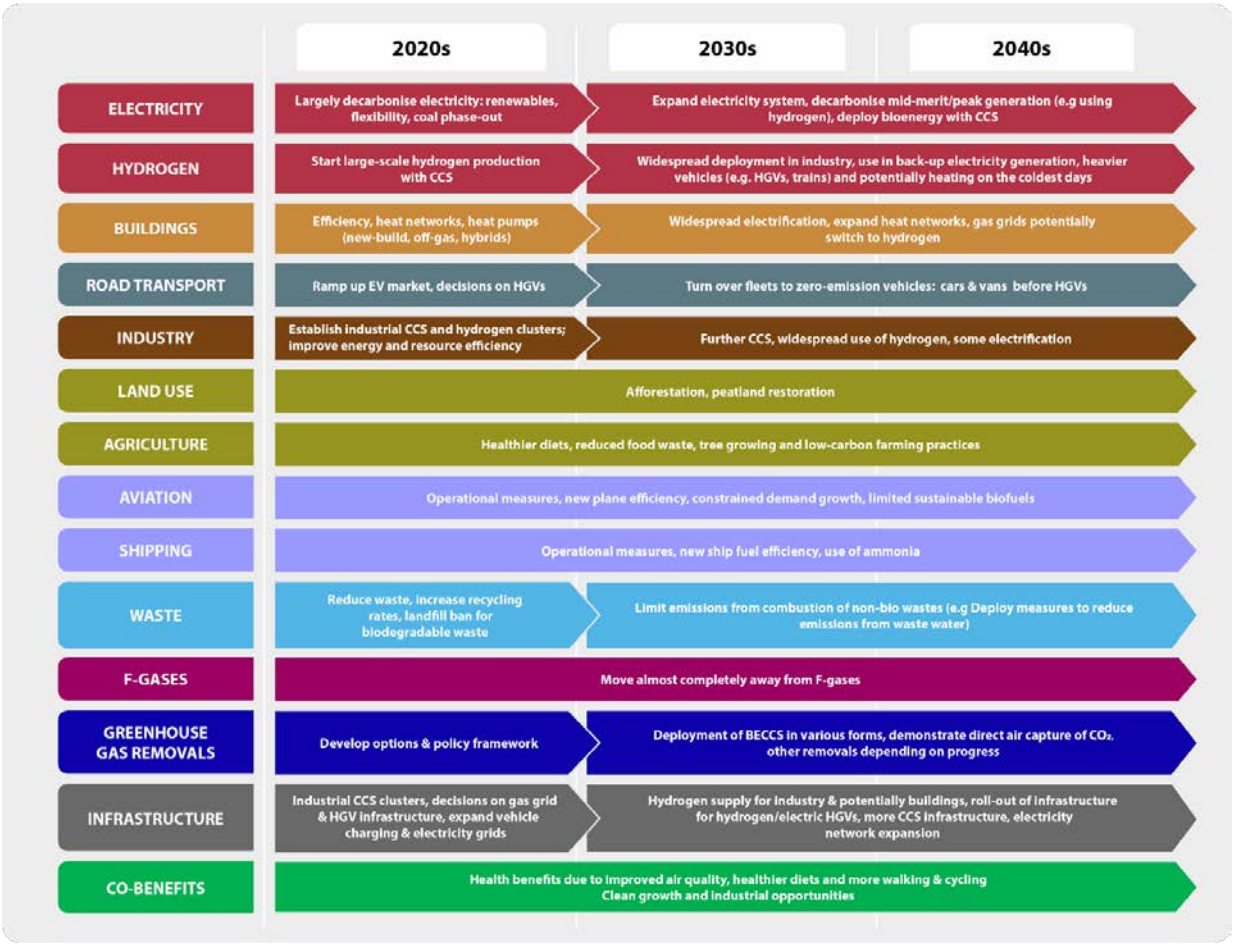
In May 2019 the Committee recommended that the UK adopt a 'net-zero' target for all greenhouse gas emissions by 2050. The Government then legislated for a net-zero target in June 2019. This implies that all sectors of the economy are required to reduce emissions towards zero by 2050, with any residual emissions (e.g. from aviation, industry, agriculture) being offset by greenhouse gas removals (e.g. afforestation or engineered removals).

Achieving the net-zero goal will require a step up in climate ambition across all the emitting sectors of the economy (Figure 3). This means embedding and integrating climate policy across all departments, at all levels of Government and in all major decisions that impact on emissions.

Whilst acknowledging that in many sectors carbon pricing alone is unlikely to bring forward the pace or required infrastructure for full decarbonisation, there is likely to be value in expanding the scope of carbon pricing. Table 2 sets out the potential role for carbon pricing and supporting policies on the path to net-zero emissions in each sector of the economy.

Carbon pricing could in most cases be applied either as a carbon tax or through an ETS. If sectors with large residual emissions in 2050 are included in an ETS, greenhouse gas removals could also be included, assuming options other than afforestation are sufficiently mature (see Box 1).

Figure 3. Illustration of the transition to the UK net-zero GHG target



Source: CCC (2019) *Reducing UK emissions: 2019 Progress Report* to *Parliament*.

Box 1. Including greenhouse gas removals in an emissions trading system

The EU ETS currently covers emissions from power stations, large industrial facilities and flights between EU countries (known as the 'traded' sectors). Emissions offsets using greenhouse gas removals (GGRs) are not included.

It is possible to envisage a future trading system between residual emitters and providers of carbon sequestration (such as GGRs). Under this system, credits could be awarded to GGRs for carbon captured and permanently stored or used. The quality of removals would need be guaranteed, ensuring accurate estimates of level of abatement, permanence of the removal and that minimum sustainability criteria and rules around appropriate use of land are met (e.g. if relating to afforestation, BECCS or other GGRs that involve land-use change).

Figure B.1 shows an example of how the level of the cap and traded allowances under an ETS including GGRs could evolve:

- In this example, GGRs are included in the ETS in 2030 (the point after which engineered GGRs are assumed to be required/mature) and sectors with residual, hard-to-abate emissions (aviation and agriculture) are included at the same time. Other sectors with residual emissions could also be included.
- The cap is increased to reflect an illustrative cost-effective path to the net-zero target for the additional sectors. Allowances are auctioned up to the level of the cap.
- By 2050 the cap reaches zero, and no further allowances are auctioned. A limit could be set for the number of GGR credits, to ensure that GGRs are additional to genuine abatement opportunities.

When might there be value to including GGRs in an ETS?

Carbon pricing, including an ETS, is unlikely to incentivise the development of engineered GGR technologies – policy support for innovation will be needed. But including GGRs in an ETS when technology maturity is reached can provide an effective mechanism for encouraging deployment.

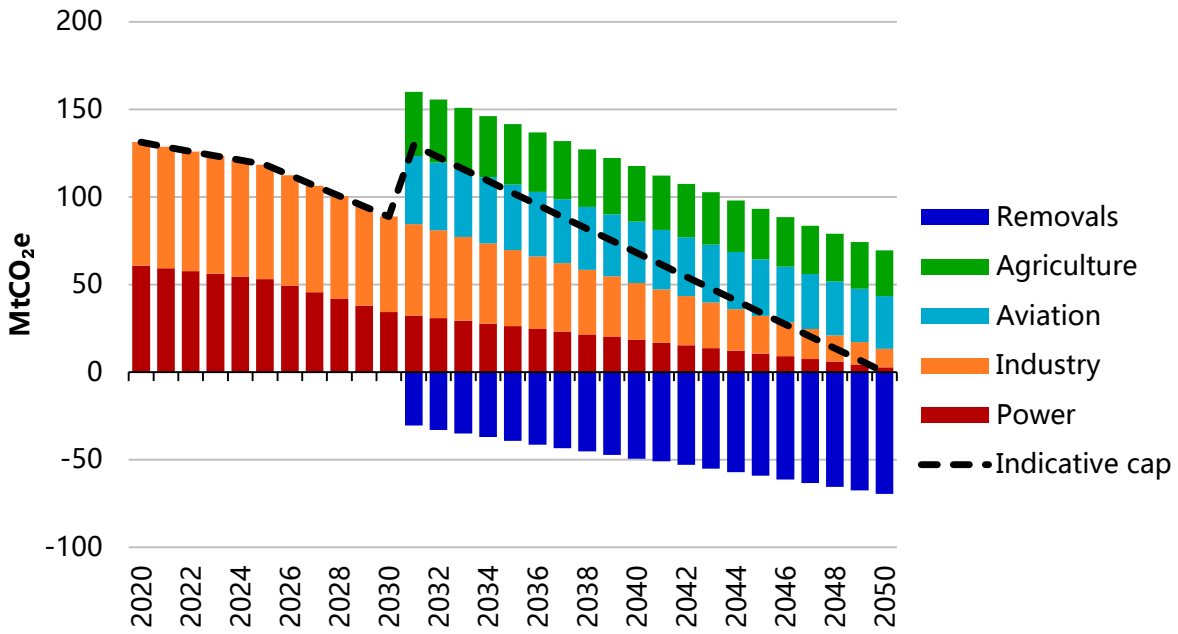
Our analysis suggests that policy can unlock low-cost abatement opportunities across most sectors of the economy. It also suggests that achieving net-zero emissions in the UK will require some level of GGR. However, GGRs are likely to be more expensive in the long-run, and should be additional to genuine and affordable abatement opportunities. This points to considering certain conditions for inclusion of removals in an ETS, such as also including sectors with hard-to-abate residual emissions (as in the example in Figure B.1). Other factors should also be taken into account:

- If inexpensive GGRs (e.g. afforestation, which costs around £10/tCO_2e in 2050 in our net-zero scenarios) were included in the existing ETS, emitting sectors could continue carbon-intensive practices while purchasing cheap offsets. In principle this enables cost-effective decarbonisation, but in practice it could limit the uptake of cost-effective measures like energy efficiency and fuel switching that are estimated to be required to achieve long-term emissions reductions, taking into account timeframes for developing low-carbon infrastructure in UK industry and a likely upper bound on the amount of UK forestry available.
- Therefore, if land-based GHG removals like afforestation or bioenergy with CCS (BECCS) were included in an ETS, the upper bound of what is desirable in terms of take-up (to avoid competing with other land uses, or breaching sustainability constraints) could be quickly reached, meaning that land-based solutions might not be available to offset emissions sources which are truly expensive and/or difficult to decarbonise in the long-run.
- In the long-term, GGRs other than afforestation – such as BECCS and direct air capture of CO_2 with storage (DACCS) – will be needed, but are currently more expensive and likely to require further innovation support before inclusion in an emissions trading scheme.

Box 1. Including greenhouse gas removals in an emissions trading system

- This suggests that there may be a case for limiting the number of credits provided to GGRs (e.g. at the level of expected residual emissions) in order to avoid these adverse effects.

Figure B.1. Indicative allowance and cap trajectory for a UK ETS including GGRs



Source: CCC analysis.
Notes: Represents an illustrative pathway for the level of the emissions cap and allowances in an ETS, where the cap of the system reduces to net-zero by 2050, with trading between sectors with residual emissions and emissions removals. The pathway out to 2030 is based on the cost-effective emissions reduction path for the power and industry sectors from our fifth carbon budget analysis. The pathway between 2030 and 2050 is a linear interpolation of the fifth carbon budget level in 2030 and the net-zero target. The example of a cap from 2030 includes the addition of agriculture and (domestic and international) aviation as they are assumed to be the sectors with large levels of hard-to-abate emissions, although it would also be possible to include other sources of residual emissions in the period to 2050.

Table 2. Role of carbon pricing and supporting policies to achieve a net-zero GHG emissions target

Sector	Role of carbon pricing	Role of supporting policies
Power sector emissions can be reduced to close to zero by 2050. *(currently traded in the EU ETS, and pays the CPS)*	• Has been effective in incentivising switching from coal-fired power generation to lower emissions natural gas and efficiency improvements. • Beyond coal closure, must be maintained at a sufficiently high level to continue to provide an incentive for lower-carbon dispatch decisions. • Carbon pricing on its own is unlikely to drive longer-term investment in renewables, nuclear and CCS.	• While many low-carbon options no longer need subsidies to continue their expansion, Government intervention may still be needed, for example by backing long-term contracts aligned to expected wholesale prices. • Innovation support for new technologies has proven effective in the power sector so far and will continue to be valuable in promoting new low-carbon technologies (e.g. floating offshore wind). • New infrastructure networks required to support low-carbon technologies (e.g. CO_2 transport and storage infrastructure) will require Government support (e.g. planning permissions, development of a delivery mechanism). • Further market reforms are required to ensure that sufficient flexibility will be available and that the system will always be operable.
Industry is likely to have relatively high residual emission by 2050 (around 10 $MtCO_2e$) despite significant emissions reductions. *(currently traded in the EU ETS, and pays the CCL)*	• The EU ETS carbon price and benchmarking process provide incentives to improve industrial energy efficiency and some fuel switching and can continue to do so in the future. • Given expectation of residual industrial emissions in 2050 carbon pricing could play a bigger role in achieving net-zero emissions if the sector were part of a trading system including opportunities for genuine and additional offsets (see Box 1). • Carbon pricing is unlikely to drive long-term investment decisions needed to incentivise the use of hydrogen, bioenergy, electricity and CCS, and greater production of hydrogen unless supported by supplementary policies.	• Policies should include a funding mechanism for industry decarbonisation, to support near-zero emission technologies (including use of hydrogen, electrification and CCS), a mechanism to support CO_2 transport and storage infrastructure and support for energy and resource efficiency. • CO_2 transport and storage infrastructure should be operational in multiple industrial clusters by the mid-2020s and available to all major industrial clusters soon afterwards, alongside hydrogen for all clusters where it is the best fuel-switching option for some sites. A network to provide hydrogen to industry outside the main industrial clusters should be established by 2035, or potentially slightly later if 'hydrogen-ready' appliances can be deployed in industry prior to this. • Non-price barriers to energy efficiency suggest policies other than carbon pricing are likely to be needed.

Aviation is expected to have significant residual emissions in 2050 (up to 30 $MtCO_2e$) due to a lack of mature technological solutions to fully decarbonise the sector. *(emissions from intra-EEA flights currently traded in the EU ETS)*	• Could help encourage further aircraft efficiency improvements and some take-up of biofuels. • If prices are high enough to pass through onto consumers via ticket prices could encourage a reduction in aviation demand, which would in turn reduce emissions. • Carbon pricing could play a bigger role in reducing net emissions from aviation through CORSIA (the international aviation industry's planned trading scheme), the EU ETS or unilaterally. The UK could support a net-zero target for aviation, requiring that all emissions are offset by sustainable removals (see Box 1).	• Improving aircraft fuel efficiency – both through technological innovation and via more direct routes – will reduce fuel burn and hence emissions. • Globally available non-fossil fuels means a global low-carbon supply of the fuels, and a global refuelling infrastructure network. These changes will rely on international cooperation (e.g. across the EU and more widely) to realise the full benefits. • Supporting policies will be needed to limit the growth in demand, to the extent that this is not achieved through carbon pricing.
Shipping emissions can be reduced to close to zero by 2050.	• Could drive energy efficiency improvements and incentivise some switching to alternative non-fossil fuels (e.g. ammonia or synthetic hydrocarbons).	• As with aviation, global low-carbon fuel supply will be required for shipping. Asset owners may not want to invest in alternative fuel ships until a global supply network is in place, but airports and ports may not want to invest in the supporting infrastructure until demand can be credibly demonstrated. Policy may be required to overcome this coordination problem.
Buildings can be largely decarbonised by 2050.	• Carbon pricing on downstream gas consumption could reduce the current price distortion between residential gas and electricity and encourage some take-up of low-carbon heating solutions and efficient usage of hybrid heat pumps (set to use electricity rather than gas).	• Decarbonising buildings will require widespread roll-out of energy efficiency in homes and low-carbon heating solutions which a carbon price applied to domestic and commercial gas use is unlikely to drive on its own. A fully funded overhaul of the approach to low-carbon heating and energy efficiency which protects vulnerable consumers is needed. • Government has already announced an end to the connection of new homes to the gas grid from 2025. Alongside delivering this commitment, by 2050, the majority of heat provided to UK homes will have to be from low-carbon sources. Low-carbon options for heating homes need to be available in order to switch away from fossil-fuelled

		heating. This includes trials of hydrogen for heat in UK homes, and successful deployment of CCS technology. • Further Government support may be required to ensure an adequately trained workforce to install new heating systems and energy efficiency measures and support for new supply chains.
Surface transport emissions can reach close to zero by 2050.	• Fuel duty may in part represent a carbon price for surface transport, although it is designed to address other externalities (e.g. congestion). It is also an important source of revenue for the Exchequer. • Increasing and making the carbon-related component of fuel duty explicit could result in some demand and emissions reduction, but supply-side measures are likely to be more effective in encouraging electric vehicle take-up. • Could encourage some switching to low-carbon HGVs, but refuelling infrastructure will need to be in place for this to happen (including internationally).	• By 2035 at the latest, and ideally by 2030, all new cars and vans should be electric (or use a low-carbon alternative such as hydrogen). A ban on petrol and diesel vehicles should be put in place by either 2030 or 2035, depending on when confidence that supply chains will be able to match demand can be determined. • Enabling the expansion of electric vehicle charging networks and electricity grid capacity will be important in facilitating strong growth in electric vehicles. • The Government will need to make a decision on the required infrastructure for zero emission HGVs, with international coordination, in the mid-2020s ready for deployment in the late 2020s and throughout the 2030s.
Agriculture and Land use still likely to represent a residual source of emissions by 2050 (up to 26 $MtCO_2e$).	• Agricultural inputs and products can be emissions intensive. Carbon pricing on the GHG emissions content of nitrogen fertilisers could encourage more efficient fertiliser use. • Pricing on emissions-intensive animal products (lamb, beef and dairy) could incentivise a shift in diet towards chicken, pork and plant-based proteins. • These changes would not be enough to fully decarbonise the agriculture sector. Additionally: • Financial payments in the UK Agriculture Bill should be linked to actions to reduce and	• Government should introduce consumer-focused policies to encourage healthier diets and reduce food waste more proactively. The public sector should take a strong lead for example, by providing plant-based and lower-meat options in schools and hospitals. • Continued investment in R&D, testing and piloting of options to deliver agricultural productivity improvements and enhanced forest productivity will be needed. • Government should also provide support to help land managers transition to alternative land uses through skills, training and information.

	sequester emissions, providing an effective carbon price. • Including agriculture in an emissions trading scheme which incorporates greenhouse gas removals could also be a viable solution to achieve net-zero emissions in the sector (see Box 1).	
Waste emissions can reduce to close to zero by 2050.	• UK's landfill tax successfully reduced the amount of waste sent to landfill and consequently GHGs from waste. Although the primary purpose of the tax has been to reduce the volume of waste to landfill, rather than GHGs specifically, it can in part be considered a carbon tax. • Carbon pricing linked to the carbon content of waste could further reduce GHGs associated with landfilled waste, although an outright ban would be easier to implement.	• Bio-degradable waste streams should be banned from landfill after 2025. • To achieve this Government and the devolved administrations must ensure that separate waste collection is available by 2023. • Supporting measures to increase municipal recycling rates to 70% by 2030 at the latest and to achieve a 20% reduction in avoidable food waste by 2025 should be introduced.
CCS will be essential to achieve a net-zero target.	• Could help incentivise facilities to fit and use CCS, and ensure that those that do face lower costs than those that do not (once CO_2 transport and storage infrastructure is available).	• The Government will need to take a lead on co-ordinating infrastructure development, alongside wider support (e.g. long-term contracts) to encourage investment in CCS and reduce costs.
Engineered greenhouse gas removals are likely to be needed by 2050.	• Including greenhouse gas removals (GGRs) in an ETS (by awarding credits to GGRs for carbon captured and permanently stored or used) could provide an effective funding mechanism to encourage deployment of mature GGR options (see Box 1).	• The Government should expand support for early-stage research across the range of GGR options, including trials and demonstration projects. • It should also signal the longer-term market, which is clearly needed to meet a net-zero target, by developing the governance rules and market mechanisms (which may be an ETS) to pay for emissions removals.

Source: CCC (2019) *Net zero – The UK's contribution to stopping global warming*. Grantham Research Institute (2019) *How to price carbon to reach net-zero emissions in the UK*. ESC (2019) *Rethinking decarbonisation incentives*.