Market design for negative emissions in the UK ETS

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Glossary of terms

Term	Description
Negative emissions technologies (NETs)	Technologies that lead to a reduction in greenhouse gases (GHG) in the atmosphere. To be classed as a NET, the technology must cause a removal of GHGs from the atmosphere, not merely a reduction in the amount emitted, and must result in an overall reduction in atmospheric greenhouse gasses (GHGs). Examples are afforestation, Bioenergy with Carbon Capture and Storage (BECCS), and Direct Air Carbon Capture and Storage (DACCS).
Greenhouse gas removals (GGRs)	The removal of GHGs from the atmosphere. GGRs can be done by NETs. We also refer to a 'unit of GGRs', which is a certified amount of GGRs analogue to an emission allowance (see below).
Carbon offsets	A reduction in, or removal of, emissions of carbon dioxide or other greenhouse gases that is undertaken in order to compensate for emissions generated elsewhere.
Emissions reductions/ abatement	A reduction in emissions of CO_2 or GHGs that does not remove carbon from the atmosphere but slows down the increase of GHG levels in the atmosphere.
Negative emissions	Deliberate removal of greenhouse gases (GHGs) from the atmosphere by human activities—i.e. in addition to the removal that would occur via natural carbon cycle processes.
Net zero emissions	Where the flows of emissions of greenhouse gases (GHGs) to the atmosphere are balanced by GHG removals over a specified period.
Net zero target	The year in which net zero emissions are aimed to be achieved.
Emissions Trading Scheme (ETS)	Also known as a 'Carbon Cap and Trade' scheme or system. A cap-and-trade system that caps the total level of greenhouse gas emissions that companies covered under the scheme are allowed to emit. Companies are required to buy Emissions Allowances to emit GHGs, creating a carbon market with a carbon price signal to incentivise decarbonisation. The EU Emissions Trading System (EU ETS) has been in operation since 2005, and the UK ETS has been separate since January 2021. In this report 'ETS' refers to the UK ETS unless otherwise specified.
Emission allowances (EAs)	Certificates that companies currently buy in the ETS.
Carbon capture and storage (CCS)	Process in which CO_2 emissions (e.g. from industrial and/or power generation) is separated (captured), conditioned, compressed and transported to a storage location for long-term isolation from the atmosphere.
Bioenergy with carbon capture and storage (BECCS)	Process that combines energy production (e.g. electricity, heat or hydrogen) from biomass with carbon capture and storage (CCS) of the CO_2 emitted, resulting in a net removal of GHGs from the atmosphere if the source of the biomass is sustainable.
Direct air carbon capture and storage (DACCS)	Process that involves separating CO_2 from the air through chemical processes and storing it. A key advantage is that the approach can be significantly scaled up, but it requires a large amount of zero-carbon energy and is currently a high-cost NET option.
Carbon capture, utilisation and storage (CCUS)	Process in which CO_2 is captured and used as an input to the production of another product, or is stored. CCUS may or may not lead to negative emissions, depending on how the CO_2 is used and for how long it is stored. CCUS results in emissions reductions of the CO_2 so long as the CO_2 is not subsequently released to the atmosphere. CCUS may result in negative emissions if the CO_2 is from BECCS or DACCS.[1]
Carbon contracts for differences (CCfD)	A contract in which the government pays the organisation that is reducing emissions the difference between the market price for carbon (see ETS) and an agreed price (the strike price) that is necessary to make the project being supported financially viable.

[1] International Carbon Action Partnership (2021), 'Emissions Trading Systems and Net Zero: Trading Removals', May.

Executive summary

Oxera has been commissioned by Drax to advise on market design options to include greenhouse gas removals (GGRs) in the UK's emissions trading scheme (UK ETS).[2] The scope of this report is specifically to propose mechanisms that link GGRs to the ETS, although we note that other voluntary or mandatory international markets are likely to develop following recent agreement on the rulebook for Article 6 of the Paris Agreement.[3] Accordingly, this report develops a number of potential market design mechanisms that can enable the uptake of GGRs within the UK ETS framework while ensuring that polluters retain incentives to decarbonise.

Reaching the UK's net zero ambitions and meeting its obligations under the Paris Agreement requires all sectors to reduce or offset their emissions.[4] As some sectors, such as heavy industry, agriculture and aviation, are inherently difficult to decarbonise completely, the delivery of net zero will only be possible with GGRs that take emissions out of the atmosphere.[5] Importantly, these removals are to be used in addition to a significant abatement of emissions across all sectors, with most sectors needing to reduce emissions close to zero without offsetting by 2050.[6]

Negative emission technologies (NETs) that produce GGRs include nature-based solutions—such as afforestation, reforestation and soil carbon sequestration—as well as technologies such as bioenergy with carbon dioxide capture and storage (BECCS), and direct air carbon capture and storage (DACCS).[7] Engineering-based GGRs have not yet been commercially deployed at scale and are currently more expensive than most abatement technologies. However, it is projected that such technologies will need to be deployed at scale in the coming years, removing 5–10MtCO_2 per year by 2030; correspondingly, it is projected that the costs will decline considerably as the technologies mature.[8] By 2050 more than 70MtCO_2 per year of engineering-based GGRs will be needed.[9] This requires policies to be in place to incentivise investment in NETs now, as the National Infrastructure Committee has also emphasised:[10]

> Engineered greenhouse gas removals will become a major new infrastructure sector for the UK over the coming decades. The UK needs engineered removals to offset its hardest to abate emissions and achieve net zero. And it needs to act now.

We note at the outset that to incentivise the deployment of GGRs, different support options are possible, including innovation funding, carbon contracts for difference and access to carbon markets—including the ETS. As long as there is no double-counting of emissions between funding mechanisms, each funding option does not need to be used on a mutually exclusive basis. In fact,

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[2] The ETS is a cap-and-trade scheme where the government sets a cap on the total amount of greenhouse gases that can be emitted by sectors covered by the ETS. Participants need to obtain emission allowances to cover their emissions.
[3] United Nations (2015), 'Paris Agreement', Article 6.
[4] National Infrastructure Commission (2021), 'Engineered greenhouse gas removals', July.
[5] Committee on Climate Change (2020), 'The Sixth Carbon Budget - The UK's path to Net Zero', December, chapter 11.
[6] Committee on Climate Change (2020), 'The Sixth Carbon Budget - The UK's path to Net Zero', December, chapter 11.
[7] International Carbon Action Partnership (2021), 'Emissions Trading Systems and Net Zero: Trading Removals', May, p. 31.
[8] National Infrastructure Commission (2021), 'Engineered greenhouse gas removals', July.
[9] Department for Business, Energy and Industrial Strategy (2021), 'Net Zero Strategy: Build Back Greener', October.
[10] National Infrastructure Commission (2021), 'Engineered greenhouse gas removals', July.

having several options can help to spread the costs and/or allow for voluntary uptake of NETs among different market participants (polluters, taxpayers, consumers and other parties who may want to go further in decarbonisation than just meeting their compliance needs), thereby accelerating the commercialisation of NETs.

To assess the market design options, we have evaluated from a public policy perspective the relevance of:

- **long-term effectiveness in reducing overall emissions** by ensuring that incentives for polluters to reduce their emissions are maintained and that the deployment of NETs is incentivised early on so that sufficient GGRs are available at reasonable cost by the time most abatement options have been exhausted. It should also be ensured that removals are of high quality by establishing robust monitoring, reporting and verification (MRV) processes;
- **efficiency of markets** by ensuring that markets are sufficiently liquid for efficient price discovery and investment signals;
- **fairness of cost allocation** by considering the impact on taxpayers, as well as industry;
- **practicality** by considering the ease of implementation of the scheme;
- **integrability with EU ETS** to allow for future integration of the UK scheme with its EU counterpart.

The market design schemes for integrating NETs within the ETS[11] that have been developed as part of this study can, in principle, accommodate all types of GGRs that meet robust MRV criteria to validate the credibility of the removal.[12] However, as NETs differ not only in terms of cost but also in terms of permanence and security of storage, relevant adjustments should be undertaken to ensure comparability across different types of GGRs.[13]

This report develops the following market design options. Options 1–3 are all based around the principle that GGR units can be purchased as an alternative to emission allowances—while tightening overall emission caps to ensure that removals are additional to existing abatement incentives.

- **Option 1: separate markets with government as a broker**—this creates a separate market for GGRs where the government diverts some of the demand for emission allowances in the ETS to GGRs. In this case, the government would have full control over the amount of GGR units purchased in the market and could align this with its net zero scenarios.
- **Option 2: separate markets with price cap**—this creates a separate market for GGRs and relies on market mechanisms (e.g. setting a price cap) to allow for uptake of GGRs. The market for GGRs can be accessed by the industries covered by the ETS and potentially more widely (i.e. participation can extend to industries that are not presently covered by the UK ETS). In order to create a link to the ETS, GGR units would count towards EAs so companies could either purchase allowances, for which the supply is progressively reduced, or GGR units. To ensure sufficient uptake of GGRs, the price in the market is capped at the prevailing ETS price. The

[11] In this report ETS refers to the UK ETS unless otherwise specified.
[12] Department for Business, Energy and Industrial Strategy (2021), 'Net Zero Strategy: Build Back Greener', October, section 3vii.
[13] Department for Business, Energy and Industrial Strategy (2021), 'Monitoring, Reporting and Verification of Greenhouse Gas Removals – Task and Finish Group report', 19 October.

outcome is thereby similar to option 1 but allows the government to play a less active role, which may become practical as the market matures.

- **Option 3: integrated markets**—this involves allowing GGRs to directly participate in the ETS by being auctioned together with allowances. In the run up to 2050, the supply of EAs would be revised to ensure that GGRs are additional to emission reductions. That is, the total amount of emission allowances in the ETS could decrease by the amount of GGR units in the market to ensure that the net level of emission allowances is declining over time, in line with the UK's net zero targets.[14]

It is also possible that these options could be introduced sequentially, starting with a separate market in which the government directly acts as a broker to 'kick-start' the uptake of GGRs, eventually moving towards full integration of GGRs within the ETS as NETs mature.

Alternatively, a fourth option directly requires polluters to obtain a future GGR for their emissions.

- **Option 4: carbon removal obligation when emitting**—this introduces an obligation for emitters to purchase not only an emission allowance but also to ensure that the emissions will be taken out of the atmosphere in the future. Under this option GGRs and emission allowances become complements. That is, whenever an emission allowance is purchased, there is a concurrent obligation for a future GGR to be purchased. This option therefore sharpens the incentive for polluters to directly abate their current emissions.

Under option 4, industries would no longer purchase an effective permanent right to pollute as they do in the ETS but rather they would be responsible for the whole lifecycle of their emissions, including removing these from the atmosphere. Accordingly, this option also has the highest marginal incentive for companies to invest in decarbonisation and direct abatement, since the cost of polluting would increase, due to the obligation to buy future removals. However, given the cost on industry in meeting the obligation, additional mechanisms would need to be put in place to avoid companies moving production to other countries with less stringent policies in order to circumvent these rules. The carbon border adjustment mechanism (CBAM) is one example of such an additional measure. Also, the scale and speed with which the financial impact is borne by polluters can be moderated by other policies—for instance, through subsidies, or by increasing the level of obligation over time.

These market design options—in combination with other funding routes—would incentivise the deployment of NETs alongside decarbonisation, which will be essential for reaching net zero goals. Which of the market design options is most suitable depends on the government's priorities.

- Option 1 grants the government the most direct control and could be implemented immediately by only changing the supply of allowances in the ETS. As technologies mature, the policy could then evolve towards greater integration with the ETS (i.e. move from option 1 towards option 3).
- Alternatively, option 4 directly and immediately increases the uptake of GGRs through market mechanisms but requires additional instruments to

[14] In the long run, however, there would be no more emission allowances being made available by the ETS, such that a fully integrated market could function without this additional intervention.

avoid carbon leakage. It also relies on sufficient supply of GGR units and the development of a competitive market over time.

In any case, for any option to be implemented, an immediate policy requirement is to establish the processes for MRV, as well as a methodology to create a unit of GGRs that is equivalent to a unit of emission reduction.

1 Introduction

Negative emissions technologies (NETs), which can permanently reduce the amount of greenhouse gases (GHGs) in the atmosphere, will become increasingly important to compensate for any residual emissions from industries that cannot be completely decarbonised. According to the UK's net zero projections, greenhouse gas removals (GGRs) are crucial to reach the delivery of the country's climate targets by 2050.[15] In order to reach the scale of GGRs required, funding mechanisms and routes to markets need to be established.[16]

At the recent COP26 summit, an agreement was reached on the rules under Article 6 of the Paris Agreement.[17] This rulebook set the framework for cooperative approaches between countries to meet their Nationally Determined Contributions (NDCs)—for example, by the linking of ETSs or the bilateral trade of emissions reduction credits between countries (Article 6.2).[18] The rules also create a framework for the certification of tradable credits from emissions reductions generated by specific projects. By enabling trade between countries and the use of credits generated by a project in one country to offset emissions in another country (Article 6.4),[19] the Article 6 rulebook is expected to help expand the market for NETs and make it simpler for projects to benefit from a wider global market.

The purpose of this study is to analyse one particular route to market—integrating NETs within the ETS. In particular, the scope of the report is to develop a number of potential options in which NETs could be integrated within the UK ETS without preventing future integration of the UK and EU ETSs.

The remainder of this report is structured as follows.

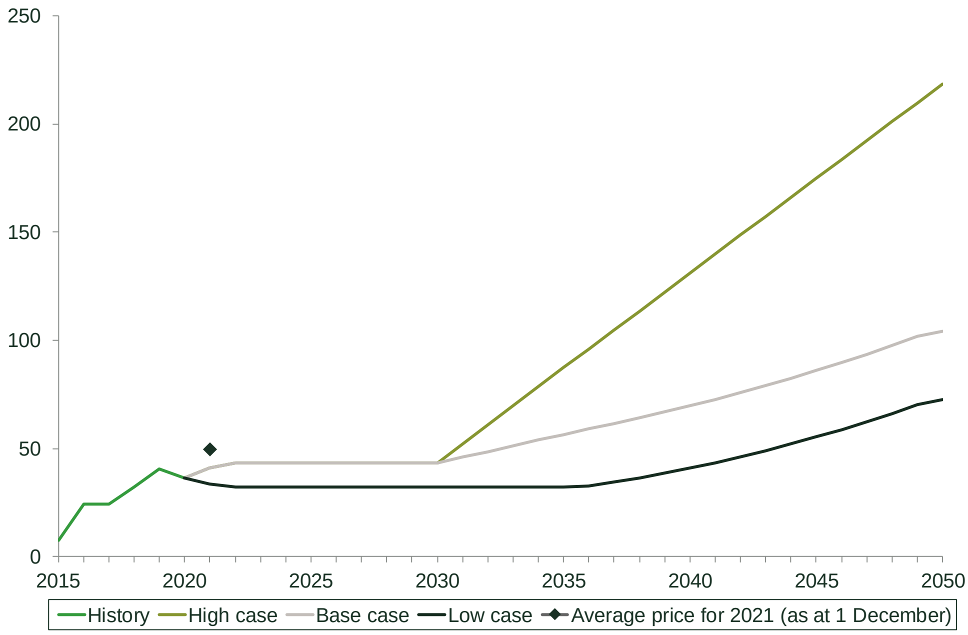
- Section 2 sets out the context around why GGRs are needed, what the different types are, and how their deployment at scale can be incentivised.
- Section 3 sets out the core principles and evaluation criteria against which the design options for ETS integration are assessed.
- Section 4 describes and discusses four different market design options for ETS integration.
- Section 5 concludes.

[15] Committee on Climate Change (2020), 'The Sixth Carbon Budget - The UK's path to Net Zero', December.
[16] Department for Business, Energy and Industrial Strategy (2021), 'Net Zero Strategy: Build Back Greener', October.
[17] United Nations (2015), 'Paris Agreement', https://unfccc.int/sites/default/files/english_paris_agreement.pdf (last accessed 14 December 2021).
[18] United Nations, 'Guidance on cooperative approaches referred to in Article 6, para. 2, of the Paris Agreement', https://unfccc.int/sites/default/files/resource/cma3_auv_12a_PA_6.2.pdf (last accessed 14 December 2021).
[19] United Nations, 'Rules, modalities and procedures for the mechanism established by Article 6, paragraph 4, of the Paris Agreement', https://unfccc.int/sites/default/files/resource/cma3_auv_12b_PA_6.4.pdf (last accessed 7 January 2022).

2 The need for incentivising negative emissions technologies

Reaching the UK's net zero ambitions and meeting the UK government's obligations under the Paris Agreement requires all sectors to reduce, prevent or offset their emissions by 2050.[20] In fact, to adhere to the 1.5°C target set by the Paris Agreement, the world needs to be net zero by 2050 and net negative thereafter.[21] The Paris Agreement was finalised this year at COP26 in Glasgow, at which nearly 200 countries reaffirmed their commitment to the Agreement and outstanding elements were agreed upon.[22] However, even though more and more emissions are being abated, some emissions—such as those from aviation or hard-to-decarbonise industrial and agricultural processes—are likely to remain too costly or impractical to eliminate fully.[23] As the easy-to-abate emissions are reduced in the coming years and decades, these more expensive emissions will be left, implying that the cost of reducing the remaining CO_2 emissions will increase significantly over time. To contextualise this trajectory, National Grid estimated that, in its base case, carbon prices in the UK will more than double by 2050 compared with today, with the possibility of much steeper increases also modelled in its forecasts up to 2050 (see 'High case' in Figure 2.1 below).[24] Given that the average UK out-turn carbon price in 2021 has already exceeded National Grid's projections, the UK seems likely to be on a steep carbon price trajectory.

Figure 2.1 UK carbon price projections (£/tonne CO_2)



Source: National Grid (2021), 'Future Energy Scenarios 2021 – Data Workbook', CP2; Oxera analysis based on ICE Report Center, 'UK Emissions Auctions', https://www.theice.com/marketdata/reports/278 (last accessed 13 December 2021).

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[20] National Infrastructure Commission (2021), 'Engineered greenhouse gas removals', July.
[21] International Carbon Action Partnership (2021), 'Emissions Trading Systems and Net Zero: Trading Removals', May.
[22] See COP26 (2021), 'COP26 keeps 1.5C alive and finalises Paris Agreement', November, https://ukcop26.org/cop26-keeps-1-5c-alive-and-finalises-paris-agreement/ (last accessed 2 December 2021).
[23] Fuss, S., Lamb, W.F., Callaghan, M.W., Hilaire, J., Creutzig, F., Amann, T. and Minx, J.C. (2018), 'Negative emissions - Part 2: Costs, potentials and side effects', March, *Environmental Research Letters*.
[24] National Grid (2021), 'Future Energy Scenarios 2021 – Data Workbook', CP2.

Other measures of the cost of carbon ascribe a much higher valuation than the above figures. For example, the Department for Business, Energy and Industrial Strategy's (BEIS's) carbon values for 2021—which represent a monetary value that a social planner should place on one tonne of CO_2 equivalent (tCO_2e)—are in the range of £122–£361/tCO_2e, increasing to £189–£568/tCO_2e by 2050.[25]

2.1 The need for Negative Emissions Technologies (NETs)

In light of this, NETs, which can permanently remove GHGs from the atmosphere, will become increasingly important to compensate for any residual emissions from industries that cannot be completely decarbonised. NETs include nature-based solutions, such as planting trees, and engineering-based technologies that capture and store GHGs. According to the UK's net zero projections, GGRs are crucial to reach the country's climate targets.[26] Importantly, GGRs are to be used in addition to a significant abatement of emissions across all sectors, with most sectors needing to reduce emissions close to zero without offsetting by 2050.[27] The sixth carbon budget requires gross emissions in the UK to be less than 100$MtCO_2e$ by 2050;[28] this is a reduction of more than three quarters compared to the UK's current emissions in 2020 of 414$MtCO_2e$—and the latter may even be depressed due to the COVID-19 pandemic.[29] That is, GGRs are not an alternative to abatement, which companies can pay for to avoid having to cut emissions. Instead, GGRs will become necessary to compensate for the last unavoidable emissions with significant reductions still needing to be achieved.

In addition to balancing residual emissions that cannot be abated by the mid-century, carbon removals might also be necessary to compensate for GHGs that are already in the atmosphere, including historic emissions. While anthropogenic activity can control the 'flow' of carbon into the atmosphere, warming in fact depends upon the concentration of carbon in the atmosphere, or the 'stock'.[30] Reducing the stock of residual emissions is likely to be necessary in two respects.[31]

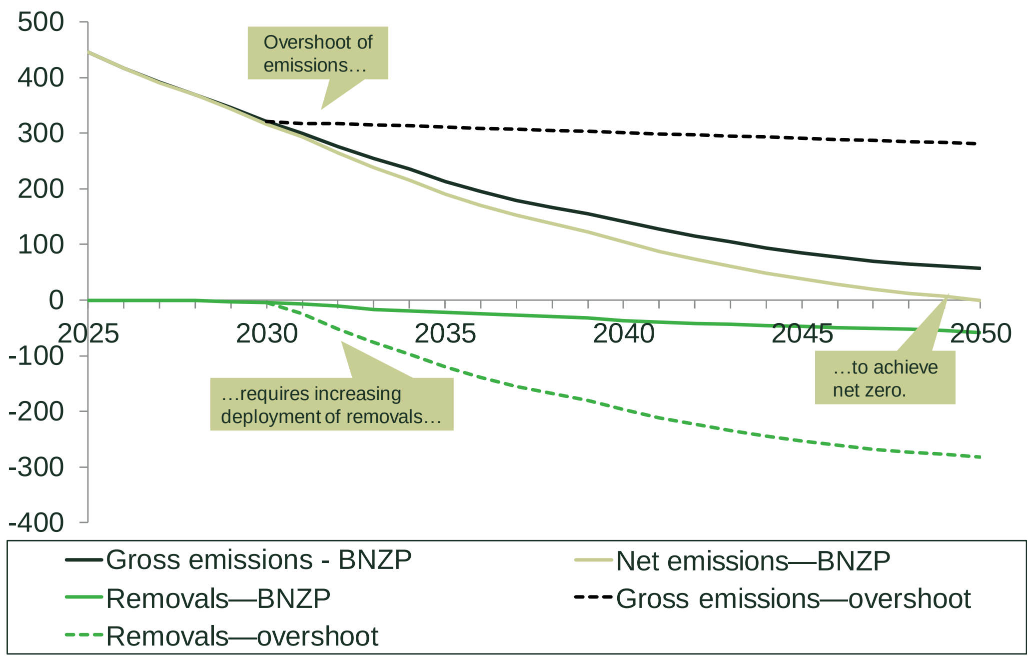
- NETs can be useful in removing historic emissions that have led to a higher concentration of CO_2 in the atmosphere, and which therefore are still contributing to warming today.
- NETs can also compensate for the emissions resulting from the warming of the biosphere itself, which occurs indirectly as a result of past emissions.

Additionally NETs may be necessary to reduce the stock of carbon in the atmosphere in the likely scenario that the world overshoots its carbon

[25] Department for Business, Energy and Industrial Strategy (2021), 'Valuation of greenhouse gas emissions: for policy appraisal and evaluation', 2 September, Annex 1, https://www.gov.uk/government/publications/valuing-greenhouse-gas-emissions-in-policy-appraisal/valuation-of-greenhouse-gas-emissions-for-policy-appraisal-and-evaluation#annex-1-carbon-values-in-2020-prices-per-tonne-of-co2 (last accessed 15 December 2021).
[26] Committee on Climate Change (2020), 'The Sixth Carbon Budget - The UK's path to Net Zero', December.
[27] Committee on Climate Change (2019), 'Net Zero - The UK's contribution to stopping global warming', May.
[28] Department for Business, Energy and Industrial Strategy (2021), 'Net Zero Strategy: Build Back Greener', October, Chapter 2.
[29] Committee on Climate Change (2019), 'Net Zero - The UK's contribution to stopping global warming', May, Figure 5.3; Department for Business, Energy and Industrial Strategy (2021), '2020 UK greenhouse gas emissions, provisional figures', 25 March.
[30] See London School of Economics Grantham Institute (2018), 'Why does climate change get described as a stock-flow problem?', 1 May, https://www.lse.ac.uk/granthaminstitute/explainers/why-does-climate-change-get-described-as-a-stock-flow-problem/ (last accessed 29 November 2021).
[31] See World Economic Forum (2021), 'Net-Zero to Net-Negative: A Guide for Leaders on Carbon Removal', November.

trajectories by not reducing future emissions fast enough. A slower transition to net zero will leave us with a higher stock of GHGs in the atmosphere, which will increase warming even after we have reached net zero. The more significant the overshoot of emissions becomes, the larger the scale of GGRs that is required to counteract the overshoot and the faster the GGRs need to be available, as shown in Figure 2.2 below. This might make the scale of GGRs that would be required to counteract such an overshoot scenario infeasible.[32]

Figure 2.2 Removals required in Balanced Net Zero Pathway Scenario and hypothetical overshoot



Note: Balanced Net Zero Pathway figures from Climate Change Committee (2021), 'The sixth carbon budget – charts and data in the report'. Overshoot figures are for illustrative purposes only.

Source: Oxera.

Given the need for significant emission reductions, any viable market design option for integration within the ETS needs to ensure that incentives to abate remain sufficiently high. Otherwise—if GGRs were to substitute for emission reductions at a large scale—this could be counterproductive, if it disincentives businesses from making the necessary investments to reduce their own emissions. This could permanently lock countries into a higher emission pathway, whereby businesses reduce more slowly than would otherwise be the case.[33]

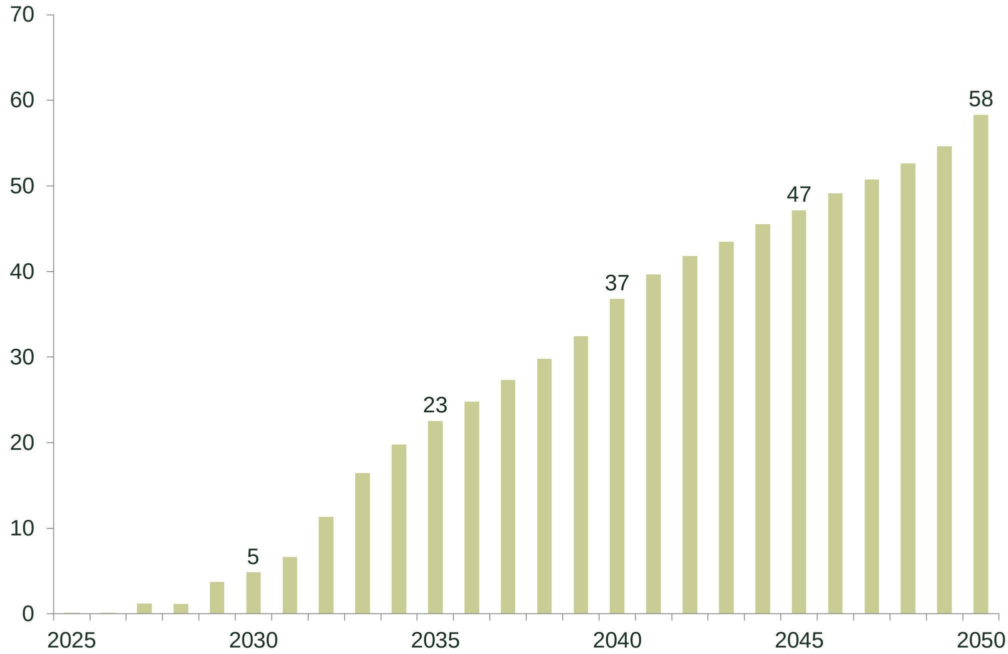
To ensure sufficient GGRs are available at scale in the future, it is necessary to send the appropriate market entry signals for the required technologies today. This is also emphasised by the National Infrastructure Commission's report on GGRs, which states:[34]

[32] Committee on Climate Change (2020), 'The Sixth Carbon Budget - The UK's path to Net Zero', December, p. 369.
[33] International Carbon Action Partnership (2021), 'Emissions Trading Systems and Net Zero: Trading Removals', May.
[34] National Infrastructure Commissions (2021), 'Engineered Greenhouse Gas Removals', July.

> Engineered greenhouse gas removals will become a major new infrastructure sector for the UK over the coming decades. The UK needs engineered removals to offset its hardest to abate emissions and achieve net zero. And it needs to act now.

Incentivising timely uptake is a relevant consideration because these technologies will be needed in the coming years, and there is a significant lead time for development and commercial deployment. Even in 2035, around 15–25MtCO_2e of engineering-based GGRs are required but deployment at scale can take decades—for instance, Drax has started developing its BECCS technology but it will take until 2027 to complete the first installation.[35,36] Scaling up is necessary to reduce costs, which tend to decline with commercial deployment, while performance also tends to improve as technologies mature.[37] Figure 2.3 shows the extent to which GGRs will need to be scaled up according to the CCC's Balanced Net Zero Pathway. The sixth carbon budget even shows a scenario where up to 115MtCO_2e of engineering-based GGRs are required by 2050.[38]

Figure 2.3 Necessary engineering-based GGRs to achieve net zero in the UK according to the Sixth Carbon Budget Balanced Net Zero Pathway (MtCO_2e per year)



Source: Committee on Climate Change (2020), 'The Sixth Carbon Budget Greenhouse gas removals', December, Figure A3.11.a.

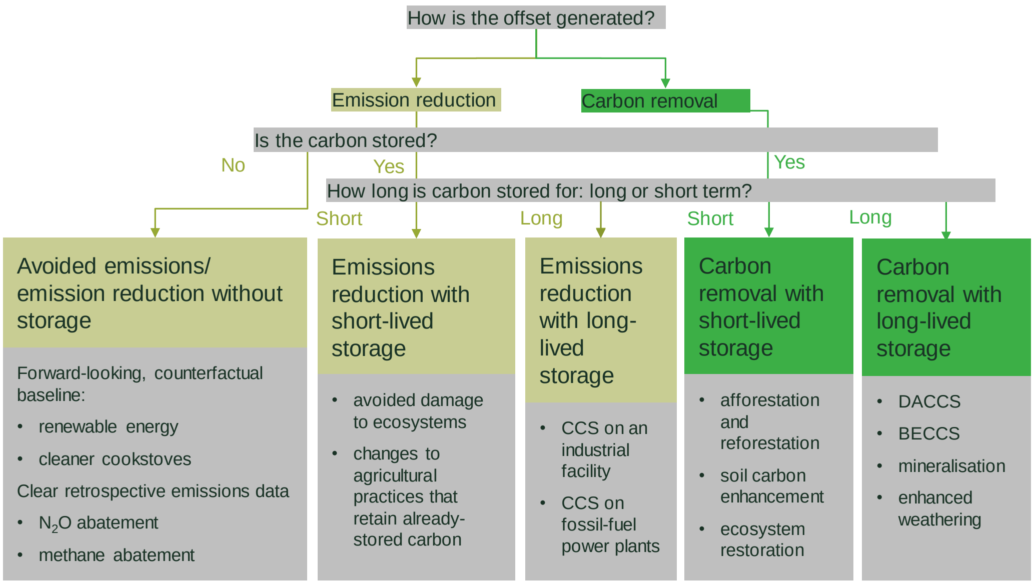
2.2 Different types of negative emissions technologies (NETs)

A distinction can be drawn between emission reductions and carbon removals, as well as in how carbon is subsequently stored.[39] Emission reduction measures are more common and reduce emissions compared to a baseline.

[35] Drax, 'BECCS timeline', https://www.drax.com/about-us/our-projects/bioenergy-carbon-capture-use-and-storage-beccs/ (last accessed 13 December 2021).
[36] According to Drax the development of BECCS takes at least seven years, see Drax, 'BECCS timeline', https://www.drax.com/about-us/our-projects/bioenergy-carbon-capture-use-and-storage-beccs/ (last accessed 13 December 2021).
[37] National Infrastructure Commissions (2021), 'Engineered Greenhouse Gas Removals', July.
[38] Committee on Climate Change (2020), 'The Sixth Carbon Budget Greenhouse gas removals', December, Table P11.1.
[39] University of Oxford (2020), 'The Oxford Principles for Net Zero Aligned Carbon Offsetting', September.

This can include switching from a diesel to a gas generator, reducing emissions as gas emits less than diesel; or having carbon capture and storage (CCS) on an industrial facility, which reduces the volume of CO_2 released into the atmosphere from that facility. Figure 2.4 illustrates carbon reductions and removals, and long- and short-term storage.

Figure 2.4 Distinction between emission reductions and removals



Source: University of Oxford (2020), 'The Oxford Principles for Net Zero Aligned Carbon Offsetting', September.

NETs include:[40]

- **afforestation** and **reforestation**, which involves planting trees that take in carbon as they grow and naturally store it in the biosphere;
- **soil carbon sequestration** where the soil carbon content is enhanced through changes to agricultural practices, storing carbon in the soil;
- **bioenergy with carbon dioxide capture and storage (BECCS)**, which extracts energy—as electricity, heat or biofuels—from sustainable biomass and stores the emitted carbon through capture and geological storage;
- **direct air carbon capture and storage (DACCS)**, which involves extracting CO_2 from the air and storing it.

The first two NETs here are nature-based technologies where carbon is captured and stored in the biosphere, such as in in trees or soil. BECCS and DACCS are often referred to as engineering-based GGRs. Engineering-based technologies capture and store carbon in the geosphere from which fossil fuels originate, in secure geological storage. We note that BECCS also relies on natural processes but as the CO_2 is stored in geological storage (rather than in the biosphere), it is referred to here as an engineering-based technology. While both nature-based and engineering-based storage options have advantages and are both widely thought to be needed to reach net zero, engineering-based solutions tend to provide higher permanence of storage and

[40] International Carbon Action Partnership (2021), 'Emissions Trading Systems and Net Zero: Trading Removals', May, p. 31.

lower leakage risk. At the same time, nature-based solutions are likely to provide additional benefits, such as enhancing biodiversity.

Specifically, GGRs vary significantly across a number of dimensions, which can broadly be classified into the effectiveness and permanence of CO_2 removal. Relevant considerations include *additionality*, *net negativity*, and *permanence of storage* and associated risk of reversal, as well as the *ability to monitor*.[41]

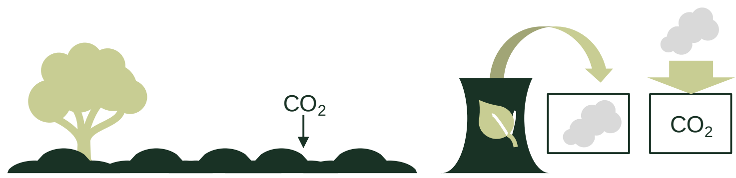
- The **effectiveness of removal** includes factors that need to be demonstrated for any genuine NET. Any scheme for developing a market for negative emissions will need to provide policymakers and other stakeholders with confidence that it legitimately leads to a reduction in GHGs in the atmosphere. This means that negative emissions need to be monitored, reported and verified, which might be achieved following similar guidelines to those for ETS monitoring, reporting and verification (MRV). [42,43] Under the ETS MRV rules, industrial installations and aircraft operators covered by the ETS are required to have approved monitoring plans for their emissions. They need to submit annual emissions reports, with data being verified by an accredited verifier. The MRV process for removals will need to be established in a robust way. NETs are likely to differ in the accuracy, with which monitoring can be undertaken—as well as the cost and frequency of the monitoring that is required—to verify the quantity of CO_2 stored.[44] BECCS and DACCS are relatively easy to monitor, as they generate a stream of CO_2 that can be measured, whereas other technologies are likely to require the use of proxies. Other factors that need to be considered to demonstrate a genuine removal in GHGs include the following.
- ‘**Additionality**’ refers to whether removals are taking place *in addition* to what would have happened anyway. For instance, it can be difficult to prove that afforestation or soil carbon sequestration leads to negative emissions compared to normal practices in forests or agriculture that would have happened anyway.
- It is important to ensure NETs are genuinely **net negative.** For instance, the net negativity of NETs relies on demonstrating the net neutrality of the entire supply chain,[45] including the source of the required electricity.[46]
- The ‘**permanence of storage**’ refers to how long the carbon can be stored once sequestered, including the risk of re-emission.[47] Generally, engineering-based NETs tend to have more security and permanence of

[41] Department for Business, Energy and Industrial Strategy (2021), ‘Monitoring, Reporting and Verification of Greenhouse Gas Removals – Task and Finish Group report’, 19 October.
[42] Department for Business, Energy and Industrial Strategy (2021), ‘Net Zero Strategy: Build Back Greener’, October, section 3vii.
[43] European Commission, ‘Monitoring, reporting and verification of EU ETS emissions’, https://ec.europa.eu/clima/eu-action/eu-emissions-trading-system-eu-ets/monitoring-reporting-and-verification-eu-ets-emissions_en (last accessed 7 January 2022).
[44] Department for Business, Energy and Industrial Strategy (2021), ‘Monitoring, Reporting and Verification of Greenhouse Gas Removals – Task and Finish Group report’, 19 October, p. 8.
[45] For instance, by using sustainably sourced biomass feedstocks from forests which are growing at the same rate (or faster), alongside CCS, BECCS technology can be net negative.
[46] For instance, DACCS requires electricity, which needs to be renewable for the technology to be net negative.
[47] For completeness, it should also be noted that carbon captured through CCS is sometimes reused rather than being permanently stored. In this case, the carbon can be re-emitted, for instance, by burning synthetic fuels, which can therefore at best be carbon neutral (see: Department for Business, Energy and Industrial Strategy (2021), ‘Monitoring, Reporting and Verification of Greenhouse Gas Removals – Task and Finish Group report’, 19 October, p. 15). If the carbon was not taken out of the atmosphere in the first place then capturing and burning the carbon as fuel simply delays the initial emission.

storage than nature-based NETs due to differences in the processes used. BECCS and DACCS rely on CCS to capture carbon before storing it in geological formations—a form of storage that has been shown to be secure and at very low risk of leakage.[48] Nature-based methods are also capable of storing carbon for the long term, as long as changing conditions do not lead to a reversal in the storage. They may be more vulnerable than engineering-based methods to physical events such as fires, natural disasters and droughts, as well as political and economic pressures (e.g. to reverse decisions to protect woodlands), which may lead to higher risk of re-emission in the medium term. However, we note that apart from creating GGRs, these natural measures are likely to be valuable in their own right—for instance, in enhancing biodiversity.[49]

Table 2.1 summarises relevant features of different NETs.

Table 2.1 Summary of NETs features



	Afforestation and reforestation	Soil carbon sequestration	BECCS	DACCS
Permanence	Higher risk of reversal leading to low permanence		Lower risk of reversal and higher permanence	
Status	In use	In use	Demonstration	Demonstration/ commercial
Cost (£/tCO_2)	1–100	0–100	90–225	180–900
Deployment in 2050* ($MtCO_2$/year)	N.A.	N.A.	53	5

Note: *According to the CCC's Balanced Net Zero Pathway. Includes all types of BECCS.

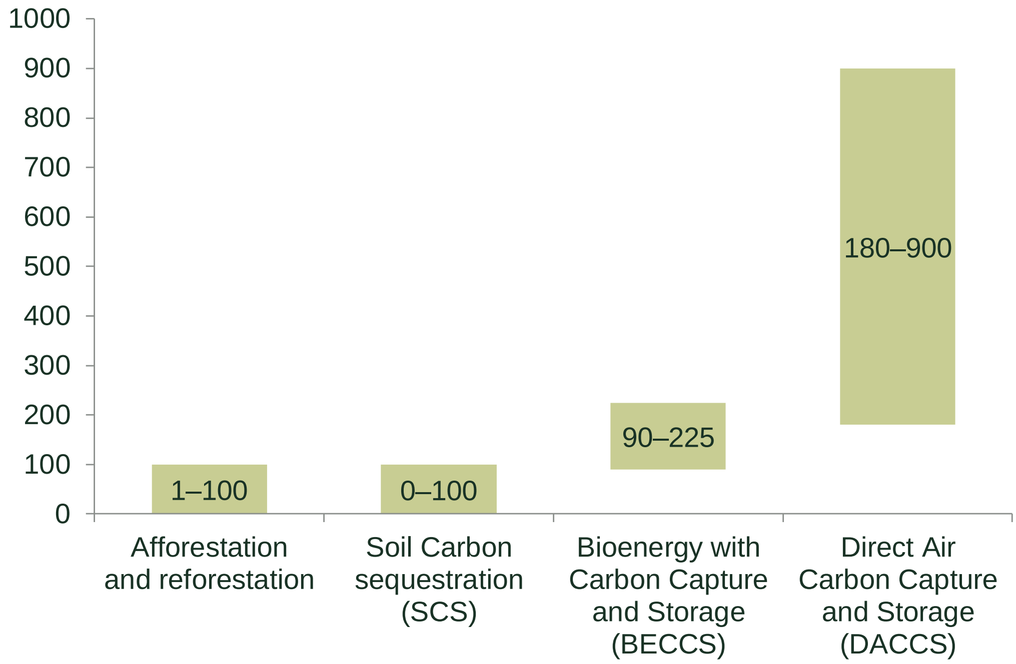
Source: Minx, J.C., Lamb, W.F., Callaghan, M.W., Fuss, S., Hilaire, J., Creutzig, F. and Del Mar Zamora Dominguez, M. (2018), 'Negative emissions - Part 1: Research landscape and synthesis', May; International Carbon Action Partnership (2021), 'Emissions Trading Systems and Net Zero: Trading Removals', May; Coalition for Negative Emissions (2021), 'The case for Negative Emissions', June; Committee on Climate Change (2021), 'The Sixth Carbon Budget Greenhouse gas removals', March.

As highlighted in the table above, different types of GGRs have varying cost implications, with engineering-based solutions being generally more costly at the moment. Figure 2.5 shows current ranges of cost estimates for different NETs. Afforestation and soil carbon sequestration can be inexpensive, with soil carbon sequestration having a minimum of zero costs if it just requires changes to farming practices. BECCS and in particular DACCS have a larger range, depending on the specifics of the technology. The CCC estimates current costs

[48] Department for Business, Energy and Industrial Strategy (2021), 'Monitoring, Reporting and Verification of Greenhouse Gas Removals – Task and Finish Group report', 19 October.
[49] See University of Oxford (2020), 'The Oxford Principles for Net Zero Aligned Carbon Offsetting', September, p. 12.

of DACCs to be around £400/tCO_2,[50] while other sources show a range of £180–255/tCO_2 for liquid solvent economics and £450–900/tCO_2 for solid solvent economics.[51] BECCS is significantly cheaper than DACCS, currently expecting to cost between £90/tCO_2 and £225/tCO_2.[52]

Figure 2.5 Current costs of NETS (£/tCO_2e)



Source: Minx, J.C., Lamb, W.F., Callaghan, M.W., Fuss, S., Hilaire, J., Creutzig, F. and Del Mar Zamora Dominguez, M. (2018), 'Negative emissions - Part 1: Research landscape and synthesis', May; International Carbon Action Partnership (2021), 'Emissions Trading Systems and Net Zero: Trading Removals', May; Coalition for Negative Emissions (2021), 'The case for Negative Emissions', June; Committee on Climate Change (2021), 'The Sixth Carbon Budget Greenhouse gas removals', March.

We note that these costs are likely to decrease significantly as the technologies mature. For instance, the CCC expects the cost of DACCS to decrease from £400/tCO_2 to £180/tCO_2 by 2050 and BECCS costs to also fall (albeit with a wide range to £40–190/tCO_2).[53] Similarly, the Coalition for Negative Emissions (CNE) expects the cost of BECCS to fall by 45–50% as its global negative emissions capacity climbs from 0.1GtCO_2 to 8GtCO_2, while the cost of DACCS is expected to reduce by 50–80% with the same growth in capacity.[54] This would take the cost of BECCS on power from £90–£225/tCO_2 today to £45–£145/tCO_2 once deployed at scale. It would take DACCS from £180– £265/tCO_2 today to around £75–£125/tCO_2 for liquid solvent technology and from around £450–£900/tCO_2 to around £80–£175/tCO_2 for solid sorbent technology.[55] This is because these technologies can reap the benefits of efficiency improvements, as well as a lower cost of financing as they move away from being first-of-a-kind technologies, and achieve greater economies of scale. However, the degree and speed with which the costs of these

[50] Committee on Climate Change (2021), 'The Sixth Carbon Budget Greenhouse gas removals', March, p. 24.
[51] Coalition for Negative Emissions (2021), 'The case for Negative Emissions', June, p. 75.
[52] Ibid., p. 66.
[53] Committee on Climate Change (2021), 'The Sixth Carbon Budget Greenhouse gas removals', March.
[54] Coalition for Negative Emissions (2021), 'The Case for Negative Emissions', June, Figure 6.
[55] Ibid., p. 54.

technologies will reduce is uncertain, and depends on the level of investment, and the extent to which they are taken up, to deliver economies of scale.

At the same time, the natural limit—scarcity of land— and rising land costs might mean that nature-based solutions are likely to become more expensive in the long term. As such, the prices of nature-based and engineering-based solutions are likely to converge in the long run.[56] However, BECCS and DACCS, which rely on geological storage, may also be constrained in the very long term, both by availability of and proximity to geological storage, and, in the case of DACCS, large volumes of electricity needed.[57] BECCS may also be constrained in the long run due to limited availability of sustainable biomass, and the potential for competition for land use with food production and water security. However, the CNE estimates that these technologies can sustainably be deployed capturing several billion tonnes of emissions a year at a global level. With different supply constraints at play, it thereby appears possible that the cost of nature-based NETs might increase with resource scarcity in the long term. For engineering-based solutions, while significant technological cost efficiencies (that come with commercial deployment) are likely to lead to price reductions in the near term, it is also possible that prices may eventually rise in the very long run.

All of these price and availability dynamics will affect the development of the market for future abatement and negative emissions. The expected changes in costs over time should ideally feed into market prices to allow for efficient price signals; this has implications for market design. Also, we note that due to increasing costs of abatement and decreasing costs of NETs, we can reasonably expect price dynamics of convergence between abatement and negative emissions in the lead up to delivery of net zero targets by 2050. We can also expect some cost convergence of nature-based and engineering-based NETs as technologies become more mature.

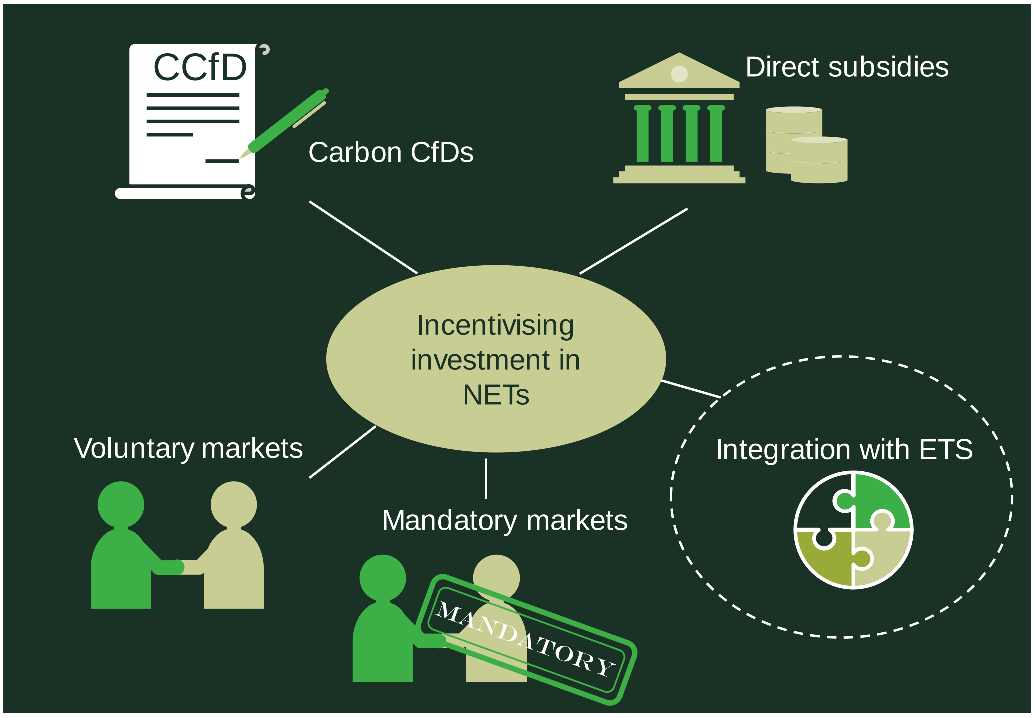
2.3 Incentivising sufficient investment in NETs

Given the required scale of NETs in meeting the UK's carbon budget requirements, there is a need to encourage the development and deployment of NETs today by sending the right market entry signals. The UK government, acknowledging that carbon removals will play a 'critical role' in decarbonising the economy, has committed to developing markets and incentives for GGRs to enable early investment and support early commercial deployment.[58] It also mentions different funding routes, including £100m in innovation funding for DACCS and the UK ETS as a potential market for GGRs—noting the need to establish 'a single, integrated compliance market for carbon, with negative emissions supporting liquidity as the ETS allowance cap falls over time'.

NETs can be incentivised through various mechanisms, some of which are illustrated in Figure 2.6.

[56] Coalition for Negative Emissions (2021), 'The Case for Negative Emissions', June, p. 55.
[57] For example, using DACCS to sequester the upper bound estimate of 30GtCO_2/year would require 50EJ/year electricity and 50EJ heat. See Vivid Economics (2020), 'An investor Guide to negative emissions technologies and the importance of land use', October.
[58] Department for Business, Energy and Industrial Strategy (2021),'Net Zero Strategy', 18 October, Executive Summary and section 3vii.

Figure 2.6 Examples of schemes to incentivise investment in NETs



Source: Oxera.

Each funding option does not need to be used on a mutually exclusive basis, and in fact having several options can help to spread the costs and/or allow for voluntary uptake of NETs among different market participants.

As part of their climate strategies, many businesses, regions and institutions already rely on **voluntary** carbon offsetting—defined as a payment to receive credit for a unit of emission reduction or removal carried out by another actor.[59] This can occur through several mechanisms.

- In the past, countries have been able to purchase offsets certified under the Clean Development Mechanism (CDM) of the Kyoto Protocol. This allows countries to implement an emission reduction, or removal, project in developing countries, earning a Certified Emission Reduction (CER) certificate, each equivalent to one tonne of CO_2.[60] Under the recently agreed Paris Agreement rulebook for Article 6 some of the CERs will now be carried forward into the new framework. Article 6 creates a new framework for countries to use emissions reductions in other countries to meet their Paris targets.
- There may be privately certified offsets that might not be CDM compliant: a variety of these exist, including both reductions and removals, with varying prices.

As the market for offsets develops, mechanisms for quality assurance and verification are also likely to grow. Previously the offset market has experienced issues, with both a lack of external certification schemes and less

[59] University of Oxford (2020), 'The Oxford Principles for Net Zero Aligned Carbon Offsetting', September.
[60] See UNFCCC, 'The Clean Development mechanism', https://unfccc.int/process-and-meetings/the-kyoto-protocol/mechanisms-under-the-kyoto-protocol/the-clean-development-mechanism (last accessed 3 November 2021).

rigorous historic offset certification schemes leading to low-quality offsets being purchased that fail to robustly and verifiably deliver emission reductions.[61] Robust MRV processes are necessary to ensure the quality of offsets, including whether they permanently remove carbon from the atmosphere while also taking account of additionality and the potential for double-counting.[62] Currently new players in the carbon reduction market are developing tools and frameworks to assess and verify the quality of offsets.[63] This development might extend to carbon removals, establishing voluntary markets for GGRs.

Similarly, once credible voluntary markets for GGRs have been established, participation in these may become **mandatory** for some industries (e.g. for those where abatement is particularly difficult).

Integration with the ETS would provide GGRs access to a market covering a number of sectors, such as aviation, industry and power generation. This would have a number of advantages.

- Including NETs in the ETS would require accurate MRV processes, in order for GGRs to be traded. While this is likely to be required for any government support, integration with the ETS might accelerate the MRV process for removals, making it similar to the one taking place in the market for ETS at the moment. This would significantly improve credibility and the confidence of market participants about high-quality emission removals, compared to the current offset market.
- Including NETs in the ETS is likely to allow for relatively efficient price formation. Specifically, within the system, carbon prices are determined by market demand and supply, using a well-designed secondary trading market.
- Under the ETS, the polluter bears the current carbon cost of emissions (if it has to buy allowances, rather than receiving free allowances or reducing emissions directly). This differs from direct government funding and contracts for differences, which impose costs on the taxpayer or energy consumers' bills, depending on the funding mechanism. It also differs from voluntary markets, where companies choose to offset emissions, but where the prices paid may not reflect the ETS price of carbon, and companies can withdraw at any time. We note that it is also possible to design the ETS market for NETs such that participation extends beyond just meeting compliance requirements, by allowing voluntary participants to also trade.
- Furthermore, we note that voluntary carbon markets are organised presently on an 'opt-in' basis, with each firm that buys offsets contributing to a public good, which all participants in the economy benefit from.[64] This is a textbook economics 'free-rider' problem whereby goods and services that generate positive externalities tend to have under-production and/or under-consumption. Accordingly, there will tend to be underfunding of GGRs if left to the voluntary market—whereas the inclusion of NETs in an ETS market,

[61] See, for example, Turner, G. and Grocott, H. (2021), 'The Global Voluntary Carbon Market: Dealing with the problem of historic credits', January.
[62] The Department for Business, Energy and Industrial Strategy (2021), 'Monitoring, Reporting and Verification of Greenhouse Gas Removals: Task and Finish Group Report', p. 9.
[63] See, for instance, Sylvera's website, https://www.sylvera.com/ (last accessed 3 November 2021).
[64] A public good is a good which is non-rivalrous—meaning that there is no limit to the number of players who can benefit from it simultaneously—and non-exclusionary—meaning that one cannot stop someone from benefiting from it. The environment can be seen as a public good.

can be designed with caps or targets to induce higher NET uptake than would otherwise be achieved.[65]

Besides constructing a revenue stream within the ETS market, we note that NETs can also be remunerated and incentivised through **government subsidies**. This includes direct funding, such as the UK government's commitment of £100m of investment in GGR innovation over the coming years.[66]

Governments can also offer carbon contracts for difference (**CCfDs**), in which the government provides revenue support for negative emissions, potentially as a top-up to revenue received from the ETS and/or the voluntary carbon market.[67,68] Contracts for differences currently exist for low-carbon electricity generation but not GGRs.[69,70] For CCfDs to operate as a top-up mechanism to a market carbon price, GGRs need to be able to access a market where they can be paid the prevailing market price, which is currently not possible.[71]

Some commentators suggest that a CCfD and/or including NETs in the ETS would preclude BECCS from participating in the voluntary market as the emissions would already be accounted for in the ETS or carbon removal market.[72] However, it should be possible to have both a CCfD and/or ETS mechanism for negative emissions, and also trade GGRs on the voluntary market, as long as the carbon removed from the atmosphere is not double-counted in any of the schemes, thereby complying with Article 6 of the Paris Agreement. When setting strike prices for the CCfDs, additional revenue streams, such as sales through the voluntary market, would need to be accounted for.[73]

In fact, multiple revenue streams for monetising NETs would be practical provided that the same emissions reductions are not sold (and credited) more than once. This could help spread the cost of emissions reductions between the taxpayer or consumers (through CCfDs), polluters (through the ETS if they do not receive free allowances or other markets), and actors who want to go further (through the voluntary market).

[65] Note: some, but not all, of this effect will be counteracted by brand and reputational advantages to offsetting, which will affect some companies more than others.
[66] See HM Government (2021), 'Net Zero Strategy: Build Back Greener', October, p. 28.
[67] HM Government, 'Contracts for Difference', https://www.gov.uk/government/publications/contracts-for-difference/contract-for-difference (last accessed 15 December 2021).
[68] In theory, a CCfD has the effect of correcting the externality in the carbon offset market, which comes from the fact that the social good of removing the carbon from the atmosphere outweighs the private good to the company of purchasing the removal. A positive externality occurs when there is social benefit from a product or service that outweighs the private benefit derived from that product. Since the buyer is only prepared to pay for the private good rather than the social good, the good will be undersold and therefore underprovided in the market. See Mas-Colell (1995), *Microeconomic Theory*, September, published by Oxford University Press.
[69] HM Government (2020), 'Contracts for Difference (CfD): Allocation Round 4', 2 March, https://www.gov.uk/government/collections/contracts-for-difference-cfd-allocation-round-4 (last accessed 14 December 2021).
[70] The government already offers a similar scheme for afforestation through the Woodland Carbon Guarantee. This involves verification checks to assess how much CO_2 was captured by a forest and paying a guaranteed price up to 2055. Alternatively, woodland owners can sell the credits in the voluntary market. See HM Government (2019), 'Woodland Carbon Guarantee', 4 November, https://www.gov.uk/guidance/woodland-carbon-guarantee (last accessed 14 December 2021).
[71] While most CfDs place the cost on governments, other models are also possible; current energy CfDs place the cost of decarbonising on electricity consumers.
[72] Element Energy and Vivid Economics (2021), 'Investable commercial frameworks for Power BECCS', May, p. 60.
[73] This does imply that revenue recovery via participation in ETS or in voluntary carbon markets would displace the extent of revenue that needs to be recovered via governmental support in CCfD payments. This is analogous to renewable generators being allowed revenues from Guarantees of Origin (GOs), as well as government support. This assumes that the GO revenues are taken into account when the renewable generators bid in competitive tenders for additional support.

3 Core principles and evaluation criteria

Having discussed the important role of NETs in achieving net zero targets, as well as differences in NETs that need to be factored into efficient market design, we now turn to the principles for market design. In this section, we set out core principles for market design options for NETs, which can also act as evaluation criteria in weighing up the pros and cons of different options. We discuss these criteria before turning to the market design options in the following section.

From a public policy perspective, we consider that the criteria summarised in Table 3.1 are of particular relevance for market design in integrating NETs within the ETS. We note that these are also largely aligned with the criteria developed in the report BEIS commissioned on commercial frameworks for BECCs (i.e. effectiveness, efficiency, feasibility, replicability).[74]

Table 3.1 Evaluation criteria

Criteria	Entails
Long-term effectiveness in reducing overall emissions	• Maintaining incentives to reduce emissions while also allowing deployment and uptake of GGRs in line with net zero scenarios • Emissions not shifted to other countries (‘carbon leakage’) • Establishing and maintaining a robust MRV process to ensure high quality of removals • Incentive to invest in the most effective technologies over time
Efficiency of market(s)	• Brings together sufficient buyers and sellers making the market sufficiently liquid for efficient price discovery • Lowest overall costs per tonne of CO_2 removed • Level of government control and flexibility to make changes
Fairness of cost allocation	• Avoid placing disproportionate amount of costs on industry, which could force certain industries out of business or encourage carbon leakage • Avoid placing too high costs on taxpayers and billpayers
Practicality/ease of implementation	• Low administrative effort required • Can involve consideration of ‘one-off’, as well as ongoing efforts • Political acceptability
Integrability with EU ETS	• Changes which would not affect future integrability of the UK ETS with the EU ETS

Source: Oxera.

[74] Element Energy and Vivid Economics (2021), ‘Investable Commercial Frameworks for Power BECCS’, June.

We note that there are likely to be trade-offs involved between some of these criteria. For instance, options that are better suited to reduce emissions in the long term may also come with a higher administrative effort. The remainder of this section discusses the criteria in more detail.

3.1 Long-term effectiveness in reducing overall emissions

Several factors affect the long-term effectiveness of a market design option in reducing overall emissions, which are discussed in turn.

Market design options should ensure that there are **ongoing incentives to reduce emissions** while also allowing for the development and deployment of NETs. On the one hand, the mechanism should ensure that NETs are sufficiently incentivised now given their increasing importance to meet net zero targets (set out in detail in section 2.1).[75] On the other hand, it is essential for businesses to continue to have incentives to reduce their own emissions. If GGRs were to substitute emission reductions at a large scale, this could be counterproductive if it disincentives businesses from making the necessary investments to reduce their own emissions.[76] As the academic literature[77] and policy papers stress,[78] using NETs should work alongside, and not disincentivise, efforts to rapidly and drastically abate emissions.

Another design principle is that the mechanism should reward **high-quality removals**, ensuring that standards in terms of MRV are met. In addition, the mechanism should take into account the differing impact of NETs—for instance, in terms of permanence. Allowing inexpensive and less permanent GGRs into the market at a large scale can have unintended consequences—for instance, reducing prices in the ETS—thereby giving the wrong price signals. This happened in New Zealand after forestry was allowed to enter the ETS market in 2008. Subsequent movement in the pricing of ETS led to unintended consequences in relation to forestation projects.[79]

Another risk that the mechanism should seek to address is that emissions could be shifted overseas—this is known as '**carbon leakage**'. Without a mechanism to address this, companies may attempt to avoid the cost of carbon that is placed on them by high environmental standards domestically by shifting their carbon-intensive production abroad. Likewise, consumers could replace UK-produced products with cheaper, more carbon-intensive imports. Elsewhere this has been addressed by mechanisms such as the EU's carbon border adjustment mechanism, which adjusts prices of imports to account for the cost of carbon. When other jurisdictions reach equivalent environmental standards, their products are no longer subject to the adjustments, meaning it also incentivises other countries to improve their environmental standards.[80] The UK is considering similar policy options to address carbon leakage.[81]

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[75] University of Oxford (2020), 'The Oxford Principles for Net Zero Aligned Carbon Offsetting', September.
[76] International Carbon Action Partnership (2021), 'Emissions Trading Systems and Net Zero: Trading Removals', May.
[77] For instance, International Carbon Action Partnership (2021), 'Emissions Trading Systems and Net Zero: Trading Removals', May.
[78] See, for instance, Department for Business, Energy and Industrial Strategy (2021), 'Net Zero Strategy: Build Back Greener', October, section 3vii.
[79] Reductions in pricing of ETS provided an incentive to change land use away from forestry. See Evison, D. (2016), 'The New Zealand forestry sector's experience in providing carbon sequestration services under the New Zealand Emissions Trading Scheme, 2008 to 2012', *Forest Policy and Economics*, **75**, October.
[80] See European Commission (2021), 'Carbon Border Adjustment Mechanism: Questions and Answers', May, https://ec.europa.eu/commission/presscorner/detail/en/qanda_21_3661 (last accessed 29 November 2021).
[81] HM Treasury (2021), 'Net Zero Review: Analysis exploring the key issues', October.

Additionally the mechanism should allow sufficient government control and **flexibility to make changes**. For instance, a fully integrated market between reductions and removals certificates, with no intervention, allows the price to be solely determined by the market and removes government control. This has potentially positive implications for cost-efficiency via efficient price formation and market entry signals, but may reduce the market's effectiveness in reducing carbon emissions if the government loses the ability to oversee and influence the trajectory of overall emission reductions. Having some degree of government control over NETs volumes and prices could also ensure that there is a balance in the use of emission removal and abatement technologies. It is important to note, however, that the flexibility to make changes (e.g. in allowing new NETs to enter the market) should not come at the expense of ensuring a stable environment for existing investments. This generally means that changes to the market should be introduced over time in a transparent manner, and on a forward-looking basis.

3.2 Efficiency of market(s)

The market design mechanism should ensure efficient functioning of markets. This means there should be enough buyers and sellers in the market to ensure sufficient liquidity, meaning that a unit of GGR can be bought and sold at a price reflecting its intrinsic value. This would promote competition and allow for an effective price formation mechanism. Efficient markets would also tend to lead to the lowest overall cost option being chosen—among the NETs that were allowed to participate in accordance with the first principle.

3.3 Fairness of cost allocation

The mechanism should ensure a fair cost allocation, split appropriately between emitters, taxpayers and energy billpayers. There is a general textbook principle that the polluter should pay for the problem it causes ('negative externality') and being exposed to the cost of emitting incentivises companies to take actions to reduce emissions.[82] At the same time, however, there is also a case for socialising the cost of supporting new technologies that will become necessary in the future. The government may also be concerned about industries becoming internationally uncompetitive if the costs they are faced with are too high.

Also, we note that it is important to consider the cost implications of all support schemes for NETs, not just market-based mechanisms in isolation. For instance, if direct government funding was available for NETs, the cost of providing this funding could still be allocated to polluters via a market-based mechanism or policy (e.g. a separate tax) in order to expose them to the right incentives to abate their emissions.

3.4 Practicality/ease of implementation

The preferred market design option should avoid overly complicated administrative processes. It should also be practical in that new buyers and sellers should be able to gain access to the market—e.g. if new NETs are developed over time. Practicality also entails that the operation for market participants should be relatively easy.

[82] Also referred to as Pigouvian taxes based on Pigou, A.C. (1932), *The Economics of Welfare*, fourth edition, Macmillan, London, chapter IX.

Ease of implementation requires political acceptability, which is also linked to fairness of cost allocation. Wide political acceptability helps ensure a more stable policy and investment environment for GGR projects.

3.5 Integrability with EU ETS

It is relevant to note that following the UK's exit from the EU, the country launched its own scheme, the UK ETS, in May 2021. This system is very similar to the EU scheme, covering the same industries and setting a cap that is 5% lower than it would have been under the EU ETS. The scheme is currently not linked to the EU ETS, but this may happen in the future. In particular, the EU has identified the following criteria for linking its ETS with other markets:[83]

- system compatibility (the systems have the same basic environmental integrity, and a tonne of CO_2 in one system is a tonne in the other system)
- the mandatory nature of the system, and
- the existence of an absolute cap on emissions.

We consider that the market design options identified as part of this report should make a future integration of the UK ETS and the EU ETS possible—although this will, of course, depend on developments in the EU as well.[84] In this context, it is important to note that the European Commission published its 'Fit for 55' proposals in 2021, setting out how it should reach its legally binding target to cut emissions to 55% below 1990 levels by 2030.[85] Related to this, the Commission will publish a proposal on carbon removal certification in 2022.[86] The ETS Directive[87] currently does not contain a legal basis for generating GGR units, although the 'Fit for 55' package provides a new opportunity to make amendments to the Directive.

[83] European Commission, 'International carbon market', https://ec.europa.eu/clima/eu-action/eu-emissions-trading-system-eu-ets/international-carbon-market_en (last accessed 15 October 2021).
[84] Also, there may well be scope for using GGRs beyond the ETS—for instance, to decarbonise sectors not currently covered by the ETS. In this case, integrability with the EU ETS would be less relevant.
[85] European Commission (2021), ''Fit for 55': delivering the EU's 2030 Climate Target on the way to climate neutrality', 14 July.
[86] European Commission (2021), 'State of the Union 2021 – Letter of intent', 15 September.
[87] European Commission (2003), 'DIRECTIVE 2003/87/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL', 13 October.

4 Market design options

There is a growing economics literature on negative emissions, with different design methods being put forward on how to include negative emissions within the ETS.[88] This section assesses four options for how this could be achieved. In order to arrive at these options, various design parameters need to be set—these are summarised upfront, before the options are described in more detail.

Supply of GGRs

In order for any such mechanism to work, rules need to be in place to guarantee that the accounting of negative emissions is done in a credible way, including in terms of MRV standards and taking into account differences in permanence. This is necessary to allow a unit of GGRs to be counted towards emission reduction targets (i.e. allowing for market participants to be confident that GGRs provide a one-for-one conversion option, relative to emission reductions, where feasible). Rules around the supply of GGRs in a negative emissions market are discussed in section 4.1 prior to setting out the full options, because such rules are necessary across all proposed options.

Demand for GGRs

The demand for GGRs is an important factor that can vary across options—either industries covered by the ETS, a broader set of buyers, or only the government could participate in the market. This is relevant because it determines the scale of demand for the market.

Level of integration with the ETS

Models in the literature range from options where NETs are simply included in the ETS (full integration), to options where there are separate markets for NETs. The level of integration is a key design feature, and one that must be considered in order to achieve a market outcome that produces the right portfolio of abatement and removal of emissions in an economy.

Role of the government

The level of government participation can also vary across options, with the government either simply setting up the rules of the market or having a more involved role that includes actively buying and selling. This is a relevant consideration affecting the administrative effort for the government, as well as the level of control it has over outcomes compared to letting the market determine outcomes (e.g. on pricing, the split between GGRs and EAs, etc).

Cost allocation

Depending on the set-up of the market, the costs of funding NETs might fall on different players, such as the government, industries or energy billpayers. It is important to consider this design feature alongside other funding mechanisms to determine whether the overall cost is divided fairly across the market participants. The more market participants are exposed to the costs of their

[88] For instance, Rickels, W., Proelß, A., Geden, O., Burhenne, J. and Fridahl, M. (2021), 'Integrating Carbon Dioxide Removal Into European Emissions Trading', *Frontiers in Climate*, June, **3**:690023; International Carbon Action Partnership (2021), 'Emissions Trading Systems and Net Zero: Trading Removals', May; Bednar, J., Obersteiner, M., Baklanov, A., Thomson, M., Wagner, F., Geden, O., Allen, M., Hall, J.W. (2021), 'Operationalizing the net-negative carbon economy', *Nature*, **596**, March, pp. 377–83; Coffman, D. and Lockley, A. (2017), 'Carbon dioxide removal and the futures market', *Environmental Research Letters*, January, **12**:015003.

emissions, the stronger the incentives that they face will be, to take actions to reduce emissions.

4.1 Accounting for differences across NETs in supplying effective units of GGRs

As a prerequisite, it is essential that MRV standards are introduced and followed to demonstrate that GGRs genuinely remove emissions. GGRs that do not meet the MRV standards cannot be allowed to participate in the market.

In addition, as described in section 2.2, there are differences across NETs in terms of how permanent the CO_2 removal is likely to be. After ensuring the MRV standards of a NET are met, the next step is to determine how these differences in permanence are captured and accounted for within a design framework.

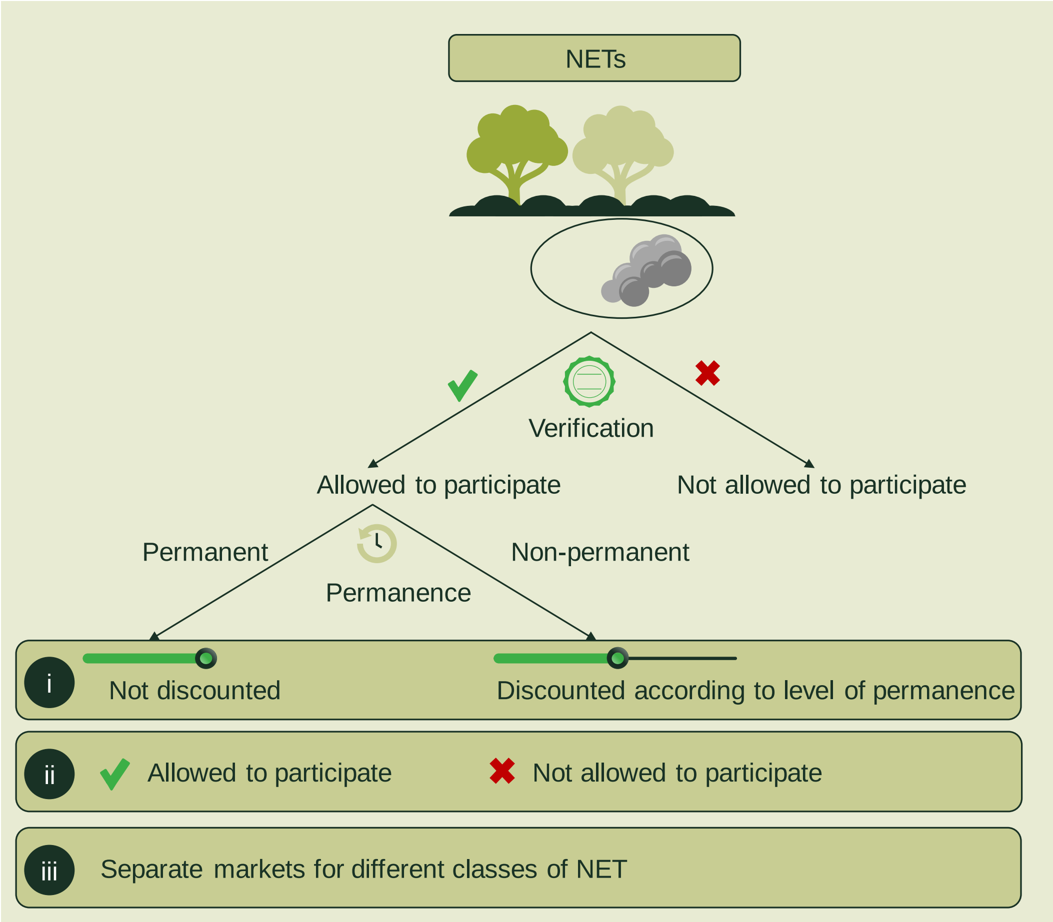
The difference in storage means that technologies also differ in their contribution to long-term climate goals,[89] and there are different ways of addressing this issue in accounting for the quantity and/or pricing of GGR units within the market. Relevant approaches to integrating different types of NET in the ETS market include the following.

1. **Discounting less permanent NETs**. For instance, while a tonne of CO_2 that is removed permanently could be awarded one unit of GGR, a tonne of CO_2 that is more prone to leakage or reversal would be worth less than one unit of GGR. We note that BEIS' paper on MRV for GGRs suggests that a NET that results in CO_2 leakage after 100 years could be awarded at most 39% of a full unit of GGR.[90]
2. **Threshold**. Alternatively, a permanence threshold could be introduced, such that only NETs with a minimum level of permanence can participate in the market.
3. **Separate markets**. A third option is to create separate markets for different classes of NETs. This would involve grouping NETs according to their permanence, and would result in different prices depending on how long CO_2 is removed for.

These options are represented in Figure 4.1.

[89] Department for Business, Energy and Industrial Strategy (2021), 'Monitoring, Reporting and Verification of Greenhouse Gas Removals – Task and Finish Group report', 19 October, p. 11.
[90] Ibid., p. 12.

Figure 4.1 Potential approaches to including different types of NETs in the ETS



Source: Oxera.

There are advantages and disadvantages to all three approaches to including NETs in the market for ETS.

- **Approach i: discounting less permanent NETs**. This is the most precise approach, as it quantifies the relative contribution of different NETs to climate targets and reflects these in the discount rate. At the same time, it increases the supply of GGR units in the market relative to the other options, which has efficiency benefits. However, it relies on a transparent and scientifically approved process for determining discount rates. If this—potentially complex—process is not accurate—or if the efficacy of different technologies in terms of permanence changes over time—then this option risks over-remunerating GGRs that are not actually very helpful in reducing atmospheric CO_2 in the long term. Similarly, it may create a risk of under-remuneration for technologies that turn out to be more effective than expected by the discounting process. A practical approach may be for the government to set default discounting values per technology group, which could then be reviewed periodically.
- **Approach ii: threshold**. This option has the advantage of being fairly simple, as it involves determining only whether a NET satisfies a minimum permanence threshold. However, there is a spectrum of permanence associated with NETs, while a threshold offers only binary options (to include or exclude certain NETs from the market). The use of a threshold is therefore a blunt instrument to distinguish between more and less

permanent NETs. In addition, it decreases the size of the market, which would reasonably be expected to affect the functioning of the market in terms of (in particular) efficiency of price formation and liquidity.

- **Approach iii: Separate market for different classes of NET.** Finally, this approach allows different types of NET to participate, but divides them into separate markets, which allows for different prices to be formed depending on permanence. In a way, this allows the price of less permanent GGRs to be discounted (relative to the volume being discounted in option 1). However, it requires different classes of NETs to be established—which is a potentially complex process. Such structural market separation may also inhibit market growth, if there are barriers or timing lags in approving and creating markets for new NETs over time. Moreover, creating separate markets decreases the size of each market, leading to less competition and liquidity—and thereby reduced efficiency of price formation and price entry signals—within each market. Most importantly, this option creates different types of GGR units and it may not be clear to market participants how these should be compared from a carbon removal perspective (for example, one GGR unit now does not necessarily mean that one tonne of GHGs is permanently removed from the atmosphere). This makes it impossible to directly treat units of GGRs as homogenous, and as substitutable for EAs within the ETS (unless a discounting process such as that in option 1 is established). We therefore consider approach 1 and/or 2 to be superior compared to approach 3.

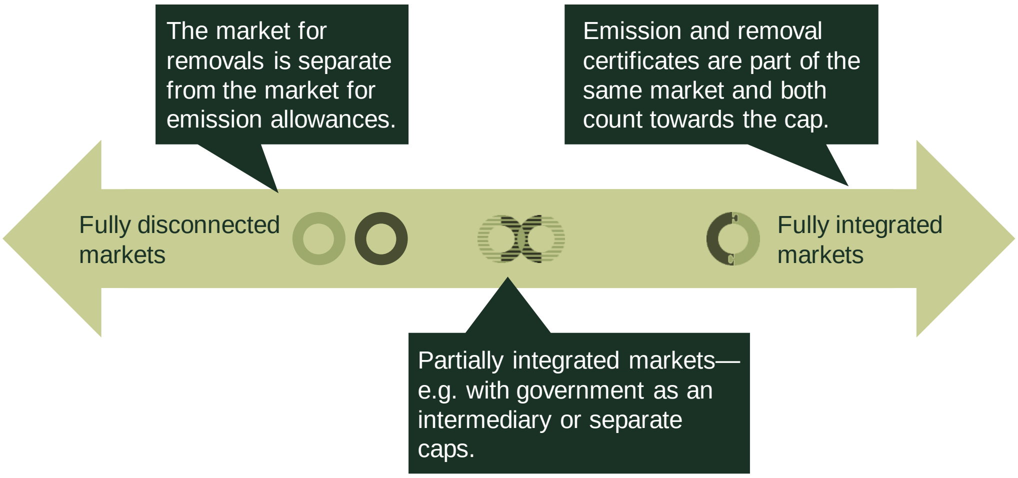
With any selected option, a periodic re-evaluation mechanism could be included, to allow the government to make changes to the proposed treatment of certain NETs if objectives change over time, or new information becomes available.

4.2 Economic representation of integration

Having established the comparability of different NETs, this allows for the creation of a unit of GGR, which is equivalent to a tonne of GHGs, similar to an EA. Such a unit of GGRs is necessary for the integration of GGRs in the ETS as discussed in the remainder of this section.

Different levels of integration between the market for NETs and the ETS are possible, ranging from fully disconnected to fully integrated markets, as demonstrated in Figure 4.2.

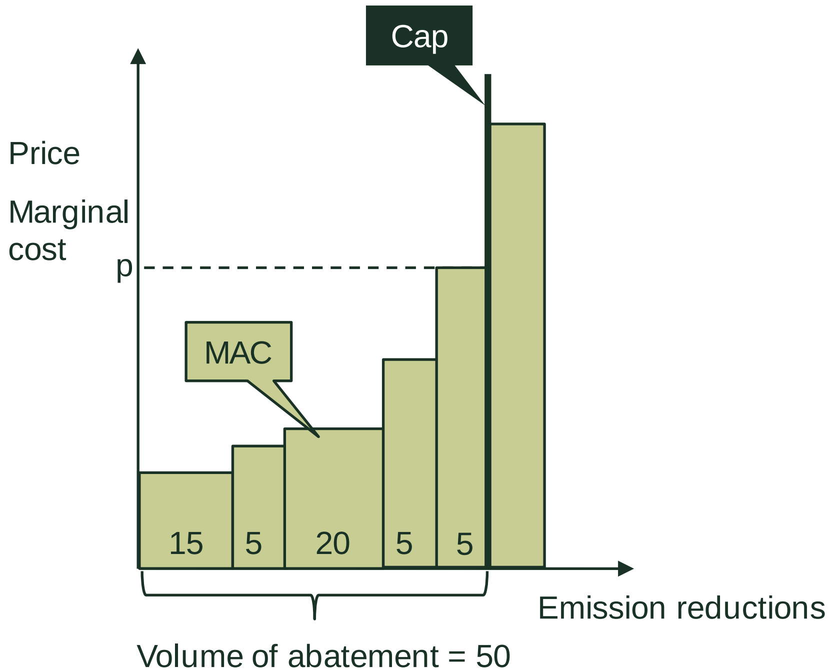
Figure 4.2 Range of market integration



Source: Oxera.

Before turning to the specific market design options, it is worth discussing the representation of an emissions market from an economics perspective. One way of representing this market is with an upward-sloping marginal abatement cost (MAC) curve, as in Figure 4.3 below.[91] The width of each box shows the quantity of emissions abated, and the height represents the marginal cost of abatement, which increases as more abatement is achieved. The clearing price is set by the marginal abatement unit that is required to reach the cap.

Figure 4.3 Marginal abatement cost curve



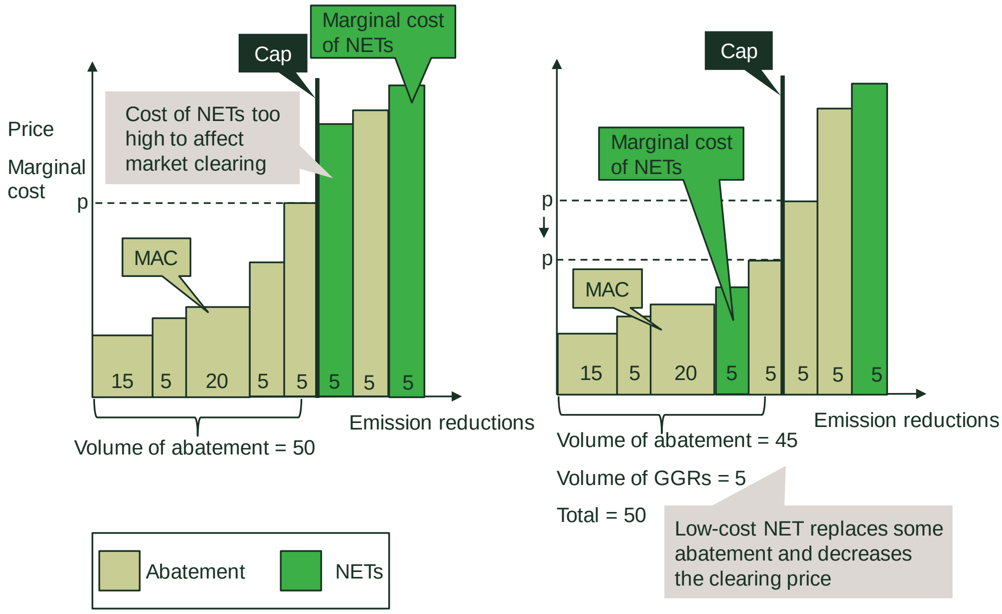
Source: Oxera.

The introduction of negative emissions can also be represented along the x-axis. To illustrate this, in the figure below, negative emissions are shown as dark green bars. Importantly, this assumes that GGRs are fully verified and

[91] Another representation uses demand and supply for emissions, see, for instance, Rickels, W., Proelß, A., Geden, O., Burhenne, J. and Fridahl, M. (2021), 'Integrating Carbon Dioxide Removal Into European Emissions Trading', *Frontiers in Climate*, June, **3**:690023.

sufficiently comparable to abatement such that one unit of GGRs counts towards the same volume of emission reductions. The use of NETs to meet the emissions cap of 50 will depend on the cost of NETs relative to abatement. In the left-hand chart of Figure 4.4 the marginal cost of NETs is higher than the marginal cost of abatement so NETs do not contribute to meeting the cap. In the right-hand chart the lowest marginal cost of NETs is lower than some of the abatement costs so the cap is met by 45 units of abatement and 5 units of NETs.

Figure 4.4 Introducing NETs into the ETS (illustrative example)



Source: Oxera.

This demonstrates that full integration without additional rules may not be feasible in the short run because the more permanent NETs are likely to be too costly at early stages of deployment, while policymakers may also want to avoid large-scale substitution of abatement with GGRs in order to retain incentives to abate. In the example above both result in net emission reductions of 50 in line with the cap. However, in the left-hand chart, gross emissions are lower than in the right-hand chart as 5 of the net emission reductions are fulfilled by GGRs. One option to address this could be to introduce a separate cap for NETs. This could be done in either of the following two ways:

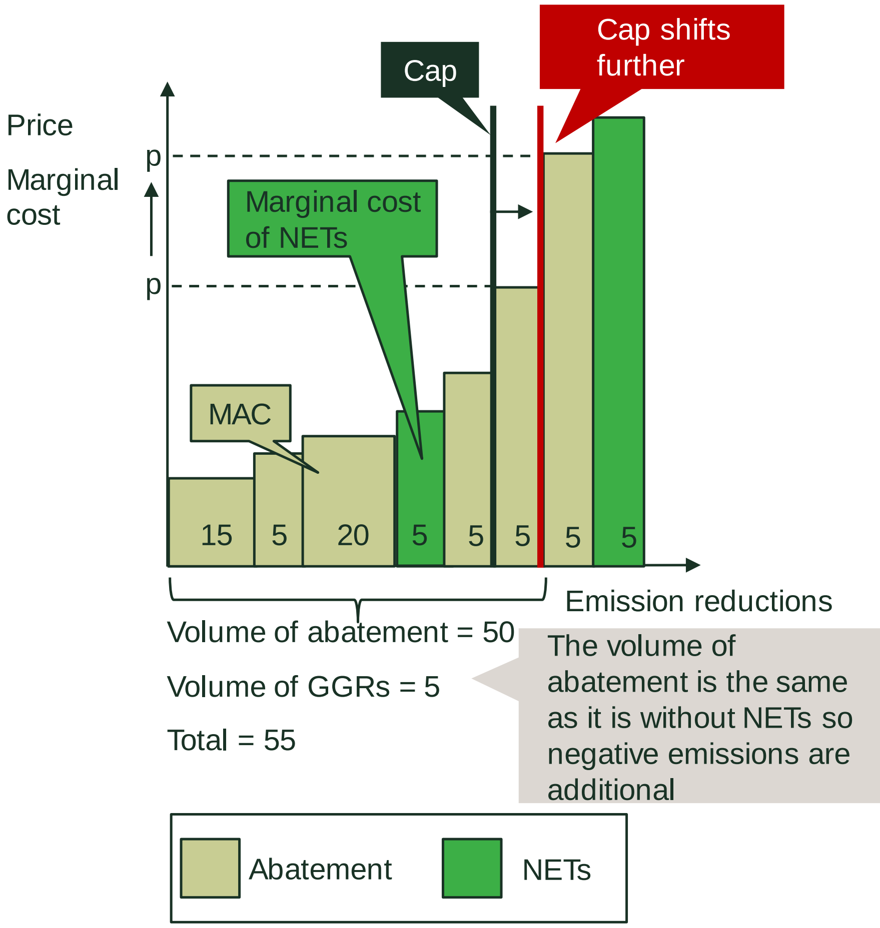
- specifying a proportion of the overall cap that needs to be fulfilled by NETs (in which case there would be some substitution of abatement by GGRs as a specified amount of GGRs would always be used);[92]
- tightening the overall emissions cap by an amount less than or equal to the level of GGRs to maintain incentives to reduce emissions.

An example of the latter with a more ambitious target is shown in Figure 4.5 below. A tighter cap on emissions would shift the line in this representation to the right as more abatement or negative emissions are needed (red line). This would ensure that the volume of abatement remains as high as before (in this

[92] A cap was also used to limit the expansion of biomass under the Renewables Obligations (ROs). See: https://www.gov.uk/government/publications/the-400-mw-cap-on-new-build-dedicated-biomass-projects-renewables-obligation (last accessed 7 January 2022).

example, at 50), with negative emissions as an additional factor (in this example, an additional volume of NETs of 5 is successful in the market). In both cases, the government would have some control over the mix of abatement and GGRs and could align this with its scenario modelling for what is required to reach net zero.

Figure 4.5 Low-cost NETs provide additional removals (illustrative example)



Source: Oxera.

It should be noted that, while some NETs may appear to be costly and not competitive (at the outset of the deployment lifecycle) in an integrated market, there are several scenarios under which this could change.

- In the future, the cost of engineering-based NETs may well decrease as technologies become more mature. At the same time, abatement is likely to become more expensive as harder-to-decarbonise areas need to reduce emissions. This will tend to lead to cost convergence and increased competitiveness of NETs (see section 2.2).
- NETs are likely to be subsidised until sufficient maturity levels are reached. The government has acknowledged the need for NETs and has already committed to funding.[93] This shows a parallel to the adoption of renewable generation technologies, such as solar and wind, for which costs (and

[93] Department for Business, Energy and Industrial Strategy (2021), 'Net Zero Strategy', 18 October, Executive Summary and section 3vii.

thereby subsidy levels) have reduced dramatically over time.[94] If NETs are sufficiently subsidised at the outset of their deployment lifecycle then they will tend to become competitive even in an integrated market.

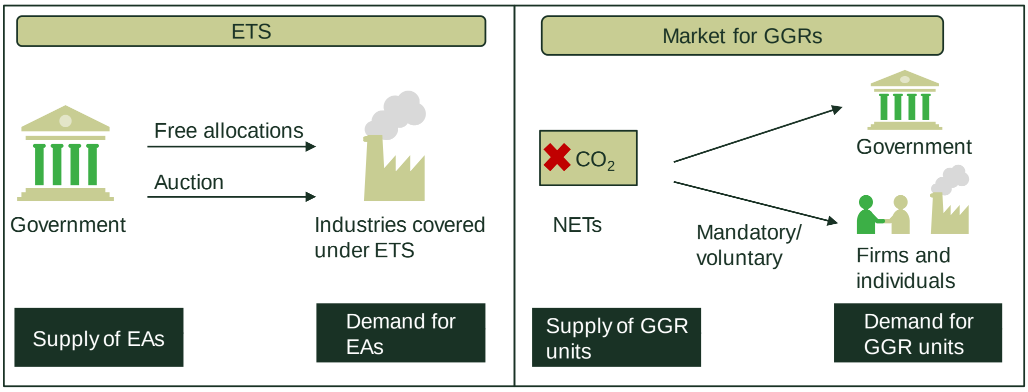
- Demand for NETs may well increase as companies need to achieve (either voluntary or mandated) net zero targets.

To illustrate these points, consider how they would affect the figures shown above. The first two points would decrease the cost of NETs—i.e. lower the height of the dark green bars in the figures above. This would shift NETs to the left and make them more competitive. The third point would increase demand—i.e. shift the vertical cap line to the right. Again, this would mean that more GGRs are demanded.

4.3 Market design options with varying degrees of integration

The basic workings of the ETS (market for EAs) and a separate market for GGRs are shown in Figure 4.6.

Figure 4.6 Separate markets for EAs and GGR units



Source: Oxera.

In this study, we focus on a separate NETs market that has a link back to the ETS or models that integrate both markets. However, the scope for a separate market could theoretically be broader, and involve other sectors that are decarbonising—voluntarily or because they are mandated to do so—by participating in the market. Article 6 of the Paris Agreement facilitates wider market participation as it enables more opportunities for trading genuine carbon reductions or removals.[95] For instance, the government could mandate emissions targets for other sectors that are not currently covered by the ETS, such as heating of buildings or road transport. These targets could then also be met using GGR units from this separate market.[96]

A separate market for NETs can help to deal with the current cost divergence between NETs and emission reductions, and would allow for a broader role of NETs beyond the ETS. While, in theory, there could even be a separate market for each NET, this would be problematic if it leaves the number of competitors within each market too small for effective price formation and for efficient price entry signals to be conveyed. It would also come with additional

[94] See, for instance, Oxera (2020), 'Making a difference: supporting investment in low-carbon electricity generation', 29 October, Figure 1.
[95] Although this is not the focus of this study, the link would therefore not necessarily need to be via the ETS, and GGRs could also be accepted more widely.
[96] In theory, individuals could also participate in the market. However, given the minimum volumes that are usually required, this would probably need to be via an aggregator.

administrative responsibilities, as new markets would need to be formed when new technologies become available. It therefore seems preferable to create a single market for NETs, which would then need to use discounting to take into account differences in permanence.[97,98]

The following options show how a link can be established between the left box (market for EAs) and right box (market for GGRs).[99] Options 1–3 therefore all allow for effective substitutability between EAs and GGR units, while achieving:

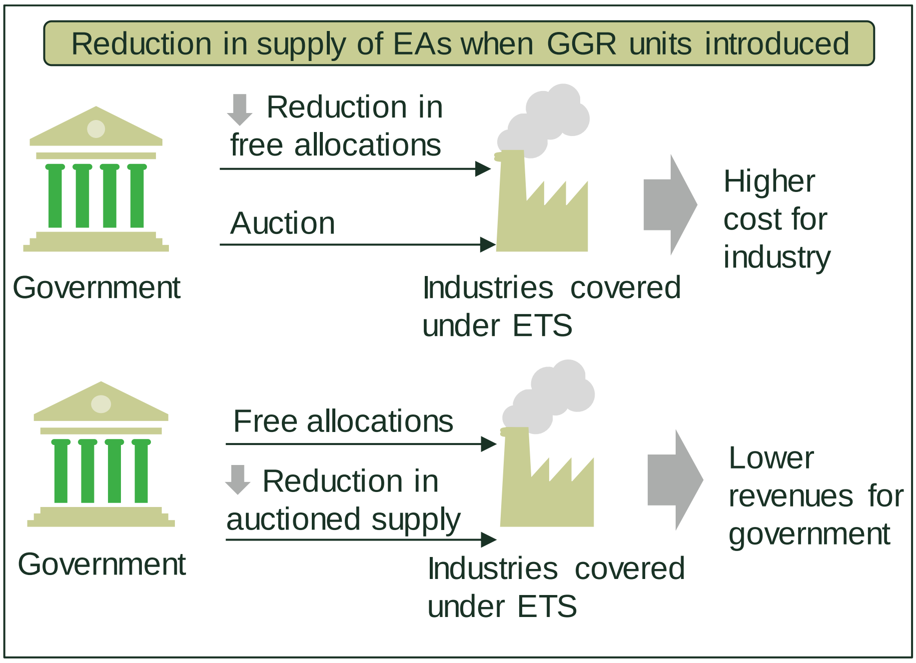
- an uptake of GGRs within the ETS market, to facilitate the growth of NETs;
- an overall reduction in the level of emissions.

The following three options could also be implemented sequentially (i.e. moving from separation to integration), with later options being introduced as the market matures.[100]

We note at the outset that for any of the options where we speak of reduced supply in EAs as GGR units are introduced, this could be effected in a number of ways, which would potentially affect the allocation of costs. One way of reducing EAs is by decreasing the number of free allocations; this would tend to increase costs for the industry that would then need to achieve a higher level of abatement or purchase EAs that it previously obtained for free. Another way of reducing EAs would be to decrease the number of EAs that are auctioned; this lowers the government's revenues from the ETS and directs the forgone revenues towards the funding of NETs, thereby reducing additional funding requirements. That is, if the government wanted to support GGRs up to a certain cost, then this option would be cost neutral for the government if it re-routes the same level of combined funding through the ETS and direct support. The two options are depicted in Figure 4.7.[101]

[97] Section 4.1 sets out how differences in permanence across NETs can be taken into account—for example, using discounting.
[98] Note that in a single market, subsidies for different technologies can be calibrated to be cost-reflective such that a variety of NETs is encouraged to enter the market.
[99] Importantly, it should be stressed that all options presented here rely on robust MRV processes to be in place, ensuring the credibility of removals, and on discounting of different types of NETs to make them comparable. This allows creating a unit of GGR that is equivalent to a tonne of CO2 and can be traded alongside EAs.
[100] Instead of implementing options 1-3 in sequence it is possible to move to later options 2 and 3 directly. However, more policy interventions would be required in line with the relative immaturity of the market.
[101] We note also that the higher costs for industry in the former option and the lower revenues for government in the latter option, are immediate distributional implications, but they can be affected by policy choices. For example, even in the case of higher costs being borne by industry in the former option, a subsidy could be given to mitigate this effect.

Figure 4.7 Two ways of reducing the supply of EAs in the ETS



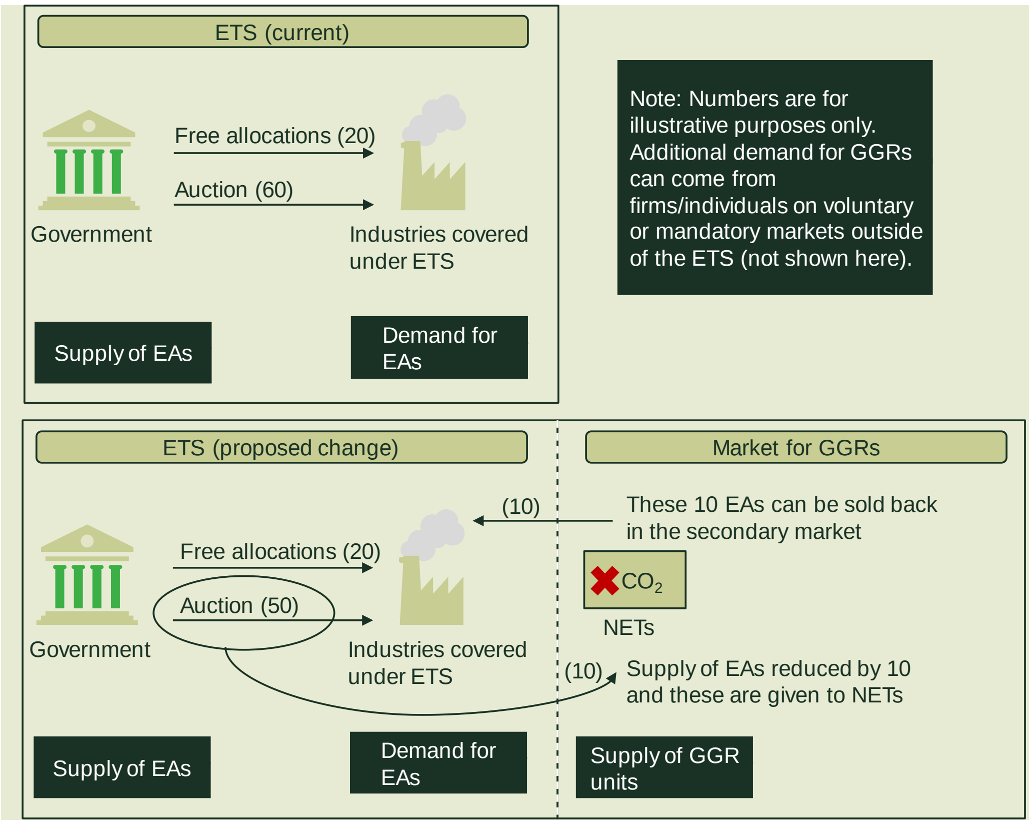
Note: When the supply of EAs is reduced, GGR units are instead introduced into the market so the figure does not take into account a price effect from reduced overall supply.

Source: Oxera.

We now set out the market design options, in turn.

4.3.1 Option 1: separate markets with government as a broker

Box 4.1 Summary of option 1: separate markets with government as a broker



Note: The above figure shows the supply of auctioned EAs being reduced but the government could also choose to reduce the number of free allowances (see Figure 4.7).

- Description: separate markets where the government reduces the supply of allowances in the ETS and gives these EAs to NET operators in return for an equivalent amount of GGR units (which the government could then use to offset its own emissions or sell e.g. in the voluntary market). The NET operators can sell the EAs in the secondary market. The overall number of EAs available to the industry therefore remains the same (in the illustrative example above it stays at 80). Demand for GGRs is therefore intermediated or brokered by the government, which would 'kick-start' the participation of NETs in the ETS. However, other buyers (in a voluntary or mandatory market) could also purchase GGRs units, especially as the market matures. In this market design option, the government can directly determine the amount of GGR units in circulation within the ETS.
- Efficiency of markets: government determines the number of GGR units that enter the ETS, which may not be as efficient as letting market forces determine the role of NETs.
- Who pays: In the first instance, the government pays for GGRs by using EAs it removed in the ETS; however, note that this role is of intermediation or brokerage (which does not lead to additional costs of purchasing GGRs per se) because the government is effectively substituting EAs by GGRs.I In the case of the number of auctioned EAs being reduced there would be foregone government revenues from the ETS, but this would reduce any separate NET funding requirements. And in the case of free EAs being removed, the cost to industry would increase, but the cost could be offset by subsidies. Therefore, in either case, the cost allocation could be calibrated through additional measures to distribute costs between taxpayers and industry in line with policy objectives. The total number of EAs available for purchase would remain the same (60) with 50 via auction by the government and 10 sold on the secondary market by the NET operators. Ceteris paribus, the carbon price level would remain the same so incentives on companies to reduce their emissions would remain the same.

  It should be noted, however, that additional funding for engineering-based NETs is likely to be required initially to make up the difference between the prevalent carbon price and the current cost of removal technologies; this difference is expected to diminish as the engineering-based removal technologies mature. This funding could take the form of a taxpayer subsidy, a CCfD or a levy on industries that participate in ETS.
- Practicality: active role for the government as an intermediary but no significant re-working of markets required. Note that both the UK and EU ETS already have mechanisms to alter the amount of allowances made available for auction (their respective market stability mechanisms) and these could be adapted.
- Integrability with EU ETS: no changes to the ETS apart from reducing the supply of EAs.

Note: Illustrative numbers.

Source: Oxera.

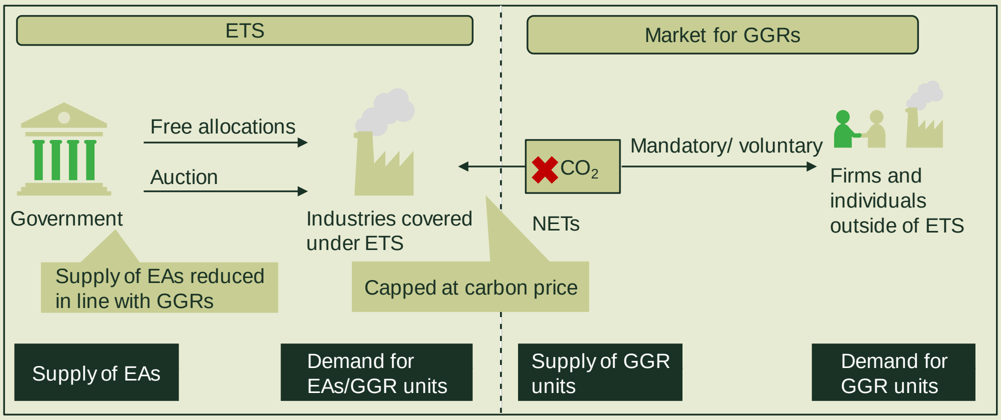
Under option 1 (as summarised in Box 4.1), a separate market for GGRs is created. The government acts as a broker connecting the two markets. In practice, this option would therefore result in a certain amount of EAs being fulfilled using GGRs—i.e. redirecting some of the ETS market towards NETs. Supply in the primary market is reduced—but as NETs operators can sell their EAs on the secondary market, the overall supply of EAs is actually unchanged. Overall, this might therefore not lead to an additional financial commitment for firms in so far as the level of EAs in the market—and therefore prices—could remain unchanged. The cost allocation depends on whether free or auctioned EAs are being removed from the supply in the primary market (see Figure 4.7). Either case relies on NETs being willing to operate at the prevailing carbon price, which is likely to require additional sources of funding for engineering-based GGRs. Under this option the government would be actively involved and could decide how many GGR units to purchase, thus directly controlling the GGR units in circulation and adjusting the supply of EAs accordingly. Additionally, no changes to the existing ETS are required—the government would only adjust the supply of EAs.

Notwithstanding the direct role for the government in brokering a substitution of EAs by GGRs (which implies an administrative responsibility) this option is practical at an early stage of market operations for including NETs in the ETS. Other options, discussed next, would need a number of additional policies and interventions to achieve uptake of NETs while reducing overall emissions.

4.3.2 Option 2: separate markets with price cap

Rather than acting as a broker, once the market matures, the government could create a separate market for GGRs where industries covered by the ETS buy GGR units directly.

Box 4.2 Summary of option 2: separate markets with price cap



- Description: GGR units are sold in a separate market but accepted as alternatives for EAs. The industries covered by the ETS can buy units of GGRs directly but additional demand might come from other firms or individuals outside of the ETS. In contrast to option 1, if the Government is not directly brokering the substitution of EAs by GGRs, then it will need to rely on additional policies to ensure the uptake of GGRs. First, to ensure price competitiveness up to the point that NETs mature (towards price parity with EAs), the government could cap the GGR unit prices at the prevailing carbon price to route some market demand from EAs to GGR units instead. Second, the government would still need to use other policy mechanisms to ensure that overall emissions are declining (e.g. by reducing the number of EAs in the market, rather than simply allowing for the purchase of more GGRs alongside the same number of EAs). In effect, therefore, while this option differs from option 1 by reducing the direct role of the government as an intermediary in the ETS market, if introduced today this mechanism would need additional policy interventions.

- Efficiency of markets: as in option 1, there are no effective price signals for NETs given the cap at the carbon price.

- Who pays: Firms directly buy GGR units instead of EAs. In the case of the number of auctioned EAs being reduced there would be foregone government revenues from the ETS, but this would reduce any separate NET funding requirements. And in the case of free EAs being removed, the cost to industry would increase, but the cost could be offset by subsidies. Therefore, in either case, the cost allocation could be calibrated through additional measures to distribute costs between taxpayers and industry in line with policy objectives.. To achieve a cap of the price of GGR units at the ETS price, the shortfall in cost recovery by NETs (to make up the difference between the prevalent carbon price and the current cost of engineering-based removal technologies) would then have to be compensated. This additional funding could take the form of a taxpayer subsidy, a CCfD or a levy on industries that participate in ETS with the latter option placing a higher cost and abatement incentive on industries. Nonetheless, integration of NETs with the ETS in the way described considerably reduces the additional funding requirement by enabling NET operators to earn revenue from the direct sale of GGRs.

- Practicality: less direct role for government as a participant in the ETS market compared to option 1 but active intervention still required to ensure the emissions cap is not in effect increased by the use of GGRs.

- Integrability with EU ETS: larger changes compared to option 1 as GGR units now need to be accepted in the ETS directly, rather than the government intermediating the substitution of EAs with GGR units.

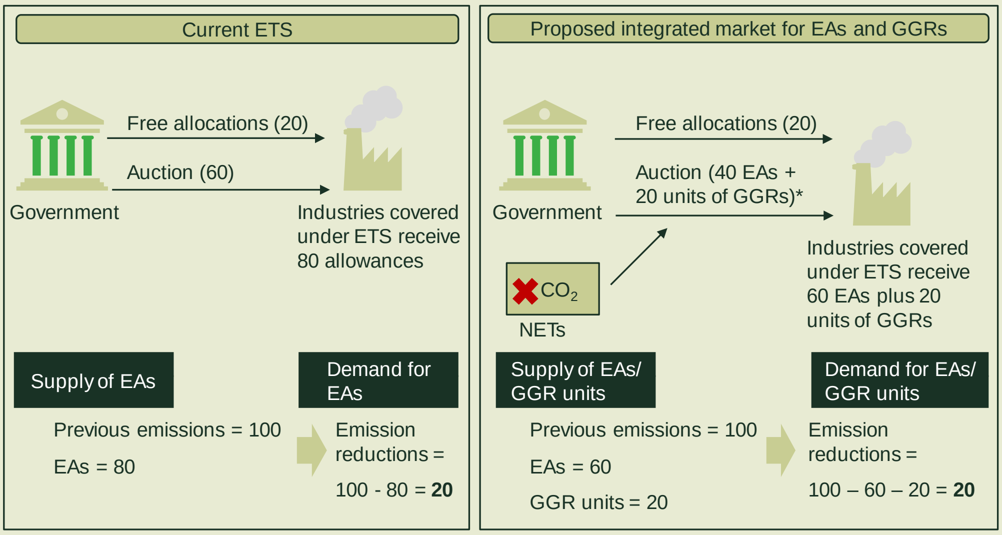
Source: Oxera.

As discussed under option 1, the NETs market could extend to other industries as well but the focus here in on the industries covered by the ETS as potential buyers. With this market design option, in order for GGRs to achieve initial uptake, prices could be capped at prevailing clearing prices in the ETS (with additional funding required at least initially to make up the difference between the carbon price cap and the current cost of engineering-based NETs). This design feature could be revisited over time and potentially changed once the NETs market becomes more mature. To avoid large-scale substitution of abatement with removals (i.e. firms buying GGR units in addition to the existing EAs, which would allow them to emit more than before, removing the additional amounts via GGRs), the government could reduce the supply of EAs in the ETS.

The advantage of this option is that it reduces the direct role for the government in the operation of the ETS market. However, leaving the trading of GGRs to free market operations would tend to lead to initially limited uptake of engineering-based NETs, and could also lead to a loss of control in reducing the overall level of emissions. These issues would then need to be corrected with other policies (i.e. the price cap, and control on supply of EAs). In contrast to option 1, option 2 therefore can be seen as a more viable market design option as and when the market for NETs matures—i.e. at the point in time where greater cost and price parity between GGRs and EAs has been achieved, and the supply of new EAs has become increasingly limited.

4.3.3 Option 3: integrated markets

Box 4.3 Summary of option 3: integrated markets



* This illustration assumes that the government is still auctioning EAs. At the point where EAs are no longer available, the distinction in the auction of EAs and GGR units will no longer be relevant. We note this because if implemented sequentially, option 3 may be in place towards 2050, when the number of EAs available for auction would be limited and firms would mainly purchase GGR units.

Note: The above figure shows the supply of auctioned EAs being reduced but the government could also choose to reduce the number of free allowances (see Figure 4.7).

- Description: fully integrated markets where units of GGRs are auctioned together with EAs. The government may determine the amount of GGRs that is auctioned and reduce the number of EAs accordingly. This ensures that emission reductions incentives are retained as GGRs are introduced into the market. As in the current ETS, the price for EAs (and now GGRs) is determined by the demand of covered industries. This clearing price is valid across EAs and GGRs. Other firms or individuals not covered by the ETS may still purchase GGRs on a voluntary/mandatory basis.

- Efficiency of markets: price determined by demand curve for EAs/GGRs. Auctioning them together allows for greater liquidity.

- Who pays: as before, the cost impact of industry vs. government depends on whether the supply of free or auctioned EAs is reduced. The price is set by the demand for EAs/GGR units. This means that NETs only submit their volume to the auctioneer, with prices being determined by the market. This option is viable once greater convergence between costs for GGRs and prices in the ETS has been reached.

- Practicality: less active role for government compared to option 1.

- Integrability with EU ETS: larger changes compared to options 1 and 2 as units of GGRs are now auctioned within the ETS.

Note: Illustrative numbers.

Source: Oxera.

Effectively, option 3 represents how the integration of NETs in ETS can be operationalised when the market has become mature. As NETs mature and the number of EAs in circulation is reduced, greater convergence between the two markets is achieved and the price cap in option 2 could be lifted. At this point, the markets could be integrated further by selling units of GGRs and EAs together.

Again, under this option, some demand from the ETS is re-routed to GGRs while the number of EAs is reduced to maintain high incentives for industries to reduce their emissions. The advantage compared to the previous options is that units of GGRs are directly auctioned within the ETS, thereby leading to a more liquid market compared to a situation in which the markets are separated.

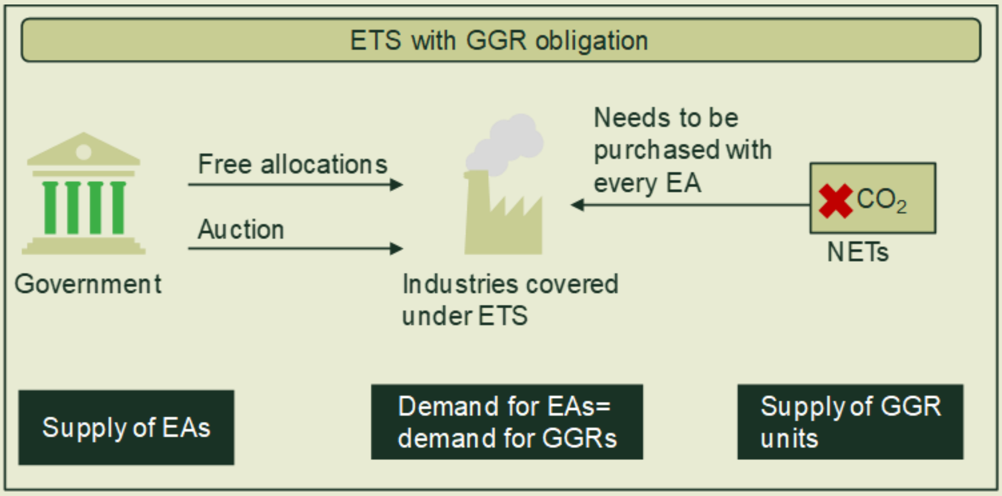
4.4 Carbon removal obligation

In options 1–3, the government is actively involved by directly or indirectly inducing demand for GGRs and adjusting the supply of EAs to ensure emissions are reduced. An alternative more market-based model requires the polluter to pay for the removal of its emissions directly.[102] The motivation for this is as follows: an EA currently allows industries to emit one tonne of carbon—i.e. it is a licence to pollute. As we reach net zero, these emissions need to be taken out of the atmosphere again. The idea of the market design option considered here is to create a carbon removal obligation. That is, companies are required not only to pay for their emissions (by purchasing EAs) but also ensure their emissions are removed in the future (by obtaining future carbon removals). Another motivation for this model is the intertemporal challenge arising from achieving net zero: emissions that need to be abated are being released into the atmosphere because of decisions that were made in the past and today. However, as abatement costs are set to increase significantly in the future, this introduces an intergenerational conflict whereby future generations pay for the removals that are necessary because of past decisions.

[102] Bednar, J., Obersteiner, M., Baklanov, A., Thomson, M., Wagner, F., Geden, O., Allen, M., Hall, J.W. (2021), 'Operationalizing the net-negative carbon economy'. *Nature,* March, **596**, pp. 377–83.

4.4.1 Option 4: carbon removal obligation

Box 4.4 Option 4: carbon removal obligation



- Description: with every EA bought in the ETS, there is an obligation for the future removal of the associated emissions. This means firms buying EAs also need to obtain an equivalent amount of GGRs (or as a transitional measure, an amount of GGRs less than the number of EAs). That is, an increase in demand for EAs would automatically increase the demand for GGRs, while additional demand might also come from other firms or individuals outside of the ETS.
- Efficiency of markets: could lead to differentiated pricing of EAs in the secondary market, based on whether the EA carries a responsibility to remove emissions or not. Apart from this, the efficiency depends on whether the GGR market is sufficiently competitive.
- Who pays: polluter pays and is required to purchase GGRs (even if prices are high).
- Practicality: the government needs to set up the rules but otherwise does not play an active role. To avoid firms being unable to fund unavoidable emissions or relocating to avoid these rules, additional measures may need to be in place.
- Integrability with EU ETS: the obligation could be imposed nationally even if the UK was participating in the EU ETS. This would mean that a UK and an EU EA would be the same (i.e. an emission allowance for a tonne of carbon dioxide equivalent) but UK firms would face an additional cost to remove emissions in the form of a mandatory GGR purchase.

Source: Oxera.

Under this option, polluters who purchase EAs (i.e. allowances to emit now), have an obligation to pay for the removal of these emissions (i.e. to buy a GGR). The authors call this a ‘carbon removal obligation’. This model would link removals with EAs in the ETS, as complements.[103] That is, an increase in demand for EAs would automatically increase the demand for GGRs, potentially with a time lag. This mechanism would address the intertemporal challenge described above, as emitters are always responsible for removing the GHGs they have put into the atmosphere. Rather than paying for current emissions and leaving the additional stock of GHGs to be removed (and paid for) by future generations, polluters would need to take on the responsibility of removing their own emissions. This implies that an EA no longer represents a

[103] In the models above EAs and units of GGRs are substitutes. However, GGRs are still additional to existing emission reductions because the supply of EAs is reduced as GGRs are introduced.

permanent right to pollute. Instead, industries are responsible for the whole lifecycle of their emissions up to the point of their removal. Similar approaches have been taken in other sectors. For instance, in the EU manufacturers of electrical and electronic equipment bear a degree of responsibility in recycling the products they sold in the future.[104]

Under this option, emissions removals would be financed by polluters—although of course additional public funding may be made available to reduce the cost. Polluters would face sharper marginal incentives to decarbonise. This is because their choice changes from:

- reducing emissions now vs paying for an EA;
- to reducing emissions now vs paying for an EA **and** paying for a GGR.

They are therefore more likely to choose reducing their emissions now, rather than paying for EAs as well as future removals.

There are several ways to moderate the financial impact of this option on polluters and phase in the carbon removal obligation over time.

- The obligation could be made more stringent over time. For instance, rather than having to purchase one unit of GGRs with one unit of EAs, the obligation might initially just be to purchase some proportion (e.g. half a unit) of GGRs with every unit of EAs.[105] Over time, this could converge to a one-to-one relationship.
- The timing could converge over time. Initially, the obligation could be to buy a GGR at some defined future period. This should make the GGR less expensive as costs are expected to fall over time. As the market matures, the carbon removal could be brought forward so that by 2050 any EA would need to come with an immediate removal of the associated emission.

This means that over time, the rules for polluters could become progressively more stringent. In any case, we note that by 2050, the UK cannot produce new emissions without removing them—which would have the same effect as option 4.

A carbon removal obligation is therefore a necessary instrument in the long term that could work as a market-based alternative to the options presented so far. However, it is important to note that as industries are directly exposed to the full cost of removals, additional policy measures are likely to be required to avoid relocation of industries to other countries with less stringent rules. Additionally, there need to be sufficient NET operators to allow for enough GGR units to come to market and for a competitive market to develop. For instance, if the roll-out of NETs is delayed then this would have more wide-ranging consequences compared to the other options.

4.5 Summary of evaluation of options

The market design options presented in this section all rely on robust MRV processes and a discounting procedure in order to create units of GGRs that are equivalent to a tonne of emission reduction. The options work by

[104] See, for instance, European Commission (2007), ‘The Producer Responsibility Principle of the WEEE Directive’, https://ec.europa.eu/environment/topics/waste-and-recycling/waste-electrical-and-electronic-equipment-weee_en (last accessed 14 December 2021).
[105] In theory, this could lead to differentiated pricing of EAs within the secondary markets, if future EAs are traded with an obligation to purchase (some proportion of) a unit of GGR. This could be avoided if the trading of EAs is undertaken after the responsibility to purchase (some proportion of) a unit of GGR has been exercised.

(i) inducing an uptake of GGRs and (ii) ensuring a reduction in emissions. In options 1–3, this is achieved by government intervention to re-route some demand for EAs towards GGRs and reducing the supply of EAs to ensure that removals are additional to the emission reductions that are already being achieved. In option 4, this is done by creating an obligation for polluters to remove their emissions at some stage, which automatically creates both demand for GGRs and ensures a reduction in emissions.

Table 4.1 summarises the evaluation of the different options.

Table 4.1 Evaluation of design options

Criteria	Option 1: separate markets with government as broker	Option 2: separate markets with price cap	Option 3: integrated markets	Option 4: carbon removal obligation
Long-term effectiveness in reducing overall emissions	Government can directly control the mix of removals and EAs and ensures that EAs in circulation decrease	Government can indirectly control the mix of removals and EAs, and ensure that EAs in circulation decrease	Number of EAs decreases as more GGRs are introduced to ensure reduction in emissions	Automatically ensures that any emissions (covered by the scheme) will be removed in the future. Carbon leakage would need to be avoided through additional mechanisms
Efficiency of market(s)	Government determines the number of GGR units that enter the market, which may not be as efficient as letting market forces determine the role of NETs	As in option 1 there are no effective price signals for NETs given the cap at the carbon price	Price determined by demand curve for EAs/GGRs. Combined market becomes more liquid	Requires competitive GGR market with sufficient supply
Fairness of cost allocation	In the case of the number of auctioned EAs being reduced there would be foregone government revenues from the ETS, but this would reduce any separate NET funding requirements. And in the case of free EAs being removed, the cost to industry would increase, but the cost could be offset by subsidies. Therefore, in either case, the cost allocation could be calibrated through additional measures to distribute costs between taxpayers and industry in line with policy objectives.. Additional funding to subsidise NETs while the market is immature may come from taxpayers or levies on industry			Places cost on polluter, thereby creating strong incentives to reduce emissions
Practicality/ease of implementation	Active role for the government as an intermediary but no significant re-working of markets required (supply can be altered via market stability reserve)	Less direct role for government compared to option 1	Less direct role for government compared to option 1	No active role for government. Additional measures may need to be in place to avoid carbon leakage
Integrability with EU ETS	No changes to the ETS apart from reducing the supply of EAs	Larger changes compared to option 1 as GGR units now need to be accepted in the ETS directly	Larger changes as GGR units are now auctioned within the ETS	Could be imposed nationally even if the UK was participating in the EU ETS. UK emitters would face an additional obligation

Source: Oxera.

5 Conclusion

This report sets out several market design mechanisms through which GGRs could be integrated within the ETS. We first discuss the need for GGRs in achieving net zero, which has already been highlighted by BEIS,[106] the CCC[107] and the NIC[108]. We note that different funding routes and incentives are possible to facilitate the deployment of GGRs including government funding, CCfDs and access to carbon markets, which can help spread the cost of removals across different market participants. While voluntary and potential future mandatory markets are all feasible, the focus of this study has been on the inclusion of GGR units within the ETS market.

The analysis in this report has shown that there are a number of feasible market design options that integrate GGRs into the ETS.

Options 1–3 presented in this report show how the diversion of some of the demand in the existing ETS market towards GGRs can be achieved. To ensure a continuous incentive for emission reductions is maintained, this involves reducing the number of available EAs in the ETS in line with the units of GGRs introduced. The options could be introduced sequentially, moving from separate markets with a direct intermediation role played by the government towards integrated markets for EAs and GGRs as NETs mature. Specifically, option 1 grants the government most control and could be implemented initially. As NETs mature and the number of allowances in the ETS reduces, raising carbon prices, the government could step back and take a more indirect role (option 2). Finally, with price parity being established, the ETS could be made more liquid by fully integrating GGRs into the market (option 3).

Alternatively, the carbon removal obligation presented in option 4 directly ensures sufficient uptake of GGRs. Under this option, any demand for allowances in the ETS automatically leads to additional demand for GGRs. This also provides a sharper incentive for polluters to reduce their emission as they are faced with the direct cost of GGRs. A carbon removal obligation is therefore a more direct market-based approach of linking GGRs to the ETS. However, it requires sufficient availability of GGRs and a competitive market, as well as additional policy measures to address the cost implications for affected industries and mitigate the risks of carbon leakage to other countries with less stringent rules. The government needs to balance these considerations of degree of control, administrative requirements and political acceptability including the impact on industry when choosing between options 1–3 and option 4

There are two key and immediate practical steps for the government to take in order to implement any market design option for including NETs in the UK ETS.

- **Establishing an MRV and discounting process**—the government needs to put robust and credible MRV processes in place that ensure that the GGRs are genuine removals. GGRs need to be verifiable, and meet criteria of additionality and net neutrality. Only removals that fulfil the MRV criteria can be allowed to participate in the GGRs market or ETS. In addition, GGRs that vary in terms of permanence of storage need to be made comparable so that they can participate in the same market. This could include the use

[106] Department for Business, Energy and Industrial Strategy (2021), 'Net Zero Strategy: Build Back Greener', October.
[107] Committee on Climate Change (2020), 'The Sixth Carbon Budget Greenhouse gas removals', December.
[108] National Infrastructure Commission (2021), 'Engineered greenhouse gas removals', July.

of thresholds such that only GGRs with a minimum level of permanence are allowed to access the market, and/or the use of discounting to make different types of GGRs comparable. This allows the creation of a GGR unit, which can be traded in the ETS.

- **Deciding how to ensure uptake of GGRs in the ETS**—once GGR units have been created, these can be introduced into the ETS. However, if they are more expensive than existing allowances for emissions—as is currently the case with engineering-based GGRs—then additional measures are necessary to ensure the uptake of GGRs, which helps to bring down the cost to market participants. There are two broad ways in which the government can induce demand for GGRs in the ETS: either by creating additional funding schemes to ensure the competitiveness of GGRs in this market, or by mandating the use of GGRs. The government needs to decide whether to follow the first approach (corresponding to options 1–3), which would initially be more straightforward to implement, or the second approach (corresponding to option 4), which puts in place stronger incentives for the sectors covered by the ETS to decarbonise.

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