SUPPORTING THE DEPLOYMENT OF BIOENERGY CARBON CAPTURE AND STORAGE (BECCS) IN THE UK: BUSINESS MODEL OPTIONS

A report for Drax

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CONTENTS

EXECUTIVE SUMMARY

Drax Power Station is currently exploring the option of adding carbon capture and storage equipment to its biomass-fired generating units. The resulting plant could produce at least 8 million tonnes (Mt) of negative CO_2 emissions each year, as well as generating renewable electricity. Drax is planning to make a final investment decision (FID) on its bioenergy with carbon capture and storage ('BECCS in power'[1]) investment in Q1 2024, with the first BECCS unit to be operating by 2027.

The potential of BECCS as part of the path to Net Zero has been widely recognised.

- BECCS in power is an important part of all of the Climate Change Committee (CCC)'s Net Zero scenarios, contributing to negative emissions of between 16-39Mt CO_2e per year by 2050[2]. Investment needs to occur early: by 2035, the CCC sees a role for 3-4GW of BECCS, as part of a mix of low carbon generation[3].
- The Government's Energy White Paper commits, by 2022, to establishing the role which BECCS can play in reducing carbon emissions across the economy and setting out how the technology could be deployed. The Government has also committed to invest up to £1 billion to support the establishment of carbon capture, usage and storage (CCUS) in four industrial clusters [4].
- National Grid's 2020 Future Energy Scenarios (FES) indicate that it is not possible to achieve Net Zero without BECCS[5].

However, at present, a business model[6] which could enable this investment is not in place. A business model is required because a number of barriers and market failures otherwise make economic investment impossible.

- **There is no market for negative emissions.** There is currently no source of remuneration for the value delivered by negative emissions, and therefore no return for the investment needed to achieve them.

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1 Biomass can be combusted to generate energy (typically in the form of power, but this could also be in the form of heat or liquid fuel), or gasified to produce hydrogen. The resulting emissions can then be captured and stored using CCS technology. The focus of this report is on biomass combustion to generate power, with CCS, which we refer to as 'BECCS in power'. We refer to biomass gasification with CCS as 'BECCS for hydrogen'.

2 CCC (2020) , *The Sixth Carbon Budget, Greenhouse Gas Removals*, https://www.theccc.org.uk/wp-content/uploads/2020/12/Sector-summary-GHG-removals.pdf The CCC's 2019 Net Zero report also saw a role for BECCS, with 51Mt of emissions removals included in the Further Ambition scenario by 2050. CCC (2019), *Net Zero: The UK's Contribution to Stopping Global Warming*. https://www.theccc.org.uk/publication/net-zero-the-uks-contribution-to-stopping-global-warming/

3 CCC (2020), *Policies for the Sixth Carbon Budget,* https://www.theccc.org.uk/wp-content/uploads/2020/12/Policies-for-the-Sixth-Carbon-Budget-and-Net-Zero.pdf

4 BEIS (2020), *Powering our Net Zero Future,* https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/945899/201216_BEIS_EWP_Command_Paper_Accessible.pdf

5 National Grid (2020), *Future Energy Scenarios 2020*, https://www.nationalgrideso.com/future-energy/future-energy-scenarios/fes-2020-documents

6 In this report, we use "business model" to describe Government market-based incentives for investment and operation. This is in line with the use of this term by BEIS, for example in BEIS (2019), *Business Models For Carbon Capture, Usage And Storage,* https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/819648/ccus-business-models-consultation.pdf

- **Positive spillovers are not remunerated**. Positive spillovers that would be delivered by a first-of-a-kind BECCS power plant, but which are not remunerated include:
  - providing an anchor load for carbon dioxide (CO_2) transport and storage (T&S) infrastructure that can be used by subsequent CCS projects;
  - delivering learning that will help lower the costs of subsequent BECCS power plants; and
  - delivering learning and shared skills that can be used across a range of CCS projects, including hydrogen production with CCS.
- **BECCS relies on the presence of CO_2 transport and storage infrastructure**. Where this infrastructure doesn't already exist, or where the availability or costs are highly uncertain, this presents a significant risk to investors in BECCS in power.

Frontier Economics has been commissioned by Drax to develop and evaluate business model options for BECCS in power that could overcome these barriers, and help deliver timely investment in BECCS.

Business model options

We started with a long list of business model options. After eliminating options that are unsuitable for BECCS in power, we considered the following three options in detail.

- **Power Contract for Difference (CfD):** the strike price of the CfD would be set to include remuneration for negative emissions, low carbon power and for learnings and spillover benefits.
- **Carbon payment:** a contractual carbon payment would provide a fixed payment per tonne of negative emissions. The payment level would be set to include remuneration for negative emissions, low carbon power and for learnings and spillovers.
- **Carbon payment + power CfD:** this option combines the two options above. The carbon payment would provide remuneration for negative emissions and learnings and spillovers while the power CfD would support power market revenues for the plant's renewable power output.

We first considered if committing to any of these business model options for BECCS in power now might restrict future policy options for a broader GGR support scheme. We assessed whether these options could, over time, be transitioned into a broader GGR support scheme (i.e. one not just focused on BECCS in power), and concluded that this would be possible for all of them.

We then considered how these business model options could be funded, and whether the choice of a business model option is linked to a particular source of funds (for example, power CfDs are currently funded by a levy paid by electricity suppliers to the Low Carbon Contracts Company [LCCC]). We concluded that business models do not need to be attached to specific funding sources; all of the options can be designed to fit with numerous different funding options, so the two decisions can be made independently. This means that the business model options can be considered on their own terms, with thinking about funding sources being progressed in parallel.

We then evaluated the three business model options against a set of criteria developed from principles set out in the BEIS consultation on business models for CCS, summarised in the figure below.

Figure 1 Principles for design of business models

Instil investor confidence	▪ Attract innovation ▪ Attract new entrants ▪ Instil supply chain confidence
Cost efficient	▪ Drive efficient management of investment costs ▪ Drive efficient quantity of investment ▪ Drive efficient dispatch and operation ▪ Risks allocated in an efficient way, taking into account the impact on the cost of capital
Feasibility	▪ Limit administrative burden ▪ Practicality for investors ▪ Requirement for complementary policy ▪ Wider policy and state aid compatibility ▪ Timely implementation
Fair cost sharing	▪ Allows fair and practical cost distribution
Ease of policy transition	▪ Ease of transition to subsidy free system ▪ Ease of transition to technology neutral solution

Source: Frontier Economics

All three business model options performed well across most criteria. However, our evaluation highlighted some key trade-offs to consider when choosing a business model:

- **investor confidence:** the power CfD and the two-part model with a CfD performed better than the carbon payment on this measure, as they shield investors from wholesale power market fluctuations;
- **feasibility:** the power CfD performed best on this measure. Because it is already established in existing legislation and is well understood, it will be quick to implement. Introducing a mechanism to provide carbon payments may require new legislation. However, this will be needed in any case to support other CCUS technologies[7], and could be introduced in time before projects come online; and
- **potential to become technology neutral and subsidy free:** all three options could transition to a mid-term regime which could be technology neutral. However, the stand-alone power CfD performed least well as it does not deliver any learnings around remunerating negative emissions.

[7] BEIS (2020), *CCUS: An update on business models for Carbon Capture, Usage* and Storage https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/946561/ccus-business-models-commercial-update.pdf

Overall, the two-part model performed well across the criteria and would offer a clear path to a technology neutral and subsidy free world, delivering learnings that will be relevant for other GGRs as well.

Conclusions

The UK's Net Zero target will be challenging to achieve, and will require investment in negative emissions technologies to offset residual emissions from hard-to-abate sectors, as highlighted by the CCC[8]. BECCS in power is a particularly important part of this picture, and represents a cost-effective means of delivering the scale of negative emissions needed. Early investment in BECCS is also important in insuring against the risk and cost of "back ending" significant abatement effort.

However, market failures, most notably the lack of a market for negative emissions, lack of remuneration for positive spillovers and learnings, and reliance on availability of T&S infrastructure, mean that without policy intervention, the required level of BECCS in power is unlikely to be delivered in time to contribute to Net Zero.

There are a number of business options available in the near term to overcome these barriers. In our view, a two-part model combining a power CfD and a carbon payment is preferable.

This measure:

- addresses identified market failures;
- can be implemented relatively easily and in time to capture benefits of early BECCS in power investment; and
- can be structured to ensure an efficient outcome for customers (including with reference to investors' likely cost of capital) and in a way that allocates risks appropriately.

[8] CCC (2020) , *The Sixth Carbon Budget, Greenhouse Gas Removals*, https://www.theccc.org.uk/wp-content/uploads/2020/12/Sector-summary-GHG-removals.pdf

1 INTRODUCTION

Drax Power Station is a biomass- and coal-fired power plant. Four of its six generating units are biomass-fired, and the two remaining coal units are ceasing commercial operation in March 2021. Biomass combustion is a renewable form of generation, and the CO_2 released when it is burned is equal to the amount of CO_2 that the biomass absorbs from the atmosphere as it grows.

Drax is currently exploring the option of adding carbon capture and storage equipment to all the biomass units at the power station. In a first phase of development carbon capture technology would be applied to two biomass units, which together would produce at least eight million tonnes (Mt) each year of negative emissions as well as generating electricity.

Drax is planning to make a final investment decision (FID) on its BECCS investment in 2024, with one BECCS unit to be operating by 2027. This would be the first carbon negative power station in the world. The timing of the investment decision is largely driven by the government's progress towards a business model for BECCS and of the planned delivery of Transport and Storage (T&S) infrastructure.

1.1 Why BECCS?

Because of the very high costs of abatement in certain sectors such as agriculture, and the fact that total abatement in other sectors such as aviation is not currently feasible, negative emissions will need to play a key role in meeting the Net Zero target.

While most low carbon technologies abate emissions associated with economic activity (for example by displacing traditional forms of electricity generation with lower or zero carbon generation such as wind or solar), greenhouse gas removal technologies (GGRs) produce negative emissions by capturing and storing greenhouse gases that are already in the atmosphere. They can therefore be used to offset emissions from hard-to-abate sectors, and by doing so lower net emissions.

BECCS is likely to be one of the most important and earliest GGRs deployed to meet Net Zero targets. It has a number of advantages.

- BECCS delivers "permanent" greenhouse gas removals, which cannot be guaranteed for all GGR technologies. For example, soil carbon sequestration can store CO_2 for long periods of time but requires continued careful land management to be effective.
- BECCS can be a cost-effective technology to achieve Net Zero. The CCC estimates that the cost of BECCS in power in the 2030s could be between £70/tCO_2e and £150/tCO_2e[9]. This is likely to compare favourably to decarbonising hard to tackle sectors, including some parts of industry and aviation.

- BECCS is also likely to be available earlier than many other GGR technologies. Vivid Economics has evaluated the technological readiness levels of a range of GGR technologies. The highest readiness levels are found in the use of wood in construction, afforestation and soil carbon sequestration (all at either 8 or 9 out of a maximum readiness level of 9). However, BECCS is given the next highest level of readiness, at 6[10] out of 9. This compares to some of the less ready technologies including habitat restoration (5), DACCS (4), and enhanced weathering (3).

The potential of BECCS as part of the path to Net Zero has been recognised by Government and its advisors.

- BECCS in power is an important part of all of the CCC's Net Zero scenarios, contributing to negative emissions of between 16-39Mt CO_2e per year by 2050[11]. Investment needs to occur early: by 2035, the CCC sees a role for 3-4GW of BECCS, as part of a mix of dispatchable low carbon generation[12].
- The Government's Energy White Paper commits, by 2022, to establishing the role which BECCS can play in reducing carbon emissions across the economy and setting out how the technology could be deployed. The Government has also committed to invest up to £1 billion to support the establishment of carbon, capture, usage and storage (CCUS) in four industrial clusters [13].
- National Grid's 2020 Future Energy Scenarios (FES) indicate that it is not possible to achieve Net Zero without BECCS[14].

1.2 Aims of this report

While there is a consensus that BECCS could make an important contribution to delivering the UK's carbon targets, policies to enable invest in BECCS are not yet in place. In particular, under current policy, investors would not be remunerated for negative emissions or for the positive learning externalities they provide.

In this context, we have been asked by Drax to develop proposals for a business model[15] to provide remuneration for negative emissions, power output and the learnings and positive spillovers delivered by first-of-a-kind BECCS power plants in the UK.

We have undertaken the following work as part of this study:

[10] A technology readiness level of 6 means that it has been demonstrated in the relevant environment, but that it is not yet operational or proven in the relevant environment. (Based on EU Horizon 2020 definition: https://ec.europa.eu/research/participants/data/ref/h2020/wp/2014_2015/annexes/h2020-wp1415-annex-g-trl_en.pdf)

[11] CCC (2020) , *The Sixth Carbon Budget, Greenhouse Gas Removals*, https://www.theccc.org.uk/wp-content/uploads/2020/12/Sector-summary-GHG-removals.pdf

[12] CCC (2020), *Policies for the Sixth Carbon Budget,* https://www.theccc.org.uk/wp-content/uploads/2020/12/Policies-for-the-Sixth-Carbon-Budget-and-Net-Zero.pdf

[13] BEIS (2020), *Powering our Net Zero Future,* https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/945899/201216_BEIS_EWP_Command_Paper_Accessible.pdf

[14] National Grid (2020), *Future Energy Scenarios 2020*, https://www.nationalgrideso.com/future-energy/future-energy-scenarios/fes-2020-documents

[15] In this report, we use "business model" to describe Government market-based incentives for investment and operation. This is in line with the use of this term by BEIS, for example in BEIS (2019), *Business Models For Carbon Capture, Usage And Storage*

- based on the characteristics of BECCS power plants, we have reviewed the key market failures that may need to be addressed through a business model; and
- we have developed and evaluated a set of business model options, as well as assessed considerations for funding.

The remainder of this report sets out our findings. We cover the following.

- Section 2 sets out key considerations and principles for business model design to enable investment in first-of-a-kind BECCS power plants.
- Section 3 explains our approach to identifying business model options, and provides an overview of shortlisted options.
- Section 4 assesses the shortlisted business model options.
- Section 5 sets out our conclusions.

2 KEY CONSIDERATIONS FOR BUSINESS MODEL DESIGN

Section 1 illustrated that BECCS in power could help the UK cost-effectively meet climate targets.

In this section we set out key considerations for business model design to enable investment in BECCS. This covers:

- principles that should guide business model design. We will later use these principles to assess each policy option against these aims to identify strengths and weaknesses; and
- considerations around timing for a first-of-a-kind plant and its support regime, and how business model design may evolve over time.

2.1.1 Market failures and other barriers to investment

Investment in BECCS in power is constrained by the existence of market failures and characteristics of first of a kind BECCS power plants that increase the cost of capital and create barriers to investment. This means deployment is slower than would be ideal from a social perspective. Government intervention is therefore needed to address some of these market failures and other barriers.

More specifically, those barriers include the following.

- **Absence of a market for negative emissions.** BECCS in power has a number of outputs that can be sold in specific markets and therefore remunerated: power, a reliable source of capacity, and system services. However, a key source of costs is the CCS technology and infrastructure, which delivers negative emissions - around 4Mt per unit at Drax. Because there is no market for negative emissions, there is currently no source of remuneration for the value delivered by these negative emissions, and therefore no return for the investment needed to achieve them. The existing carbon price only applies to positive emissions, so incentivises carbon abatement, but only to the point of zero emissions. This causes a distortion because negative emissions technologies such as BECCS are not placed on a level footing with abatement options, meaning that emissions reductions may not be achieved in the most cost effective manner.
- **Positive spillovers not remunerated**. An investment in a first-of-a-kind BECCS power plant will lead to positive spillovers that include:
  - providing an anchor load for carbon transport and storage infrastructure that can be used by subsequent CCS projects;
  - innovation that will help to lower the costs of subsequent BECCS power plants; and
  - learnings and shared skills that can be used across a range of CCS projects, including hydrogen production with CCS.
- **Reliance on CCS infrastructure being in place.** BECCS relies on the presence of CO_2 T&S infrastructure. Where this infrastructure doesn't already

exist, or where its availability or costs are highly uncertain, this presents a significant risk to investors in BECCS. This risk is likely to raise the cost of capital and may even limit the ability for investors to raise finance, making the project unbankable. Given the complex and novel nature of T&S infrastructure, it is unlikely that investors will invest in BECCS technology until there is a high level of certainty that T&S will exist, and that they will have access to it on well-understood terms and with an understood risk allocation.

Policy can address these barriers, as we demonstrate in the remainder of this report.

2.2 Principles for business model design

In its consultation on business models and supportive policies for unlocking investment in carbon capture, usage and storage (CCUS), BEIS set out a number of principles to guide the design of these models. These principles are shown in Figure 2 below.

Figure 2 BEIS parameters to guide CCUS business model development

Overarching parameters to guide the development of CCUS business models:

- The models should be market based and incentivise CCUS to **provide value to the economy.** They should drive decarbonisation and be compatible with market operation and existing market frameworks.
- The design of the models **should instil confidence among investors** and should attract innovation and new entrants to the market.
- The models should be **cost efficient –** providing value for money for taxpayers and bill payers, driving cost reductions and attracting new investment.
- There should be **appropriate and fair cost sharing** between the Government and CCUS developers, being mindful of impacts on taxpayers and bill payers.
- There should be an **appropriate allocation of risk** between the Government and CCUS developers, that evolves as the CCUS industry matures.
- The models should have the **potential to become subsidy free**.

Source: BEIS (2019) Business models for carbon capture, usage and storage, https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/819648/ccus-business-models-consultation.pdf, p14

We have adapted these principles from BEIS into a set of assessment criteria that can be used to both guide the design and to evaluate different support options. We have focused on the principles that are most relevant for BECCS in power, and added some further detail where relevant. The final set of criteria that we use is shown in Figure 3 below.

Figure 3 Principles for design of business models

Instil investor confidence	▪ Attract innovation ▪ Attract new entrants ▪ Instil supply chain confidence
Cost efficient	▪ Drive efficient management of investment costs ▪ Drive efficient quantity of investment ▪ Drive efficient dispatch and operation ▪ Risks allocated in an efficient way, taking into account the impact on the cost of capital
Feasibility	▪ Limit administrative burden ▪ Practicality for investors ▪ Requirement for complementary policy ▪ Wider policy and state aid compatibility ▪ Timely implementation
Fair cost sharing	▪ Allows fair and practical cost distribution
Ease of policy transition	▪ Ease of transition to subsidy free system ▪ Ease of transition to technology neutral solution

Source: Frontier Economics

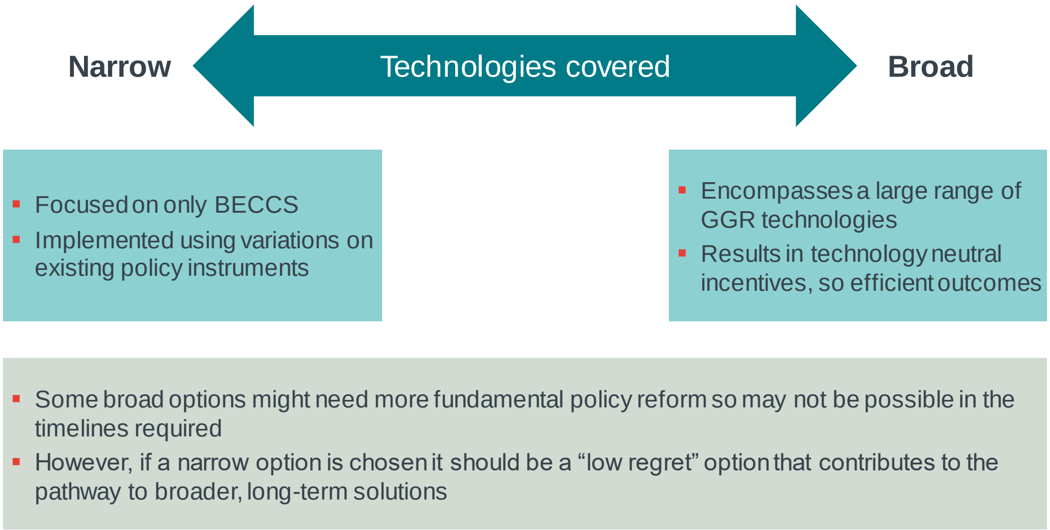
These principles have guided our design of support options, as set out in the next section. We also come back to these principles in section 4, where we carry out a more detailed assessment of the potential business model options.

2.3 Timing and business model evolution

To enable FID on a first-of-a-kind investment in a BECCS power plant in Q1 2024, a business model needs to be developed and implemented in the very near term. Speed and ease of implementation are therefore key considerations.

However, in the long-term, policymakers may wish for further BECCS in power investments to be part of a broader GGR business model (which might be more technology neutral across GGR technologies that have matured by that stage). While the design and implementation of such a business model is likely to take too long to make it relevant for an FID in Q1 2024, it is clearly important that any business model implemented in the short-term does not limit options for a future broader business model, and ideally helps move towards such a model. This would ensure that the short-term business model was “low regret” on a route to a post-subsidy world in the long run.

Figure 4 Narrow and broad business models

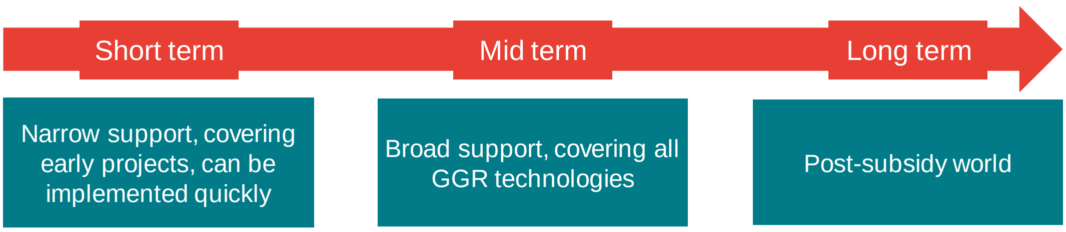


Source: Frontier Economics

To help assess the impact of short-term options, we define three timescales for policy (illustrated in Figure 5 and described in more detail below), and use these to help ensure that all of the power-related BECCS support options which we define in the short-term are capable of transitioning to the credible broader GGR support options in the mid-term, and indeed to a post-subsidy world in the long-term.

To do this, since the endpoint of a post subsidy world is clear, we work backwards from how the market would ideally work in that timescale, and use this to draw conclusions about ideal arrangements in the mid-term and then in the short-term.

Figure 5 Evolution of business models over time



Source: Frontier Economics

2.3.1 Long-term

The long-term goal of low carbon policy is a well-functioning and comprehensive carbon market so that climate change goals such as Net Zero can be met without further government intervention. It is important to ensure that for any policies implemented now, there is a clear path to this post-subsidy world.

At this point, it is highly likely that BECCS in power and other key GGR technologies will be at a well-established, nth-of-a-kind stage, given their importance in reaching Net Zero. Therefore, learnings and spillover benefits from first-of-a-kind plants will largely have been captured, and so support will not be needed to remunerate these. There will still however be a need to remunerate negative emissions.

The carbon market at this stage will therefore need to have the following features.

- It must be **mandatory and cover the relevant sectors**, including the markets for complementary products such as electricity, hydrogen, building materials and fertiliser;
- it must **recognise negative emissions** in the same way it does positive emissions,[16] to deliver consistent incentives for carbon reductions, whether through abatement or through negative emissions. This will help deliver a cost-efficient Net Zero outcome, as residual emissions in hard-to-abate sectors can purchase negative emissions from GGRs if this is more cost efficient than abatement;
- it must involve **a sufficiently high carbon price** to incentivise abatement to meet Net Zero or other climate change goals (including the required level of negative emissions); and
- it must deliver **a sufficiently stable carbon price** to provide confidence to investors.

Such a carbon market will incentivise the optimal level of GGRs through two channels:

- it will provide a price for the carbon that is captured; and
- it will have an impact on the market for complementary outputs of GGRs, for example:
  - electricity prices will reflect the carbon price (relevant to BECCS in power);[17]
  - hydrogen prices will reflect the carbon price (relevant to BECCS for hydrogen); and[18]
  - building materials or fertiliser prices will reflect the carbon price (relevant to afforestation and biochar)

These characteristics are important to note, as they will help us identify the effects that the mid-term business model options should replicate.

2.3.2 Mid-term

We characterise the mid-term as a period during which the carbon market is not yet mature enough to incentivise all of the reductions that are needed to meet climate change goals. For all GGRs, therefore, some form of support is needed to incentivise required levels of negative emissions.

However, by this point we would expect that GGR technologies are well enough established that learnings and spillover benefits from first-of-a-kind plants will be less significant. As a result, the benefits of technology specific support may be

16 This will require establishment of a regime for measuring, reporting and verifying negative emissions. The permanence of those negative emissions may also need to be considered as part of this.

17 A high carbon price would increasing the cost of unabated thermal plant. This would set a limit on the price that the next most expensive lower carbon options such as demand side response (DSR) and storage can charge.

18 Note that DACCS does not have an accompanying output that would be affected.

outweighed by the costs, and it should be possible to implement a business model that is broad across GGR technologies. This is desirable as it means that different GGRs compete for support on the same basis, and investment is in the most cost-effective.

To replicate the impact of an efficient carbon price as described above, a business model should provide remuneration for negative emissions (where these are not remunerated under existing carbon markets), and it may also make sense to have a mechanism to support the price of complementary outputs such as power or hydrogen that would have a higher price under an efficient carbon market.

It may be desirable to keep this complementary output price support mechanism separate from that which remunerates negative emissions, because the latter can be technology neutral, while the former will differ by technology. If a single mechanism is used to cover both the value of negative emissions and any complementary output (such as electricity or hydrogen), there is potential for overcompensating the amount of support required for the complementary outputs.

2.3.3 Short-term

The short-term is defined by the timescale over which BECCS in power and other nascent GGRs are at first-of-a-kind stage. At this stage, investors will bear additional risks and costs associated with deploying the technologies at scale, but will also deliver positive learnings and spillovers. For BECCS in power, this period may be over the next five to fifteen years, and final investment decisions will need to be taken well before that. As we note above, Drax is planning to be in a position to take FID in Q1 2024.

At this point the key focus is to enable first-of-a-kind plants. Fully technology neutral business models across GGRs are:

- not **desirable** at this stage, because different technologies have different spillovers and benefits, and levels of support will need to differ to reflect this (or risk that only the most mature technologies will be adopted, limiting future options for greenhouse gas reduction); and
- not necessarily **achievable** at this stage, because of the likely time it would take to design and implement the business models relative to the FID dates of infrastructure to come online in the late 2020s / early 2030s.

Therefore in the short-term, it is likely that a “narrow” business model is needed.

However, to transition effectively to the mid-term, a narrow model should:

- provide remuneration for negative emissions (including a mechanism that allows any revenue achieved from existing carbon markets to be taken into account);
- support the complementary output price (electricity in the case of BECCS in power); and
- in the short-term provide a further uplift to deliver learnings and spillovers.

Because technology neutrality is not desirable at this stage, there is no need to separate these elements, so all of the support *could* be provided through one mechanism. However, having multiple mechanisms may mean that transition to a mid-term solution is easier.

Figure 6 summarises our views, as set out above, on the evolution of policies over time.

Figure 6 Summary of business model features over different time period

	Short-term	Mid term	Long-term
Key features	▪ Provide remuneration for negative emissions (taking into account any revenue from existing carbon markets) ▪ Support the complementary output price (power in this case) ▪ Provide support to deliver learnings and spillovers	▪ Provide remuneration for negative emissions(taking into account any revenue from existing carbon markets) ▪ Support complementary GGR output prices	Efficient CO_2 market that: ▪ recognises negative emissions; ▪ has a sufficiently high carbon price; and ▪ has a sufficiently stable carbon price.
Narrow or broad	**Narrow.** Full technology neutrality across GGRs is not desirable at this stage, because different technologies have different spillovers and benefits.	**Broad.** The mechanism to remunerate negative emissions can be technology neutral across GGRs. Ideally, support for the complementary output price would be delivered through a separate, technology-specific mechanism to avoid the risk of high inframarginal rents for technologies requiring less uplift.	**Broad.** This market will be fully technology neutral across carbon abatement and GGR technologies.

Source: Frontier Economics

3 BUSINESS MODEL OPTIONS

In this section we use the approach set out in the previous section to identify and shortlist business model options. We then explain how any of the short-term options identified could be transitioned to a technology neutral mid-term option, and to a subsidy-free world. Finally, we consider whether the policies differ in terms of the funding options which they allow.

3.1 Identifying business model options

In this section we consider potential business model options in the mid-term and the short-term. Again, we work backwards considering mid-term options and then setting out short-term options which could feasibly transition to the mid-term approaches considered.

3.1.1 Mid-term business model options

The purpose of identifying mid-term options is to ensure that the short-term options we identify for first-of-a-kind BECCS power plants can be transitioned to mid-term options and ultimately to a subsidy-free system. It is important that none of the short-term options close doors to implementing any of these options in future. We identify mid-term options at a high level, and we do not give a view as to which of these options for future support is more preferable or likely.

We noted in the previous section that a mid-term business model should:

- provide remuneration for negative emissions (taking into account any revenue from existing carbon markets); and
- support the price of any complementary GGR outputs such as power or hydrogen that have associated carbon emissions.

Negative emissions can be remunerated either through a direct carbon payment for negative emissions, or a negative CO_2 obligation. Either of these models could be applied in a technology neutral way across all GGR technologies.

- **Direct carbon payment.** A carbon payment would provide a fixed payment per tonne of negative emissions, and would be a contractual mechanism between the producer and a counterparty such as the LCCC (we note that if the carbon pricing regime includes provision for negative emissions by the mid-term, this contract could be structured as a CfD[19]). Because the market price for carbon will not at this stage be high and/or stable enough to incentivise the required amount of negative emissions to meet Net Zero, the contracted carbon price will need to be set such that enough investors in GGRs can break even given their cost of capital, to deliver the required quantity of negative emissions. More

[19] The Government recently published its response on its consultation on the future of carbon pricing in the UK. Based on this, we do not expect that negative emissions will be included in the scheme in the near term, however this could be considered when the Government first reviews the policy in 2023.

See: HM Government (2020) *The future of UK carbon pricing. UK Government and Devolved Administrations' response*, https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/889037/Government_Response_to_Consultation_on_Future_of_UK_Carbon_Pricing.pdf detail on how a carbon agreement could be structured is provided in the box below.

- **Negative CO_2 obligation.** A negative CO_2 obligation would require greenhouse gas emitters covered by the obligation to secure negative CO_2 certificates to cover a given proportion of their emissions. Companies producing negative emissions would "produce" negative emissions certificates, which would then be traded and provide a source of revenue (we note that if the carbon pricing regime includes provision for negative emissions by the mid-term, these payments would be on top of any carbon market revenue).

WHAT WOULD A NEGATIVE CARBON PAYMENT LOOK LIKE?

An agreement providing payments for negative emissions would be a new mechanism, so we provide some suggestions below on how this could be structured.

Feature	Details
Type of agreement	Private law contract with LCCC or similar counterparty.
Provisions for transition	Provisions included in the contract to allow any revenue from an emissions trading scheme or the voluntary carbon market to offset some or all of the carbon payment if and when negative emissions are included in a UK emissions trading scheme and as the voluntary market develops.
Scope	Contract to be structured such that it can be used by any negative emissions technology, but payment may initially need to be technology specific until technologies are sufficiently mature.
Payment	Fixed payment per tonne of CO_2 captured. In the near term, allocation and payment level would be agreed by bilateral negotiation between the investor and counterparty. Payment level set such that the investor can recoup their investment plus a reasonable rate of return, and taking into account other potential sources of revenue (e.g. from power CfDs). In the mid-term, allocation and payment level would be determined by competitive auction.
T&S costs	Pass-through of regulated T&S costs.
Complementary policies required	A system needs to be in place for monitoring, reporting and verifying negative emissions.
Duration	To be considered. This would likely depend on asset lives, and setting a duration that minimises the cost of capital.
Other features to be considered	▪ Liability for the cost of any emissions released from storage. ▪ Frequency of payments. ▪ Point of payment (e.g. for BECCS in power it might be at the point the carbon enters the CCS pipeline).

We note that it is preferable that support for complementary output prices be delivered through a separate mechanism. CfDs are a well-established support regime in the power sector, and are also being considered for hydrogen production. This mechanism could therefore be a power CfD for BECCS in power, and a hydrogen CfD for BECCS for hydrogen.

Therefore a full mid-term business model could be structured as:

- a carbon payment and a (power or hydrogen) CfD[20]; or
- a negative CO_2 obligation and a (power or hydrogen) CfD.

3.1.2 Short-term business model options

In the short-term, we suggested that a narrow business model should:

- provide remuneration for negative emissions;
- support the complementary output price (power in this case); and
- provide support to deliver learnings and spillovers.

There is a wider set of potential types of support that could be implemented in the short-term. Some of these were set out as business model options in the BEIS CCUS business models consultation.[21] The broad categories of potential support are listed and briefly described below.

- **Regulated asset base approach.** This would involve a regulatory valuation of the electricity generation assets and setting tariffs to pass costs on to consumers.
- **Cap and floor.** This would set a minimum and maximum level of revenue, whereby investors would be topped up if earnings fall below the minimum, and would need to return earnings to consumers if they rise above the maximum.
- **Cost-plus open book.** This would involve direct payments to cover costs that are deemed to have been reasonably incurred, plus an agreed margin.
- **Power CfDs.** Power CfDs are a well-established mechanism for providing low-carbon generators with stable power market revenues, along with support required to deliver required amounts of low-carbon generation.
- **Hybrid CfDs.** This type of CfD provides lower £/MWh payments as output moves up pre-determined “bands”. The aim is to incentivise generators to reduce output when prices are low.
- **Dispatchable Power Agreement (DPA).** BEIS is considering the introduction of a DPA for gas-fired CCS. This consists of an availability payment and a variable payment, where the variable payment calculated by considering the difference in short run marginal cost between the gas-fired CCUS plant and a theoretical reference unabated plant[22].

[20] Other business models for complementary products could also be envisaged.

[21] BEIS (2019) *Business models for carbon capture, usage and storage*, https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/819648/ccus-business-models-consultation.pdf

[22] BEIS (2020), *CCUS: An update on business models for Carbon Capture, Usage* and Storage https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/946561/ccus-business-models-commercial-update.pdf

- **Carbon payment.** As described above, a carbon payment would provide a fixed payment per tonne of negative emissions, and would be a contractual mechanism between the producer and a counterparty such as the LCCC (similar to a CfD).
- **Negative CO_2 obligation scheme.** As described above, this would require greenhouse gas emitters covered by the scheme to secure negative CO_2 certificates to cover a given proportion of their emissions. Companies producing negative emissions would earn negative emissions certificates, which would then be traded and provide a source of revenue.

Given the BEIS criteria set out in the previous section, the need for a transition path to one of the mid-term options, and the specific characteristics of BECCS in power, a number of these options can be eliminated. The table below sets out which options we have eliminated, and the reasoning.

Figure 7 Initial assessment of support options

Support option	Rationale	Performance against criteria
Regulated asset base (RAB)[23]	Can deliver cashflow before production starts, and helps ensure that infrastructure will be funded regardless of subsequent levels of demand	▪ **Investor confidence:** regulatory regimes (unlike contractual mechanisms such as CfDs) may provide less certainty over revenues as they need to establish a track record and even then, can be adjusted over time ▪ **Ease of transition:** early cashflow not needed because a significant proportion of costs are operating costs and there is limited demand risk. Therefore a regulated approach is less beneficial, particularly given it may be difficult to transition away from. □ No clear transition path to mid-term options.
Cap and floor	Straightforward approach to removing risk of excessively high or low returns	▪ **Investor confidence:** in addition to points on RAB, if cap and floor set wide apart, then the approach will not be effective at addressing risks. ▪ **Ease of transition:** if cap and floor set narrow, similar issues to RAB approach. □ No clear transition path to mid-term options.
Cost-plus open book	Straightforward and the investor is guaranteed the agreed rate of return	▪ This option does not meet a number of the BEIS criteria, including efficiency, allocation of risk and ease of transition (no clear transition path to mid-term options).
Power CfDs	Provides investors with a guarantee over power market revenues, while taking into account actual revenues	To be assessed further
Hybrid CfDs	Creates efficient dispatch incentives for intermittent generators	▪ **Feasibility:** this variant of a power CfD is unlikely to be necessary or proportionate as a BECCS power plant is expected to run baseload given the value of negative emissions produced.

[23] The reasoning set out here also applies to a split CfD, which would provide an upfront payment to cover fixed capital costs (similar to the RAB approach being considered for nuclear generation), but would also provide a subsequent output-linked payment to cover variable costs (similar to a standard CfD).

Support option	Rationale	Performance against criteria
DPA	Creates efficient dispatch incentives for intermittent generators	▪ **Feasibility:** this variant of a power CfD is unlikely to be necessary or proportionate as a BECCS power plant is expected to run baseload given the value of negative emissions produced.
Carbon payment	Straightforward approach to remunerate negative emissions	To be assessed further
Negative CO_2 obligation scheme[24]	Market-based approach that, if the scheme functions well, should deliver an efficient price for negative CO_2 obligation certificates, and encourage cost efficient development of negative emissions technologies	▪ **Investor confidence:** obligations (unlike contractual mechanisms such as CfDs) provide less certainty over revenues as they can be adjusted by policy-makers over time. An obligation scheme would be particularly unsuitable at this early stage when few GGRs exist, and technology neutrality across these technologies is not possible. Having a small number of sellers at this stage could result in large fluctuations in obligation prices (e.g. due to entry and exit of sellers). ▪ **Feasibility:** designing and introducing an obligation, particularly one for negative emissions for which there is no precedent, is unlikely to be feasible in the timelines required. This is due to the need to create legal obligations around producing certificates, the challenges around monitoring and enabling trading, and difficulties around designing the scheme to tune desired outcomes. Obligations are also complex to administer (as RO experience has indicated, with parameterisation including "headroom" calculations and banding). And they are difficult to budget, unlike CfDs where a defined envelope of budget can be set.

Source: Frontier

This process of elimination leaves power CfDs and carbon payments as candidates for the short-term. These forms of support could be used individually or in combination, giving three distinct options for support. We explain below how these options would deliver the needed support to enable investment in BECCS in power.

- **Power CfD:** the strike price of the CfD would be set to include remuneration for negative emissions, low carbon power and for learnings and spillover benefits. This would therefore be a bespoke CfD for BECCS in power.
- **Carbon payment:** a carbon payment would provide a fixed payment per tonne of negative emissions, on a contractual basis. The payment level would be set to include remuneration for negative emissions, low carbon power and for learnings and spillovers. A similar business model could apply to other GGRs, noting that the level of payment would differ by technology.
- **Carbon payment + power CfD[25]:** this option is a two-part business model, combining the two options above. The carbon payment would provide

[24] We note that a number of the drawbacks set out here also apply to obligations as a mid-term option. However our focus is on evaluating short-term options, so we have not commented on the suitableness of an obligation scheme in the mid-term.

[25] There is a variant of this option where the power CfD would be replaced with a "carbon CfD" that would only stabilise the portion of power market revenues related to the carbon price. The effect of this is that investors are shielded from the variation in wholesale prices that is driven by the carbon price, but exposed to variation that is driven by fuel costs and other factors. We do not consider this variant in detail in the following sections as its effect is somewhat like a hybrid of the power CfD and the carbon payment. There is also other work ongoing exploring this option, for example by the LCCC.

remuneration for negative emissions and learnings and spillovers while the power CfD would support power market revenues.

For any of these business models, there are a number of features that are important to consider, including the duration of support and protections against specific risks. We set out in the box below some of these key features and some considerations that should be taken into account when considering the specific design of a chosen business model.

KEY BUSINESS MODEL FEATURES

Duration of support

The standard duration for CfD contracts in GB is 15 years. There is not an obvious justification for a different duration in the case of BECCS in power, given the cost characteristics of the plant. Contract length would ideally be optimised to provide the best value for money for the group(s) funding the business model;

Reference power price used (for CfDs only)

BECCS generation is non-intermittent and is likely to run at high load factors as a result of the value of negative emissions. Like nuclear, it would appear reasonable to base its payments on the baseload (season ahead) reference price. Baseload prices are calculated using a traded volume weighted average on a seasonal basis. They provide an incentive for baseload generators to avoid outages at a time when hourly prices are highest. This is because CfD payments relate to the difference between the average season-ahead price and the strike price. If generators sell forward at the season-ahead price, they ensure they receive their expected revenue. But if they then have to buy energy in the market to cover an outage, they are exposed to the difference between the hourly prices at which they buy and the season-ahead price.

Limits on T&S availability risk

As we described in section 2, because first-of-a-kind BECCS power plants would be some of the first users of T&S infrastructure, they would help deliver positive spillovers by contributing to the costs of this infrastructure and helping to demonstrate its reliability.

In doing so, however, first-of-a-kind BECCS power plants could potentially be exposed to significant risk because lack of access to T&S infrastructure would mean that a plant cannot produce negative emissions. This risk comes both in the form of possible delays to the deployment of the infrastructure, and also the possibility of technical issues in the early years that limits its availability. Furthermore, T&S availability is entirely exogenous, and because there has been limited demonstration of this infrastructure it is difficult for investors to estimate the scale of this risk.

It is therefore important that any element of a business model that is providing remuneration for negative emissions (the power CfD in the first option above, and the carbon payment in the other options) mitigates the exposure of investors to the risk of T&S outages. This may include contractual payments from the T&S operator, who may in turn draw on government support to meet these payments.

The compensation might also need to cover any losses that a generator makes if it has already sold power (and possibly negative emissions) that it is not able to deliver due to a T&S outage, and needs to buy back power/negative emissions to cover its position in the market. The mechanism for this would need to be considered further.

Limits on opex risk

The most significant operating costs for a BECCS power plant are likely to be the cost of fuel (biomass) and the cost of using T&S infrastructure. There is an option to index strike prices/payment levels to changes in biomass prices, changes in T&S costs, or both. There is also the option for indexation to apply to only a portion of the contract, e.g. under the current nuclear CfD, investors bear the risk of changes in opex during the initial 15 years but are protected from changes after this period.

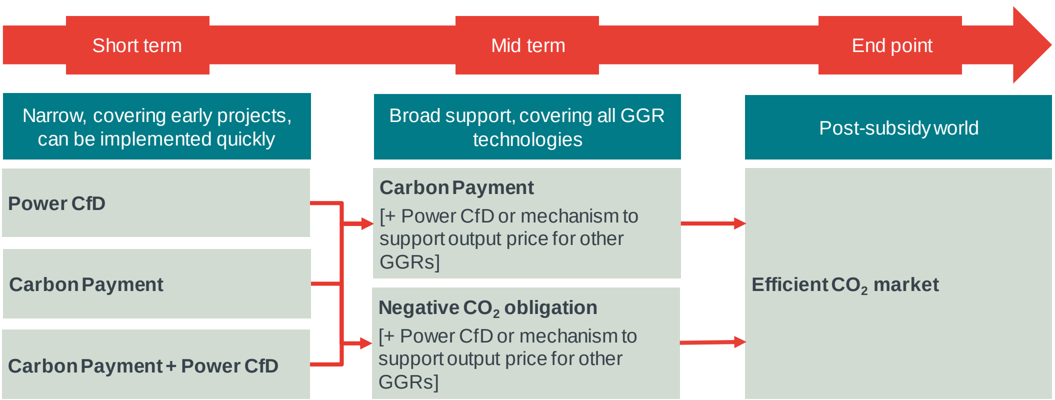
Whether indexation is used should depend on how well-placed investors are to manage these risks, and how feasible it is to find a suitable index. For example, we note that there is not currently a liquid biomass market on which to base a fuel cost index.

Furthermore, T&S costs are likely to be regulated to some extent, in which case there would be some form of protection for investors against instability, and T&S costs could be passed-through.

3.2 Transition paths from short-term business models

It is possible to transition from any of the short-term options described above to a subsidy-free world with an efficient CO_2 market, via either of the two mid-term options discussed above (carbon payment or negative CO_2 obligation). Some options are more straightforward than others, but all are possible, meaning that none of the shortlisted short-term options close any doors in future. Below we briefly explain how the relevant transitions would be possible.

Figure 8 Possible transitions to a subsidy free world



Source: Frontier

3.2.1 Short-term to mid-term

We first consider the transition routes from the short-term to mid-term options. First, we consider the transitions to a carbon payment regime in the mid-term:

- **transition from power CfD:** provided it is relatively simple to establish a ratio between the MWh of power produced and the tCO_2 captured and stored, it should be relatively simple to convert a power CfD with a price defined in £/MWh to a carbon payment with a price defined in £/tCO_2, without impacting on the financial return originally agreed under the CfD contract. If the mid-term carbon payment is accompanied by a power CfD instrument, payments under a unified short-term power CfD could be split into both £/MWh and £/tCO_2 components;

- **transition from carbon payment (with or without power CfD):** this is likely to be the most straightforward short-term to mid-term transition option. The carbon payment for negative emissions is retained in the mid-term. If a two-part business model is desirable in the mid-term, it would be preferable to apply a two-part model in the short-term.

Second, we consider the transition to a negative CO_2 obligation. In all of the short-term support options outlined above in Figure 8, there will need to be a contractual counterparty (such as the LCCC) that provides support payments. If a negative obligation was introduced, while the CfDs contracts signed in earlier periods were still ongoing , this counterparty could sell negative emission certificates (based on its support contracts) to parties obligated under the negative CO_2 obligation. This would ensure that GGR technologies signed up to CfDs could also still effectively participate as part of the supply curve of GGRs under an obligation scheme, without affecting the revenue that investors receive. In doing so, the contractual counterparty would raise some of the funds required to remunerate support contracts. That said, some form of (reduced) levy might still be needed as a backstop source of funds for the counterparty, in case the obligation scheme does not raise sufficient funds. More detail on how prices are determined in an obligation scheme is provided in the box below.

MECHANISMS TO LIMIT PRICE RISK IN AN OBLIGATION SCHEME

The Renewables Obligation (RO) was one of the main support mechanisms for large-scale renewable electricity projects in the UK. It came into effect in 2002 and closed for new generating capacity in 2017.

Under the RO, electricity suppliers are required to present to Ofgem a specified number of Renewables Obligation Certificates (ROCs) per unit of electricity supplied to their customers. ROCs are tradeable certificates issued to operators of accredited renewable generating stations for the renewable electricity they generate. The price of ROCs can fluctuate, depending on the relationship between the production of renewable electricity and energy supplied to consumers.

The RO includes two features for limiting risks around the ROC price.

- **'Headroom' is included, to ensure that the price of obligation certificates does not collapse.** The Government sets the headroom each year, generally by forecasting renewable generation for that year and adding 10%. Electricity suppliers in the UK are then obligated to purchase ROCs amounting to this 'headroom' figure. This feature aims to reduce the risk of oversupply of obligation certificates. However, given the difficulties of accurately forecasting supply, some risk remains.
- **A buyout price, set by Ofgem, is included to cap the cost of meeting the obligation.** Suppliers can pay a buyout price instead of purchasing ROC certificates. This effectively caps the market price for ROCs and reduces the risk of price spikes.

3.2.2 Mid-term to end point

While it is less relevant to the choice of a short-term approach, we also consider briefly the transition routes from the mid-term to the long-term from:

- **a carbon payment:** at some point during the transition to an efficient CO_2 market, negative emissions will need to be recognised and brought into the CO_2 markets. However, at this point, the carbon price may not yet be high enough and/or stable enough to incentivise the level of negative emissions needed to meet Net Zero or other climate change goals. At this point, fixed carbon payments could be replaced with a carbon CfD defined such that GGR investors receive a consistent level of remuneration for their negative emissions. Then, over time, as the carbon price rises, CfD payments will fall (and the issue of new carbon CfDs could gradually be phased out); and
- **a negative CO_2 obligation:** in contrast to a carbon payment regime, transitioning away from a negative CO_2 obligation may be more complex (particularly if policymakers wish to avoid investors under the obligation benefitting from rising CO_2 prices). Once GGRs are included in a carbon pricing scheme, investors in GGRs would receive revenue for their obligation certificates on top of carbon revenue, and "steering" the obligation price to respond to an evolving carbon price would be difficult.[26] Similarly, gradually

[26] Reducing the target volume of the scheme creates risk around a price "cliff edge" – in a simple obligation scheme design, once the target level of obligation is met, there is no longer a scarcity of certificates and the price will crash. In theory the penalty price (applied to those who have not met their obligation) could be

reducing take-up under an obligation scheme is more difficult, again because of the complexity of "steering" the obligation price.[27] Nevertheless, routes (such as those established for the closing and eventual termination of the Renewables Obligation) exist to phase out an obligation scheme, even if these include more direct regulation of the price of certificates or the definition of a final closing date for the scheme.

3.2.3 Conclusion on transition paths

Our analysis suggests that it is possible to transition from any of the proposed "narrow" short-term options though to a "broad" business model in the mid-term, whether that is based on a carbon payment or a negative CO_2 obligation. Implementing one of the short-term options would therefore be low regret in that, without significantly limiting the choice of mid-term options, it would enable early BECCS in power investments, and their associated benefits of:

- helping the UK meet its upcoming carbon budgets and stay on track to meet Net Zero;
- supporting the development of CCS infrastructure, by acting as an anchor load and reducing costs for other users;
- developing technical learnings that can be applied to subsequent BECCS power plants and other CCS applications; and
- assuming a business model is used for first-of-a-kind BECCS power plants, delivering policy learnings that can be applied to other GGRs.

3.3 Funding of short-term options

It is clearly important to identify the way in which support under any of the short-term business model options can be funded. A credible funding route will be of critical interest to investors, and the incidence of costs of the business model will be important from a policy perspective.

It may seem that the form of a business model and the way it is funded are strongly interlinked. For example, power CfDs are currently funded by a levy paid by electricity suppliers to the LCCC. However, business models do not need to be attached to specific funding sources; most options can be designed to fit with numerous different funding options, so the two decisions can be made independently.

In Annex B we identify some candidate groups to fund any chosen business model and set out some potential principles for deciding on funding. However, at this stage we do not form any recommendations as to a funding source. This is because once a business model has been chosen, arrangements can be put in place to raise the required funding from any chosen group. This is demonstrated in the figure below, which describes how a power CfD or a carbon payment could

used to steer the market price of certificates, but even then, there is not a straightforward link between this penalty price and the price achieved by any given plant.

[27] The government committed to "headroom" in the Renewables Obligation scheme in order to provide investors with confidence that the price would not crash in the case of an over-supply of low carbon electricity. Having done so, the scheme was then simply closed to new investors on a given date rather than seeing any gradual phasing down.

be funded by any of five candidate groups (while we apply this to the groups we have selected, this reasoning could be applied to any target group). A two-part power CfD and carbon payment would involve a combination of the two approaches (and indeed, would allow an option where the power CfD continues to be funded by electricity suppliers while the carbon payment is funded by a different group).

Figure 9 Funding a business model by different groups

Candidate groups	Power CfD	Carbon payment
Upstream fossil fuel suppliers	Levy on fossil fuel suppliers, payable to CfD counterparty	Levy on fossil fuel suppliers, payable to administering entity
Undertaxed emitters	Levy on customers in chosen sectors, payable to CfD counterparty	Levy on customers in chosen sectors, payable to administering entity
Undertaxed emitters not exposed to intl. competition		
Electricity suppliers/users	Levy on electricity suppliers (as currently) or users, payable to CfD counterparty	Levy on electricity suppliers/consumers, payable to administering entity
Taxpayers	Funding from government (general taxation revenues)	Funding from government (general taxation revenues)

Source: Frontier

Investors in early BECCS power plants will need assurance over the plan for funding as well as business model design in the next few years to enable investment decisions to be made. However, these decisions should be made independently, without tying business model options to funding sources, to secure the preferred outcome on each. Further work on designing a business model can progress in parallel with thinking about funding sources, to ensure that investors are sufficiently confident both about the nature and source of funding in time to enable early investment in BECCS in power .

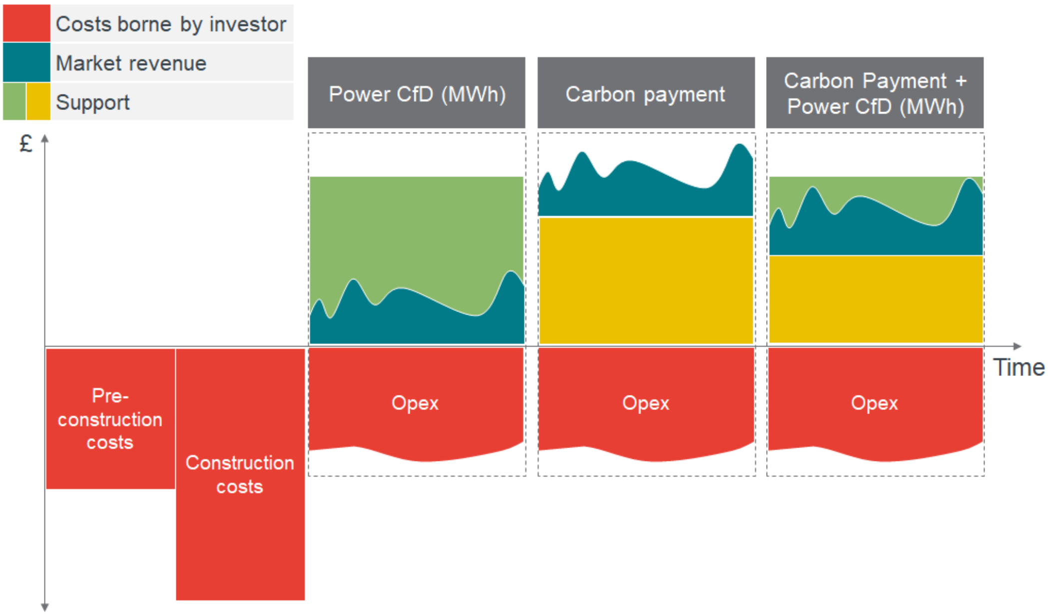
4 ASSESSMENT OF BUSINESS MODEL OPTIONS

In this section, for each of the short-term business model options identified, we first look at the impact on the costs and revenues that investors can expect to face in order to help understand the investor confidence and cost efficiency characteristics of each option. We then evaluate each of the options against the principles set out in Section 2, highlighting the key strengths and weaknesses of each option as a business model for BECCS in power. Finally we set out conclusions on the most preferable options and key trade-offs between them.

4.1 Business model impact on costs and revenues

Figure 10 illustrates the cost and revenue profiles that investors would face under each of the three proposed short-term business model options (although these are shown side-by-side they represent alternative worlds, not a sequence of support over time.)

Figure 10 Cost and revenue profiles of alternative support options



Source: Frontier
Note: Illustrations are based on assuming a constant level of output over time.

Under all options, investors would face the initial pre-construction and construction costs, and would bear operating costs such as biomass costs throughout the lifetime of the investment.

However, revenue streams would differ by business model.

- **power CfD:** under the power CfD (which in this case would provide remuneration for both power and for negative emissions), investors earn a fixed level of revenue per MWh of power generated, equal to the strike price of the CfD contract. This strike price shields investors from fluctuations in power prices, as well as including an uplift to provide revenue for negative emissions, learnings and spillovers. Investors do not face any power wholesale market risk;

- **carbon payment:** under a carbon payment, investors receive a fixed payment per tonne of CO_2 captured and stored. This payment includes an uplift for learnings and spillovers. On top of this, investors earn power market revenues for each MWh of electricity generated, meaning that they face full exposure to power wholesale market risk; and
- **two-part carbon payment + power CfD:** this option combines the two above, so there is a fixed payment per tonne of negative CO_2 stored, plus a CfD that provides a strike price that shields investors from power price fluctuations. The uplift for learnings and spillovers could be included within either of these mechanisms. Investors do not face any power wholesale market risk.

4.2 Business model assessment

Having set out the implications of each regime for cost and revenue risk, we turn to an assessment of the different business model options. As a reminder, Figure 11 below sets out our evaluation criteria.

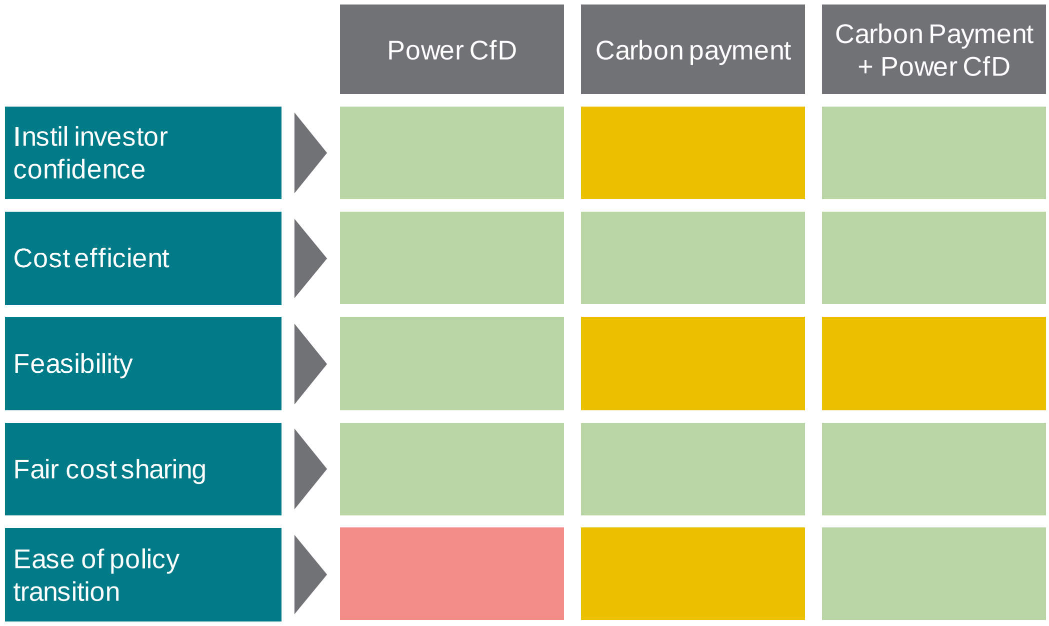
Figure 11 Criteria for assessing business model options

Instil investor confidence	▪ Attract innovation ▪ Attract new entrants ▪ Instil supply chain confidence
Cost efficient	▪ Drive efficient management of investment costs ▪ Drive efficient quantity of investment ▪ Drive efficient dispatch and operation ▪ Risks allocated in an efficient way, taking into account the impact on the cost of capital
Feasibility	▪ Limit administrative burden ▪ Practicality for investors ▪ Requirement for complementary policy ▪ Wider policy and state aid compatibility ▪ Timely implementation
Fair cost sharing	▪ Allows fair and practical cost distribution
Ease of policy transition	▪ Ease of transition to subsidy free system ▪ Ease of transition to technology neutral solution

Source: Frontier

Figure 12 provides a summary of our assessment of each of the business model options against the main criteria categories, using traffic light colour coding to indicate how well the criteria are likely to be met.

Figure 12 Assessment of business model options

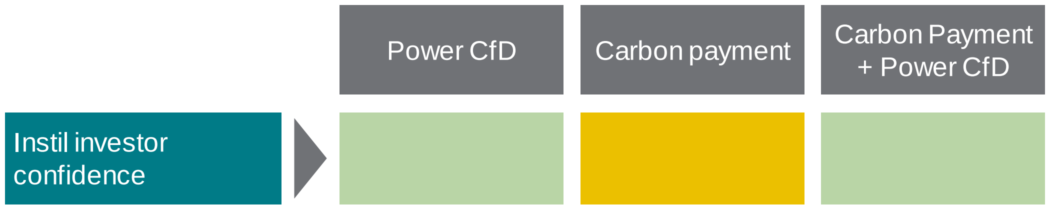


Source: Frontier

Note: Green indicates that the criteria is largely met, yellow indicates that it is partially met, and red indicates that it is not met.

We set out our reasoning in more detail below.

Instil investor confidence



The key driver of investor confidence is certainty over future revenues, which will enable investors to determine the risk that they do not make a return on their initial investment. More certainty over returns in turn will reduce the cost of capital which investors require, and (other things equal) should help attract new entrants, innovation, and instil supply chain confidence.

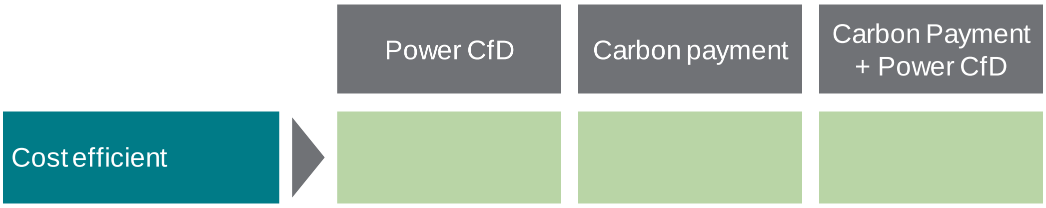
In usual circumstances, exposure to wholesale power prices is important because this provides investment signals and incentivises efficient dispatch. However, the energy transition has required significant government intervention to deliver required investment in low carbon generation. Government has taken on a decision-making role around the technologies that require investment, and the timing of that investment. Business models can be designed to incentivise broadly efficient dispatch decisions. Therefore the benefits of exposing investors in low carbon power to wholesale prices are lower, and shielding investors from this risk has the benefit of reducing the cost of capital and the cost of support. This logic has applied to investment in low carbon generation previously, and could be argued should also apply to support for early BECCS power plants.

All three options provide certainty over remuneration for negative emissions, which is contractually set, either within the power CfD strike price or as the level of carbon payment. The main distinction between these options is therefore whether or not they shield investors from power market risk. Both options with a power CfD protect investors from this risk, whereas the carbon payment does not.

The power CfD may also have a slight benefit over the other two options because it is a private law contract with an established track record, and may therefore give investors more confidence than the options that require the establishment of a new carbon payment mechanism. However, the carbon payment could be designed such that it also provides investors with a high degree of confidence.

We conclude that the two options with a power CfD perform better than the carbon payment alone.

4.2.1 Cost efficiency



The main considerations for cost efficiency are whether the business models:

- drive efficient management of investment costs;
- drive efficient quantity of investment;
- drive efficient dispatch and operation; and
- risks allocated in an efficient way, taking into account the impact on the cost of capital.

There is no significant distinction between the business models in terms of the incentives they create around management of investment costs or quantity of investment. In all cases:

- investors are exposed to investment and operating costs so are incentivised to manage these efficiently; and
- the choice of business model will not drive the quantity of investment, which will be approved administratively by government.

The business models do have different properties in terms of exposing investors to wholesale power prices. For dispatchable generation, models that leave power price risk with investors would provide more efficient dispatch incentives, as they would encourage generators to reduce output when prices are low, and vice versa. However, because of the value attached to the negative emissions that a BECCS power plant will be delivering when it is generating, it is highly probable that BECCS plants will operate with a high load factor[28]. As a result, it is less likely that

[28] We note that even issues around negative pricing of power are less of an issue for BECCS plants than for, say, a windfarm. Even if the power price is negative, there may still be an economic logic for a BECCS plant to operate, as a result of the value of negative carbon emissions.

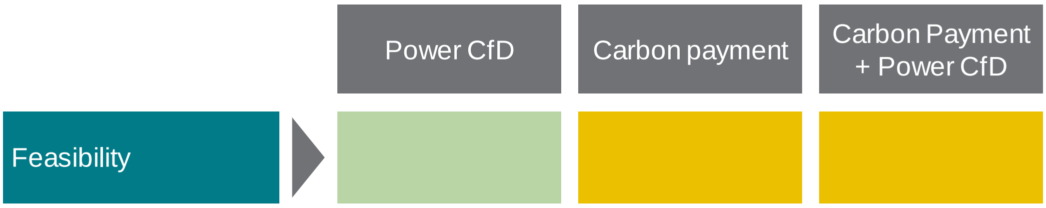
protection from power prices under a power CfD will result in significantly distorted dispatch incentives (compared to, for example, a gas CCS plant).

Regarding risk allocation, transferring risks from investors has the potential to reduce the investor cost of capital, and therefore reduce consumer/taxpayer costs. However, it also means that consumers/taxpayers will bear additional risks, and it removes the incentive on investors to manage these risks efficiently. Allocating risk appropriately involves balancing these risks.

The carbon payment strikes a different balance in that trade-off compared to the two options with a power CfD, as it leaves investors with power price exposure, likely resulting in a higher cost of capital. Investors will have some ability to respond to power price signals through their dispatch decisions. However this may be limited because, as explained above, BECCS power plants are likely to operate with a very high load factor. The options with a power CfD on the other hand shield investors from this risk, and may deliver a lower cost of capital.

Therefore we conclude that while the options have different risk allocations, all of them appear reasonable, and overall all three options perform relatively well on efficiency.

4.2.2 Feasibility



We have considered a number of features of each of the business models relating to feasibility:

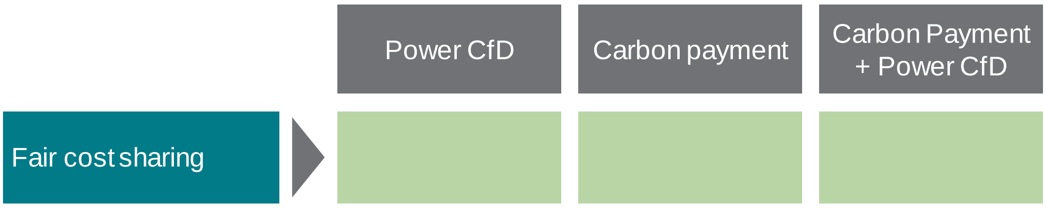
- **administrative burden:** the power CfD performs better on this than the business models involving a carbon payment. This is because carbon payments are a new form of support and there will be time and cost involved in designing and administering these payments, and potentially introducing new legislation. However, it is likely that a mechanism for rewarding carbon abated and / or removed will need to be designed in any case to support other CCS projects, in which case there would be limited additional administrative burden in designing and using the mechanism for BECCS.
- **practicality for investors:** all business models are practical for investors. However, the power CfD is likely to be preferred because investors have experience and understanding of power CfDs;
- **requirement for complementary policy:** none of the business models require the introduction of complementary policies, beyond what would be needed anyway for negative emissions and CCS technologies (e.g. monitoring, reporting and verification system for negative emissions, and policy on T&S for CCS);
- **wider policy and state aid compatibility:** all of the business models are compatible with wider policy, and we do not foresee any state aid issues in relation to business model structure (there will still be considerations around

the overall level of support, and issues around cumulation[29] of aid would need to be considered – however, we would expect any issues to be resolved relatively easily);

- **timely implementation:** the power CfD performs better than the other options on this criteria. In fact, speed of implementation is one of the main strengths of using a power CfD, as it is already well established. It would be fairly quick to adapt existing CfD terms to apply to BECCS in power. The other options may require legislation, which would need to be delivered in time for early projects to take their FIDs. .

Overall, we conclude that the power CfD performs better than the other two options.

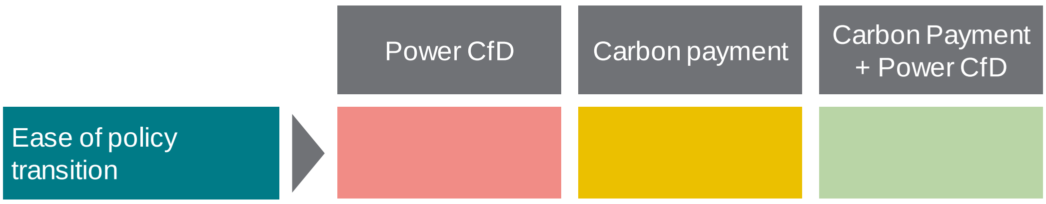
4.2.3 Fair cost sharing



As we noted above, any of the support options can be designed to be funded by any chosen group, whether that is fossil fuel suppliers, hard-to-abate sectors, electricity consumers, or others. In determining the source of funding, government will need to take into account a range of factors including efficiency, fairness and practicality. We provide more detail on these considerations in Annex B.

Therefore we conclude that all of the options can be designed to perform well in terms of cost sharing.

4.2.4 Ease of policy transition



As explained in section 3, all of the short-term options we have set out can transition to a subsidy free system in the long-term. However, some are better suited than others, particularly because they deliver learnings that will aid in the transition to an efficient CO_2 market that recognises negative emissions.

We have considered how easy or difficult it would be to transition each of the options to a technology neutral business model for future projects, and then to a subsidy free business model.

[29] For example, if the BECCS plant were to participate in a Capacity Remuneration Mechanism.

- **ease of transition to technology neutrality:** all three options are unlikely to have any technology neutral elements in the short-term, although they could transition to a mid-term regime which could be technology neutral; and
- **ease of transition to subsidy free:** while all of the options can transition to a subsidy free system, the power CfD does not create any policy learnings around treatment of negative emissions that contribute to this transition. The other two options do create learnings around a carbon payment for negative emissions that can eventually be broadened to other GGRs and then captured within an efficient CO_2 market.

Overall, we conclude that the two-part business model performs best on this criterion. The other two options perform less well, with the power CfD performing worst as it does not deliver learnings around remunerating negative emissions.

4.3 Summary

All three main business model options perform relatively well across most criteria, as we have only considered business models that are broadly fit for purpose. However, the evaluation above highlights that there are a few key trade-offs that must be considered when choosing a business model. These are as follows.

- **investor confidence:** the power CfD and the two-part model with a CfD perform better than the carbon payment on this measure, as they shield investors from wholesale market fluctuations;
- **feasibility:** the power CfD performs best on this measure. Because it is well established and understood, it will be quick to implement. Introducing carbon payments will require some time to introduce a new regime of support payments, whether administered by the LCCC or another counterparty (though we note that the Government has committed to delivering business models for industrial CCUS, and is minded to introduce carbon support payments[30]); ; and
- **potential to become technology neutral and subsidy free:** All three options could transition to a mid-term regime which could be technology neutral. The stand-alone power CfD performs least well as it does not deliver any learnings around remunerating negative emissions.

Overall, the two-part model performs well across the BEIS criteria and would offer a clear path to a technology neutral and subsidy free world, delivering learnings that will be relevant for other GGRs. The power CfD also performs well, other than on the longer term transition path. However, it is particularly attractive in terms of feasibility, so if shorter-term ease and speed of introduction are key considerations, the power CfD may be preferable.

[30] BEIS (2020), *CCUS: An update on business models for Carbon Capture, Usage and Storage* https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/946561/ccus-business-models-commercial-update.pdf

5 CONCLUSIONS

The Government's Net Zero target has significantly changed the scale and nature of the UK's decarbonisation challenge. Because of the very high costs and potential infeasibility of abatement in certain sectors, negative emissions will need to play a key role in meeting the Net Zero target.

Without BECCS in power, meeting Net Zero may not be possible, and investing in this technology early will help reduce the risk around meeting Net Zero and interim carbon budgets by helping to offset delays in abatement in other sectors.

However, given market failures and policy gaps, BECCS in power is unlikely to be delivered without further intervention. In particular, under current policy, investors would not be remunerated for negative emissions or for the positive learning externalities they provide.

We have shortlisted three main business model options to enable investment in first-of-a-kind BECCS power plants consistent with the Q1 2024 FID timeline proposed by Drax:

- a power CfD (providing remuneration for both power and negative emissions);
- a carbon payment; and
- a two-part carbon payment and power CfD.

None of these three options limits options for future business models that would apply across GGR technologies. They can therefore be evaluated and considered in their own right while thinking on mid-term GGR strategy progresses. And they do not place constraints on who funds the business model, which can therefore be considered a separate design choice. Work to define the business model options can progress in parallel while views on funding are being developed.

All three options perform relatively well across our evaluation criteria. Our assessment highlights a few key trade-offs that must be considered when choosing a business model. These are:

- **investor confidence:** the power CfD and two-part model perform better than the carbon payment on investor confidence, as they shield investors from wholesale market fluctuations;
- **feasibility:** the power CfD performs best on feasibility. Because it exists, and is well established and understood, it will be quick to implement; and
- **potential to become technology neutral and subsidy free:** All three options could transition to a mid-term regime which could be technology neutral. The two-part model and the carbon payment may provide additional learning on the remuneration of negative emissions.

Overall, the two-part model performs well across the BEIS criteria and would offer a clear path to a technology neutral and subsidy free world, delivering learnings that will be relevant for other GGRs. The power CfD also performs well, other than on the longer term transition path. However, it is particularly attractive in terms of feasibility. Both options deliver a number of desirable features:

- they address identified market failures;

- they can be implemented relatively simply and in time to capture benefits of early BECCS in power investment; and
- they can be structured to ensure an efficient outcome for customers (including with reference to investors' likely cost of capital) and allocate risks appropriately.

ANNEX A WHY IS IT DESIRABLE TO DELIVER BECCS IN THE NEAR TERM?

Achieving investment in BECCS in power in the near term has a number of benefits:

- it can support the development of CCS infrastructure, by acting as an anchor load and reducing costs for other users;
- it will develop technical learnings that can be applied to subsequent BECCS power plants and other CCS applications;
- assuming a business model is used for first-of-a-kind BECCS power plants, this will deliver policy learnings that can be applied to other GGRs; and
- it will help the UK meet its upcoming carbon budgets and stay on track to meet Net Zero.

We provide more detail on each of these points in turn below.

A.1.1 Developing BECCS will help with the rollout of CCS infrastructure, which has wider benefits

CCS is likely to be a key part of meeting 2050 abatement targets, both globally and in the UK. Globally, the International Energy Agency stresses that CCS is "one of the most-cost effective solutions available for large scale emission reductions" and calls for "urgent action" in the delivery of CCS infrastructure.[31]

In the UK, the recent Energy White Paper, sets out an ambition to capture 10Mt of carbon dioxide a year by 2030, investing up to £1 billion to support the establishment of CCUS in four industrial clusters[32]. The CCC stresses the importance of accelerating progress in CCS and advocates that the first CCS cluster be operational by 2026, with two clusters, capturing at least 10 $MtCO_2$, operating by 2030 in order to meet Net Zero.[33] The CCC also believes that CCS is important in the development of low carbon hydrogen, which is a key element of its scenarios in reaching Net Zero, and particularly important in reducing emissions from heat.[34]

Early investment in BECCS would help to provide an anchor load for CCS infrastructure. By spreading the costs of this infrastructure over the higher volume of emissions captured and stored by BECCS, costs to other users of the infrastructure (e.g. hydrogen production with CCS and other industrial sectors where carbon could be captured, such as cement, iron, steel and refineries) will be

31 IEA (2019), *Transforming Industry through CCUS*, https://www.iea.org/reports/transforming-industry-through-ccus

32 BEIS (2020), *Powering our Net Zero Future*, https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/945899/201216_BEIS_EWP_Command_Paper_Accessible.pdf

33 CCC (2019), *Net Zero The UK's contribution to stopping global warming*, https://www.theccc.org.uk/wp-content/uploads/2019/05/Net-Zero-The-UKs-contribution-to-stopping-global-warming.pdf

34 CCC (2019), *Net Zero The UK's contribution to stopping global warming*, https://www.theccc.org.uk/wp-content/uploads/2019/05/Net-Zero-The-UKs-contribution-to-stopping-global-warming.pdf

lower[35]. These lower costs in turn increase the likely take-up of CCS technologies by future users of the infrastructure.

BECCS could have other positive spill-overs to other technologies that require CCS infrastructure, for example:

- learnings around the use of the infrastructure;
- demonstrating the reliability of the infrastructure; and
- an institutional benefit of having an anchor client that can help coordinate with government and other players to ensure that the infrastructure is up and running.

A.1.2 Investment in BECCS will deliver innovation, learnings and shared skills

As discussed above, decarbonisation scenarios set out by the CCC and others involve significant quantities of BECCS by 2050. However, according to the CCC, only one large-scale BECCS power plant capturing over 1 $MtCO_2$/y is in operation in the world.[36]

Early investment in BECCS in power will help identify and overcome any technical hurdles, and will deliver the innovation to bring costs of future BECCS plants down. Some examples of the technical challenges that an early BECCS in power plant would help address include developing further understanding of:

- the use of amine solvent, which is proven with fossil use, but where further experience is needed on biomass combustion flue gases at scale; and
- optimisation of plant performance, integration with existing plant, energy efficiency and innovation, all of which have the potential to reduce costs for future BECCS in power projects.

BECCS will also deliver learnings and skills around CCS that can be relevant to many other technologies that make use of CCS, including DACCS and most types of hydrogen production. The Government already has a knowledge sharing initiative around CCS, through which learnings from the White Rose and Peterhead CCS projects have been shared.[37] These learnings include information around T&S costs and risks, insight that can help reduce the uncertainty around CCS, and encourage investment.

Investment in BECCS will provide further learnings around CCS technology in a new context. For example:

- learnings on interfacing with a T&S system (both technically and commercially);
- learnings for industrial CCS where flue gases have more in common with biomass than gas (e.g. particulates and metal elements); and

[35] If transport and storage is developed under a Regulated Asset Base model which determines a level of revenue to be recovered in any given year, a higher volume of emissions transported and stored in that year (as a result of BECCS volumes) should imply a lower unit tariff for all infrastructure users.

[36] CCC (2019), *Net Zero The UK's contribution to stopping global warming*, https://www.theccc.org.uk/wp-content/uploads/2019/05/Net-Zero-The-UKs-contribution-to-stopping-global-warming.pdfCCC (2019) Net Zero, p.93

[37] BEIS (2016), *Carbon Capture and Storage knowledge sharing*, https://www.gov.uk/government/collections/carbon-capture-and-storage-knowledge-sharing

- building on UK CCS expertise.

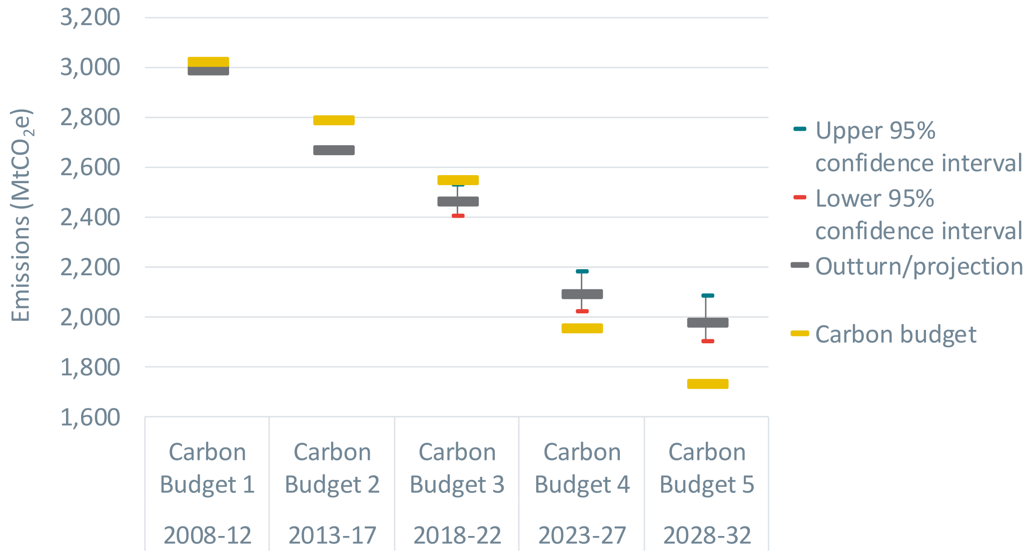
A.1.3 If a business model is used to deliver BECCS in the near term, this will provide policy learnings

Finally, assuming a business model is used to enable investment in BECCS in power, policy experience gained through the design and implementation of this model will be useful for future business models for other technologies. In particular, understanding how to remunerate negative emissions will be essential for achieving sufficient investment in GGRs of all kinds over the coming years.

A.1.4 Developing BECCS in power in the near term will help the UK meet upcoming carbon budgets and ultimately Net Zero

Although the UK met its first two carbon budgets (2008-2012 and 2013-2017) and is on its way to meeting the third (2018-2022), it is expected to miss its fourth by 109 $MtCO_2e$ and its fifth by 165 $MtCO_2e$ (2023-2027 and 2028-2032). This is illustrated in the figure below, which is based on the latest BEIS emissions projections.[38]

Figure 13 Actual and projected performance against carbon budgets



Source: Data from BEIS, Updated Energy and Emissions Projections: 2018, https://www.gov.uk/government/collections/energy-and-emissions-projections#history

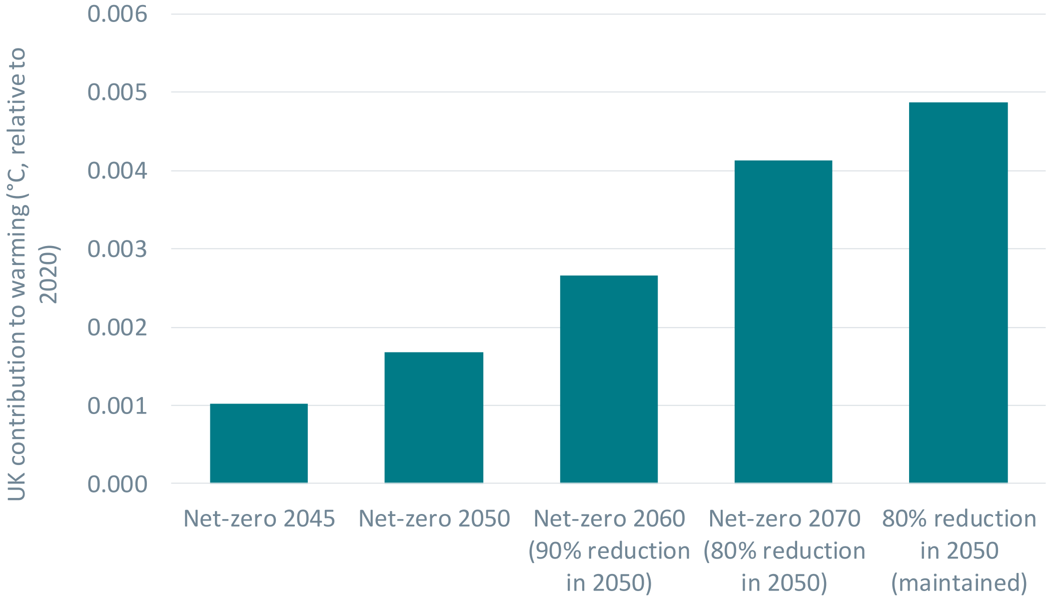
Since the carbon budgets are legally binding, missing them entails risks for the Government – for example, potentially exposing it to legal action. Given this, there is potential value in introducing a technology which can start to deliver negative emissions by the fifth carbon budget, and make a significant contribution to future carbon budgets on the path to Net Zero by 2050.

[38] BEIS (2019) *Updated Energy and Emissions Projections*, https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/794590/updated-energy-and-emissions-projections-2018.pdf

Ensuring that GGR technologies are in place early also reduces the risk of delays in deployment impacting the ability of the UK to offset residual emissions by 2050. It ensures that there is sufficient time to capture the benefits of learnings and positive spillovers from first-of-a-kind plants. It may also ensure that sufficient GGR options are available to enable competition between GGRs at a stage when technologies are sufficiently mature.

The rate at which the UK abates will have a direct impact on the UK's contribution to the global rise in temperatures. As shown below, meeting Net Zero by 2050 has a significant impact on global temperatures compared to the initial target of an 80% reduction by 2050.

Figure 14 UK impact on global temperature in 2070, under future emissions pathways

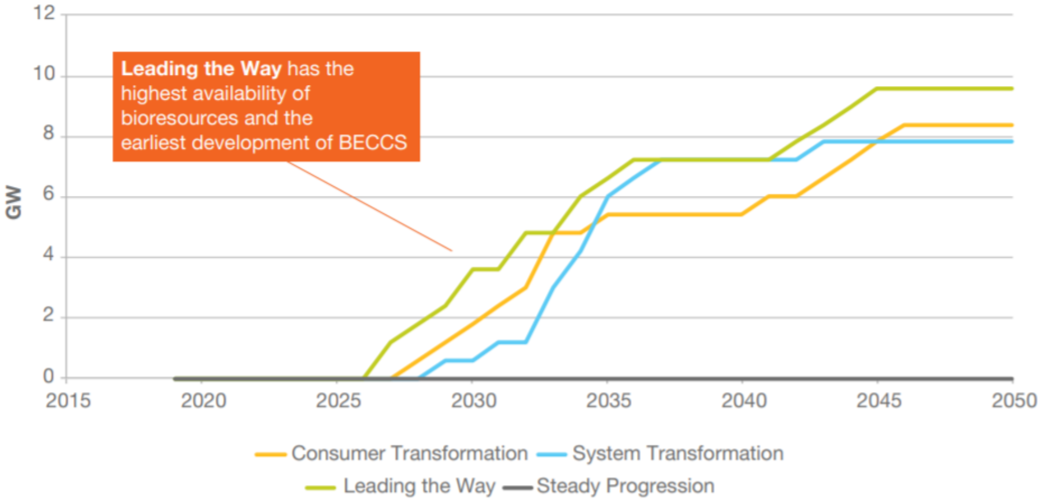


Source: CCC Net Zero supporting da*ta*, https://www.theccc.org.uk/publication/net-zero-the-uks-contribution-to-stopping-global-warming/#supporting-research,-charts-and-data, *chapter 2*

The importance of early investment in BECCS in power is reflected in National Grid's FES scenarios.[39] Across the three scenarios that meet Net Zero, BECCS in power is deployed from the period between 2025 and 2030.

[39] National Grid (2020) Future Energy Scenarios, https://www.nationalgrideso.com/document/173821/download

Figure 15 BECCS electricity generation capacity in FES



Source: National Grid (2020) FES

ANNEX B FUNDING PRINCIPLES AND CANDIDATE GROUPS

B.1 Principles to guide funding decisions

We have identified three key principles that can be used to guide a decision on which group or groups fund a chosen business model: efficiency, fairness and practicality. There are trade-offs between these principles, and these should be considered carefully when making a decision. We provide more detail around each of these principles below.

Efficiency

There are two aspects to efficiency, the first relates to creating efficient incentives, and the second relates to avoiding distortions:

- **efficient incentives:** in applying a levy to certain groups or sectors, there is an opportunity to do this in a way that tries to replicate the incentives and outcomes that an efficient carbon price would achieve. For various reasons, there are many sectors that are currently not covered by the EU Emissions Trading Scheme (or are covered, but receive free certificates), and do not face other domestic taxes based on emissions. These sectors therefore face an implicit carbon price which is lower than that of other sectors which are part of the ETS, and which do face additional taxes. We refer to these sectors as “undertaxed” sectors, and examples may include aviation and agriculture. If it is possible to raise funding for a chosen business model from these groups, then this may help deliver good outcomes in terms of delivering something closer to an economy-wide carbon price.

  However, identifying these sectors reliably may be complex, and would require a careful analysis of current effective tax rates to determine whether and by how much a sector is undertaxed.
- **avoiding distortions:** beyond ensuring a consistent carbon price across the economy, efficiently raising funding involves taxing groups that have more inelastic demand. This is because the required funds can be raised while causing fewest distortions to behaviour. This may mean, for example, avoiding recovering funds from sectors which are exposed to international competition or where there is a risk of offshoring.

Fairness

This principle refers to protecting vulnerable groups. This is in itself complex, as the relationship between income and consumption of particular products is typically complex.

However, the fairness principle may indicate that it is better to avoiding trying to recover funds from sectors which are high up typical value chains. This is because, if this cost recovery pushes up the price of significant numbers of intermediate and final products, it may then be harder to prevent it impacting vulnerable customer groups.

Practicality

This principle aims to ensure that a chosen funding approach is manageable to implement and monitor, and transparent in how it functions. This may rule out taxing sectors where there are a large number of players or a large number of inputs to a product, as this increases the administrative burden.

B.1.1 Trade-offs between principles

There are tensions and trade-offs between all of these principles. For example:

- the second efficiency principle encourages taxing groups with inelastic demand. However, this is in tension with the fairness principle, because vulnerable groups may have more inelastic demand; and
- the fairness principle encourages taxing lower down in the value chain, whereas the practicality principles encourage taxing higher up (as there are likely to be fewer entities, making business models administratively simpler).

An appropriate balance therefore needs to be struck. It may be possible to address multiple principles by imposing the levy in a way that focuses on achieving efficiency, but then making lump-sum transfers (e.g. through increased benefits) to sub-groups in order to address any fairness concerns. However this would then create additional complexity. It is also important to keep in mind that political considerations will inevitably drive a large part of this decision.

B.2 Options for groups that could fund a chosen business model

We have identified five groups that could be candidates for funding a chosen business model. These have been chosen because there is:

- a rationale (based on the principles above) for charging this group;
- a precedent for targeting this group; or
- previous research has argued that these groups should fund climate change policies.

We set out these groups in the table below, and for each we discuss the pros and cons of targeting that group.

Figure 16 Candidate groups for funding a chosen business model

Level in value chain	Candidate group	Pros	Cons
Upstream	Fossil fuel suppliers	Practical: straightforward to administer due to limited number of players	No way to focus the tax on undertaxed or inelastic sectors, or to protect vulnerable groups
	Undertaxed emitters	Incentivises behaviour that replicates outcomes of an efficient carbon price	▪ Difficult to accurately identify undertaxed emitters ▪ Some sectors (e.g. those exposed to international competition) may have elastic demand
	Undertaxed emitters not exposed to international competition	Incentivises behaviour that replicates outcomes of an efficient carbon price	Difficult to accurately identify undertaxed emitters – and exposure to international competition is a subjective measure
	Electricity suppliers/users	▪ There is precedent for taxing this group, which has relatively inelastic demand ▪ Taxing at this level makes it slightly easier to protect vulnerable groups	Electricity users already face significantly more tax than many other emitting sectors
Downstream	Taxpayers	Relatively easy to administer	No way to focus the tax on undertaxed or inelastic sectors

Source: Frontier

The table sets out a subset of credible funding options – there are clearly numerous further options which could be considered. In this report we do not provide a view on which of these groups (or other groups) should fund a chosen business model. This is a decision that will ultimately need to be taken by policymakers, by weighing up the pros and cons and political feasibility of different options.

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