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Analytical annex to Integrating Greenhouse Gas Removals in the UK Emissions Trading Scheme

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Contents

Purpose of this document

This Annex is intended to provide an overview of the analysis underpinning the consultation on Integrating Greenhouse Gas Removals in the UK Emissions Trading Scheme (UK ETS). It is not intended to reflect the full evidence base on which decisions will be taken, nor all evidence on which proposals were developed, and we seek further evidence as part of this consultation.

This Annex aims to inform consultation responses by providing evidence of three broad types. First, it presents an economic rationale for integrating GGRs into the UK ETS. Second, it presents a preliminary quantitative analysis of different options for adjusting the cap, and combines this with a qualitative economic analysis of the options. Third, it outlines some qualitative analysis including economic considerations on the remaining sections of the consultation: permanence, pathways and allowances. Finally, it summarises future analysis to support the government response to the consultation.

UK ETS Overview

The UK ETS works on the principle of cap-and-trade. A cap is set on the total quantity of emissions permitted in the system, which is reduced over time. Allowances within the cap are distributed to participants primarily via auctioning, with some given out through free allocation. Each allowance represents a permit to emit one tonne of CO2 equivalent (tCO2e). The system then provides flexibility over how and when participants within scope reduce their emissions to meet the annual cap, through the trading of allowances on secondary markets.

The allowance prices that result from auctions and trading between market participants create the incentive to reduce emissions. Participants whose marginal abatement costs are lower than the prevailing market carbon price can reduce their emissions and thereby reduce the number of allowances they need to purchase, or they can sell their allowances. Participants whose marginal abatement costs are higher than the market price can purchase allowances at a lower cost than reducing their emissions. In theory, trading will occur until participants' marginal cost of abatement is equal to the market price. This ability to trade ensures that emissions are reduced where it is most cost-effective to do so, maximising the economic efficiency of emissions reduction.

The cap is set in line with the UK's net zero strategy and its carbon budgets, with the aim of helping achieve net zero across all of the nations of the UK.[1] Each sector in the economy has a net-zero-consistent emissions trajectory, and when added up over all sectors these give the total permitted emissions in each time period. UK ETS participants are spread over several sectors (including power, industry and some transport), with the UK ETS cap consistent with their share of expected future emissions under the net zero strategy. If UK ETS participants' emissions were for any reason to be higher than the current net zero-consistent cap, other parts of the economy would have to decarbonise more than is planned in order for the UK to continue to meet its carbon budgets.[2]

The UK ETS currently covers around 25% of UK territorial emissions. It includes the power sector, energy-intensive industry, and emissions from domestic flights, flights from the UK to the European Economic Area and flights between the UK and both Gibraltar and Switzerland. The Authority is developing proposals to expand the scope of the UK ETS to include energy from waste and maritime emissions.[3] In its Long-term pathway for the UK ETS, the Authority recently committed to both legislating to continue the UK ETS until at least 2050, and to explore expanding the scheme to more sectors of the economy, including high emitting sectors.[4]

[1] See the Authority Response (July 2023) and Impact Assessment (July 2023) to its Developing the UK Emissions Trading Scheme consultation (June 2022) for further details.
[2] See Carbon Budget Delivery Plan (March 2023).
[3] See Authority Response to Developing the UK ETS (July 2023)
[4] See The long-term pathway for the UK ETS (December 2023).

Economic rationale

Greenhouse gas removals (GGRs) are technologies or processes which remove greenhouse gases from the air.[5] Further explanation and examples of GGRs are given in the consultation. UK GGRs are projected to play a key role in the way the all the nations in the UK reach and then sustain net zero.[6] There is a clear economic rationale for integrating UK-based GGRs into the UK ETS, as set out below.

Pricing a positive externality and creating demand for GGRs

GGRs generate a positive externality, the removal of carbon dioxide from the atmosphere, with a resulting social benefit in the form of reduction in damages from climate change.[7] This is the exact mirror image of the classic negative externality from activities that release carbon into the atmosphere, such as burning fossil fuels. The rationale for intervention is therefore the same.

The positive externality from removing carbon is currently under-priced, leading to a market failure in the provision of GGRs due to demand below the socially optimal level. In the case of many engineered GGRs, such as Direct Air Carbon Capture and Storage (DACCS), this carbon externality is the only output of value, so there would be no reason to build and operate these technologies if that output were unpriced. The under-pricing of carbon removals and associated limited demand is one reason why there is currently no market in the UK, a case of market failure from a missing market. Other engineered GGRs, such as power or hydrogen Bioenergy Carbon Capture and Storage (BECCS), have co-products such as electricity or hydrogen. However, these co-products are unlikely to have sufficiently high value to justify installing and running the GGR components of the production process. There are currently no power or hydrogen BECCS plants in the UK. Afforestation, the planting of new woodland which captures carbon, has other sources of value. Some have market value, such as timber, and some do not yet, such as biodiversity. Despite some demand for woodland carbon from voluntary markets explained below, its carbon is likely significantly underpriced.

There is some demand for GGRs from voluntary carbon markets. Globally, there is small but growing demand for novel engineered GGR technologies.[8] The Woodland Carbon Code is a high-quality, government-backed market that harnesses voluntary demand for woodland carbon removals. However, the Woodland Carbon Code carbon price is likely significantly below the socially optimal level.[9] The CCC and others consider the role of voluntary carbon

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[5] These processes are also commonly referred to as Carbon Dioxide Removal (CDR). Carbon removal or negative emissions are also used.

[6] The government's Carbon Budget Delivery Plan has an ambition to deploy at least 5MtCO2/yr of engineered removals by 2030, potentially rising to 23MtCO2/yr by 2035, and between 75 and 81MtCO2 by 2050 to balance the UK's residual emissions (Carbon Budget Delivery Plan, March 2023). The CCC's Balanced Net Zero Scenario features 5 MtCO2 per year of engineered GGRs by 2030, 23 Mt by 2035 and 58 Mt by 2050 (Sixth Carbon Budget Advice, December 2020).

[7] An externality is a consequence of an economic activity which affects other parties without this being reflected in market prices. A positive externality is a consequence with a beneficial impact on other parties, such as the pollination of surrounding crops by bees kept for honey.

[8] For example, Frontier is a recent advance market commitment to purchase $1bn+ of GGRs, by corporate buyers including Alphabet, Shopify, Meta, and McKinsey.

[9] There are two ways we can explore whether a particular carbon price is at the socially optimal level. First, we can look at the price directly. The Woodland Carbon Code currently pays around £25/tCO_2e for woodland, considerably below both the current UK ETS price and the UK appraisal carbon value, which the UK government

markets in delivering net zero to be 'modest but useful', since voluntary markets may not deliver the significant quantities of GGRs proposed in UK and devolved government plans.[10]

The overall conclusion for GGRs is that they are currently under-priced and this is contributing to market provision significantly below the socially optimal level. The fundamental problem is lack of demand at the prices and quantities necessary for markets to help deliver the socially optimal quantity of GGRs.[11] This is a market failure.

The rationale for UK ETS integration is to address this market failure. Including GGRs in the UK ETS would involve granting a GGR operator one allowance for each tonne of carbon they permanently remove from the atmosphere.[12] This allowance could then be sold at the prevailing price in the UK ETS and used for compliance within the scheme.[13] The positive externality of carbon removal would therefore be priced at the carbon price in the UK ETS market. This would generate demand for GGRs, on the scale of a significant compliance market.[14] The UK ETS price is currently unlikely to be equal to the marginal benefit to the UK of removing carbon from the atmosphere, in part because the UK ETS only covers around 25% of UK emissions. However, if in the future coverage increased and the UK ETS price increases, and if other GGR supply market failures have been addressed by other policy interventions (see below), then integration could support greater GGR deployment and get closer to full market provision of the socially optimal quantity of GGRs.

UK ETS integration alone will not be sufficient to deliver GGRs at the pace and scale called for in the net zero strategies laid out by the UK and devolved governments. There are multiple other market failures and barriers, both on the supply and demand side, limiting GGR deployment.[15] These include uncertainties (such as access to transmission and storage infrastructure), access to finance, and scale and learning effects. In the immediate term, government is addressing many of these market failures with other policies.

R&D support for GGRs addresses the well-known market failures in innovation in the production of new technologies. By supporting early deployment of new technologies, this

uses in place of the social cost of carbon (see BEIS Carbon values literature review (2021) for a discussion, and BEIS Valuation of greenhouse gas emissions (2021) for a description of the methodology). Second, we can see if the price is helping to deliver a given government target, and assume that the target represents the social optimum. Woodland creation targets are not currently on track to be met, as explained in the Woodland section below.

[10] The CCC describe role of voluntary carbon markets in delivering net zero in the UK as 'modest but useful', see Voluntary Carbon Markets and Offsetting (2022).

[11] We assume the socially optimal quantity of GGRs is the quantity needed to deliver our overall climate targets.

[12] By GGR operator we mean the owner of the relevant part of an engineered GGR project (no decision has been made on the exact point in the value chain where the allowance is to be awarded), or the owner of the woodland.

[13] We assume for simplicity in this section that there is no price premium for allowances from GGRs. As discussed below in the Allowances section, depending on policy design and private demand, there could be a price premium. In that case the economic rationale would be unchanged and the economic efficiency arguments would still hold.
There is also the possibility that the GGR operator could also be a UK ETS compliance entity. In which case they would obtain an allowance from their GGR and use this for compliance purposes. This would then lead to both lower supply and demand for allowances in the market, with no expected impact on prices, compared to the case where the allowance from GGRs was released into the market.

[14] Compliance markets are many orders of magnitude larger than voluntary carbon markets, globally. BloombergNEF estimate for 2021 that compliance markets were worth around $850 billion, compared to voluntary markets worth $1-2 billion. This compares to an annual average market value of the UK ETS cap of around £10 billion (see footnote 17).

[15] See CO2RE Policy Brief: Deployment support for geological Greenhouse Gas Removals (GGR) in the UK and references therein for a summary of market failures and options for correcting them in the provision of GGRs.

policy results in learning-by-doing cost reductions, which bring down the cost to society of subsequent further deployment.

The government is also developing a GGR Business Model and a Power BECCS Business Model to provide immediate revenue support to developers via a Negative Emissions Contract for Difference. This will provide a subsidy to developers, guaranteeing revenue for each unit of negative emissions sold. This addresses market failures stemming from access to finance (by providing revenue certainty), scale and learning effects (by driving early deployment of novel technologies), as well as lack of demand at prices sufficient to fund early investment in GGRs (by toping up payments from voluntary markets). Transport and storage access will also be awarded through the Government's procurement process.

Reducing policy risk and lowering the cost of capital

Policy uncertainty impacts investment in general, and this could apply to GGRs as well. If potential GGR investors did not know what kinds of policy environments will exist over the long-run duration of their investment, they would not know what kinds of returns they could be expected to make. Uncertainty of this kind would drive up the cost of capital, weakening the business case for investing in GGR projects. This could result in lower GGR supply and higher GGR costs.[16]

Including GGRs in the UK ETS would send a clear signal and reduce long-run policy uncertainty. The UK ETS and its predecessor schemes (the EU ETS 2005-2020 in the UK, and pilot UK ETS 2002-2004) have been running for over 20 years. They are considered flagship decarbonisation policies which are well understood and trusted by market participants. UK ETS market participants hold allowances worth billions of pounds, reflecting the confidence market participants have in the integrity, credibility and long-run durability of this market.[17] Responses to the Call for Evidence on GGRs within the Developing the UK ETS Emissions Trading Scheme: main response (July 2023) suggest some businesses see this as a key benefit of including GGRs in the UK ETS.[18]

If GGRs were included in the UK ETS then investors would be sent a clear signal that GGRs are set to be part of a credible, durable, investible policy framework that is widely expected to support decarbonisation in the decades to come. UK ETS inclusion alone would likely not give this kind of certainty, but when combined with the other elements of the policy package supporting GGRs, UK ETS inclusion could make a significant contribution to long-run policy certainty. This could have the effect of lowering the cost of capital for GGR projects, which would lower the market cost of supplying GGRs, and increase their rate of deployment in the UK.

[16] See Hirth & Steckel (2016) on the importance of cost of capital for the supply of clean technologies in general. See CO2RE (2022) for the importance of policy on GGRs in particular.

[17] Over its first three years of operation (2021-23), the market value of the annual UK ETS cap has averaged £10 billion per year. (The cap averaged 151 Mt, and the price averaged £64/t.)

[18] One industry stakeholder emphasised the importance of 'the policy certainty it [the UK ETS] offers', going on to say 'the UK ETS is an appropriate long-term market for GGRs as it is the UK's flagship decarbonisation policy and is well understood by government, market participants and investors. The credibility of the UK ETS should help to instil confidence in GGRs, particularly in the mid-2020s.' Another stakeholder responded that 'A clear commitment … [to GGR inclusion in the UK ETS] would … give the private sector confidence to invest'. See Developing the UK ETS Emissions Trading Scheme: main response (July 2023) for a summary of responses.

Enabling a net zero UK ETS in the long run

Including GGRs in the UK ETS is a necessary condition for moving towards a potential net zero UK ETS, for example by 2045 or 2050, which has further long-run economic benefits. A net zero UK ETS would have a net cap of zero (see Box 1 below). All allowances in the system could come from GGRs, so that all residual emissions from compliance entities are matched by a removal, leading to net zero emissions from the system overall.

From an economic perspective, if combined with other policies addressing other market failures, a net zero UK ETS could be a key part of the policy mix needed to guide the UK's market economy onto the most efficient pathway to reach economy-wide net zero.[19] This would allow economic actors to choose between (a) continuing to emit but paying someone remove their residual emissions, or (b) reducing their emissions. A net zero UK ETS could ensure businesses and individuals faced a single market price for these activities. Interactions in this market would ensure the marginal costs of abatement and removals were equalised across all sources of emissions, positive and negative. Assuming other market failures or barriers were sufficiently addressed with other policies, this market could contribute to an efficient allocation of emissions and removals across the economy.

[19] There is an interdependency between GGR integration, a net zero UK ETS, and UK ETS scope expansion. If the UK ETS is going to support some of the large quantities of GGRs in the net zero strategy as we get closer to 2050, then this increased supply will need to be matched by increased demand. This demand could come from scope expansion to high emitting sectors, consistent with the Authority's position set out in The long-term pathway for the UK ETS (December 2023).

Cap

The policy principles for GGR integration into the UK ETS are outlined in the consultation (see Principles for policy design section). Four key principles are: maintain the incentive to decarbonise, fiscal impact, maintain market integrity, and efficient long-term deployment of GGRs. A key component of policy design for achieving these principles is how we adjust the cap as new GGR allowances enter the system.

This section summarises an illustrative quantitative economic assessment of three cap adjustment options, compared to the counterfactual of no GGR integration. The options are quantitatively compared according to their impacts on traded carbon values[20] (a proxy for UK ETS prices) and gross emissions. There is also a qualitative comparison of the impacts on UK ETS revenue and the strength of the demand signal for GGR developers.

Box 1: What do we mean by 'the cap' if we integrate GGRs into the UK ETS?

Currently, the UK ETS has only one type of allowance, the UKA. The cap is approximately equal to the number of UKAs released over a given period. (There is a small discrepancy to the extent that some components of the cap, such as the Hospital and Small Emitter scheme, are not issued as UKAs over the relevant phase of the UK ETS. This discrepancy is ignored for simplicity below.)

If we were to integrate GGRs into the UK ETS there would be two sources of allowances, standard UKAs and new allowances from GGRs. These may or may not be labelled differently in the market place (see Allowances section). They are referred to differently here only to illustrate the mechanics of the cap. The cap would become:

UK ETS Gross Cap = Number of UKAs + Number of allowances from GGRs

This definition of the cap corresponds to gross emissions from the UK ETS, ie all positive emissions ignoring any negative emissions associated with GGRs. This is because both allowance types are used for compliance purposes and so result in one tonne of positive emissions.

It can also be useful to consider net emissions from the UK ETS, ie all positive emissions associated with any allowances minus all removals associated with allowances from GGRs. This would correspond to a net cap:

UK ETS Net Cap = Number of UKAs

The number of GGR allowances is excluded here because a GGR allowance represents both a positive unit of emissions from an UK ETS compliance entity, and a negative unit of emissions from the GGR operator who sold the allowance. The overall impact is zero net emissions, hence the number of allowances from GGRs does not feature in the net cap.

[20] DESNZ traded carbon values estimate the financial cost of purchasing UK ETS allowances. See Traded carbon values used for modelling purposes (2023).

Unless otherwise stated, 'cap' in this consultation refers to the first definition in this box, and 'net cap' refers to the second.

Modelling methodology

The modelling methodology for these calculations is based on that used in the Department for Energy Security and Net Zero's Carbon Market Model (CMM). For the counterfactual of no GGR integration we use the central (Net Zero Strategy aligned) scenario from the 2023 version of the model.[21] This gives counterfactual traded carbon values equal to the published 2023 traded carbon values for this scenario.

When integrating GGRs into the UK ETS, we then assume an exogenous supply of GGRs, consistent with our Net Zero Strategy GGR pathways. This translates into an increased number of allowances from GGRs entering the UK ETS, exogenous to the UK ETS price. Under the three different cap options, the supply of UKAs is adjusted in different ways in response to this same increase in allowances from GGRs. These three options are illustrated in Figure 1 and described in further detail in the individual sections below.

Modelling GGR supply into the UK ETS in this way involves making the following assumptions:

- **GGR supply is exogenous to the UK ETS price.** This means that GGR supply does not depend on the level of the UK ETS price. This assumption would hold if other supporting policies are pivotal to incentivise GGR supply. In the short term, this is likely to be true for many GGRs, where supporting Business Model payments are likely to be needed in addition to revenues from carbon markets in order to fund investments in GGRs. We therefore judge this to be a fair assumption to use for initial analysis of relatively short run impacts, which is the kind of analysis presented here. For analysis of longer-term impacts of GGR integration into the UK ETS we would look to develop an endogenous GGR supply curve within the Carbon Markets Model.
- **GGR quantities are consistent with the UK's net zero strategy.** This sets out an ambitious trajectory for GGR deployment.[22] Not all GGR deployment would take place through the UK ETS, as voluntary carbon markets are expected to play a role as well. It is very difficult to forecast the quantitative contribution voluntary carbon markets will play in the future, so for this illustrative analysis we have made some simple, high-level assumptions in order to obtain an illustrative trajectory for modelling purposes. This trajectory does not represent a desired trajectory by government or have any other relation to government policy – it is a modelling tool only. The assumptions are:

[21] There are four scenarios for which UK traded carbon values are published. See Traded carbon values used for modelling purposes (2023).

[22] Within the Net Zero Strategy (2021) GGR deployment is reported in two different sectors. 'Greenhouse Gas Removals' contains all engineered GGRs and nothing else, while 'Natural Resources, Waste & F-gases' contains afforestation (new woodland) among other activities. The total GGR trajectory used for the analysis presented here combines all engineered GGRs with all afforestation GGRs (but no other nature based GGRs). We use the Net Zero Strategy to construct an engineered GGR trajectory as follows. We assume 5Mt in 2030, 23Mt in 2035 and 75Mt in 2050. We then linearly interpolate between these points, starting at 0 in 2028. For woodland GGRs, we assume afforestation targets are met.

voluntary carbon markets support two thirds of the total GGR trajectory in the net zero strategy, until this reaches an upper limit of 10Mt.[23] The remainder of GGRs in the net zero strategy are supported through the UK ETS. Figure 7 shows the resulting trajectory of GGRs in the UK ETS.

These quantities of GGRs assumed to enter the UK ETS in the future are subject to considerable uncertainty, which we address by considering alternative scenarios. GGR supply could be significantly lower than projected in the net zero strategy, which we capture in a low scenario in which annual GGR supply into the UK ETS is 25% of its level in the central scenario described above. GGR supply could also be higher, which we capture in a high scenario in which annual GGR supply into the UK ETS is 200% of its level in the central scenario.[24] We model these scenarios as reasonable outlier scenarios, not because they are necessarily considered likely.

- **GGR integration only impacts the UK ETS through allowance supply.** Standard UKAs and new allowances from GGRs would have exactly the same compliance value, each permitting 1 tCO2e of positive emissions. UK ETS compliance entities, therefore, would presumably see no difference, for compliance purposes, if their allowances came from GGRs as compared to UKAs. It is through changes to the total supply of allowances that GGRs could have an impact on the current UK ETS market. In modelling terms, we therefore keep allowance demand unchanged from the counterfactual, with GGR integration only impacting allowance supply. We consider this a reasonable assumption for preliminary analysis, while noting that it does not capture some of the allowance differentiation considerations discussed in the consultation (see Allowances section below).[25] Subject to any new evidence contained in consultation responses, future modelling could be developed to incorporate any potential impacts on demand.

In addition to these GGR-specific assumptions, the modelling here depends on all the standard assumptions of the Carbon Market Model, and so all the usual caveats and limitations apply: the results are scenario-based projections, not forecasts or weighted by likelihoods in any way; the model assumes the net zero strategy is met; numerous technical modelling assumptions have been made (foresight, discount rates, abatement technology cost and deployment rates, etc) and each implicitly increases uncertainty in the results.[26] These results are based on the current scope of the UK ETS (power, industry and some aviation, as outlined above), and do not include the impact of potential scope expansion to energy from waste and maritime emissions.

No decision has yet been made around when GGRs would be integrated into the UK ETS. The time period we consider is dictated by 2028 being the earliest possible date GGRs could be

[23] As outlined above, these are modelling assumptions made in the context of very limited quantitative evidence of the size of future demand for UK GGRs by voluntary markets. They reflect: (1) an assumption that voluntary demand will take priority over compliance demand (hence the choice of 2/3rds, ie more than 50%, of supply going to voluntary markets); (2) an assumption that at some point voluntary demand will hit a ceiling (hence the 10 Mt upper limit, selected as a modelling device in the context of no evidence on the size of this limit in the future).
[24] The choices of 25% and 200% are not based on quantitative evidence. They are chosen to be as wide as possible, in order to reflect the considerable uncertainty around the central scenario we model.
[25] The analysis here is not inconsistent with the possibility of a price premium for allowances from GGRs compared to UKAs (as outlined in the Allowances section below). Traded carbon values could be interpreted as applying to UKAs only, so the value of allowances from GGRs is equal to the UKA proxy plus a potential price premium. Hence, while the modelling presented here does not address the price premium question, it is not inconsistent with its existence.
[26] For more details, see the 'Caveats and limitations' section of DESNZ's Traded carbon values used for modelling purposes (2023).

integrated into the UK ETS, as set out in the consultation. We then take the standard Green Book 10-year period from that date, ending in 2037. However, due to the 4-year foresight period in the Carbon Markets Model (explained below), we consider impacts on the UK ETS from 2025, which is the earliest year in the model that could register changes as a result of GGR integration in 2028. Hence the period we look at is 2025-37.

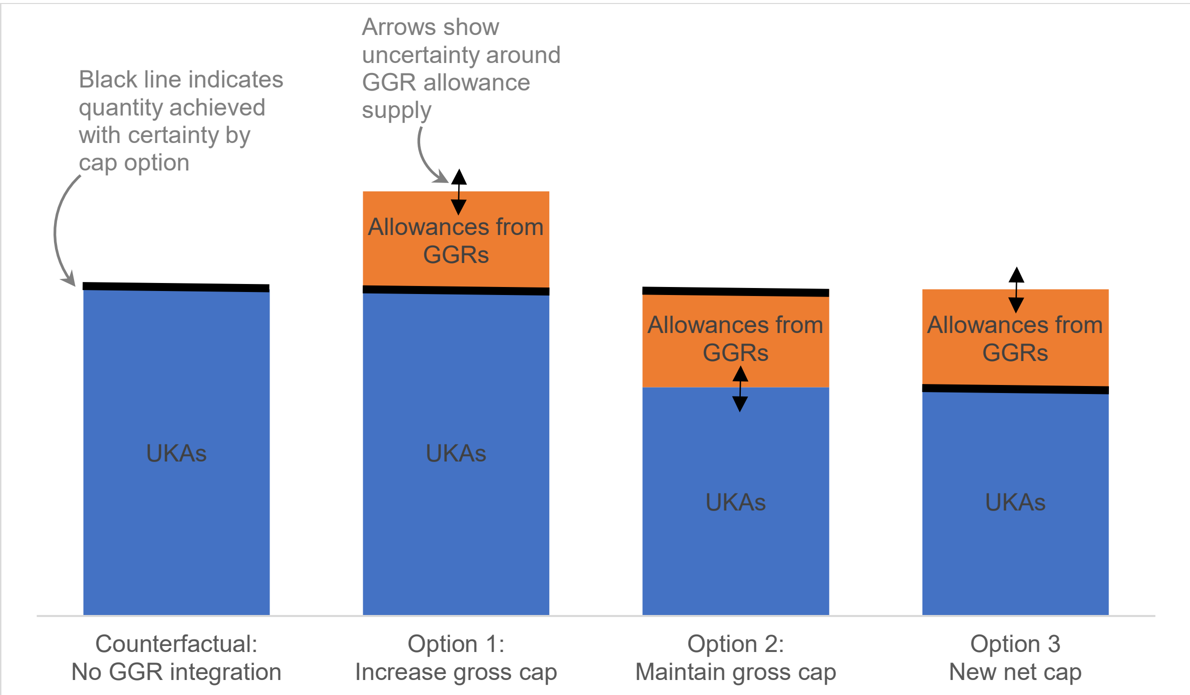
The counterfactual

If GGRs are not integrated into the UK ETS, then there are no changes to the supply of allowances in the UK ETS and the market is assumed to follow a trajectory over time equal to the department's previously published traded carbon values. The trajectories for traded carbon values and gross emissions are shown in Figure 2. The net zero consistent cap is declining, and emissions stay within this declining cap over time.[27] Prices generally rise over the period. All the impacts outlined below are changes relative to this future counterfactual trajectory.

Option 1: Increase gross cap

The first option outlined in the consultation is to allow the gross cap to increase. The number of UKAs would be kept at the same level as in the counterfactual, with GGR allowances increasing the gross cap beyond this level, as illustrated in Figure 1. The magnitude of the increase in the gross cap would depend on how many GGRs entered the UK ETS, which is uncertain.

Figure 1. Cap options for GGR integration.

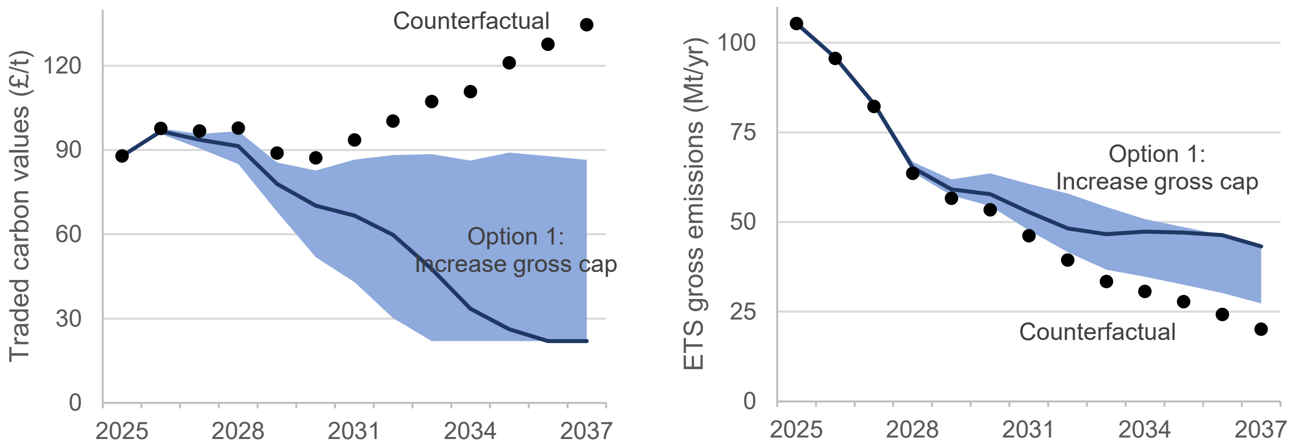


[27] The Authority recently committed to continuing the UK ETS until at least 2050, in The long-term pathway for the UK Emissions Trading Scheme (December 2023). While the current cap is only legislated to 2030, the Authority has committed to keeping the cap net zero aligned throughout this period. The cap figures for the period post-2030 are illustrative and used for modelling purposes only.

Notes: Components of the cap other than UKAs and allowances from GGRs (such as the Hospital and Small Emitters scheme) are ignored for simplicity. The diagram is qualitative only – the bars are not drawn to scale.

The modelled impacts of this cap option are shown in Figure 2. No decision has yet been made around when GGRs would be integrated into the UK ETS, but for modelling purposes we assume allowances from GGRs are first issued in 2028. The Carbon Market Model features a 4-year foresight period, since UK ETS participants are assumed to consider allowance supply up to 4 years into the future when making purchasing decisions. This means the impact on traded carbon values of additional allowances in 2028 is first felt in 2025, so we show results from that year onwards. The increased supply of allowances compared to the counterfactual results in lower traded carbon values, due to standard supply and demand dynamics. The size of the fall in traded carbon values is initially small, due to small quantities of additional allowances. However, the effect of larger quantities of GGRs entering the system in the 2030s is that the carbon value falls to its lowest possible level, the auction reserve price. There is uncertainty around this central projection due to uncertainty in GGR supply (all other sources of uncertainty are ignored in this analysis), as shown by the blue area in the figure.[28] In all scenarios, the traded carbon values are below their counterfactual level. Note that the central projection reaches the bottom of the range due to traded carbon values hitting the auction reserve price in both the central scenario and the high-GGR supply scenario (which corresponds to the lower end of the range).

Figure 2. Modelled impacts of Option 1: Increase gross cap.



Notes: The left panel shows traded carbon values and the right panel shows traded sector gross emissions (i.e. all positive emissions in the UK ETS with negative emissions from GGRs not included). The blue area indicates GGR supply uncertainty and is calculated using the high and low GGR supply scenarios outlined above. The solid line is the central GGR supply scenario.

Figure 2 also shows the impact of this cap option on gross UK ETS emissions, in the right panel. We focus on gross, rather than net, emissions because we are interested in the extent to which UK ETS sectors maintain their abatement trajectories in the counterfactual, which is consistent with the net zero strategy. If gross emissions rise above the level in the counterfactual, this will have implications for UK carbon budgets. Gross emissions are more

[28] The uncertainty is not symmetric around the central scenario, since the high and low GGR deployment scenarios are not symmetric around the central scenario. In addition, the auction reserve price (at £22/t) is the minimum level the traded carbon value can fall to, with both the central and high GRR supply scenarios resulting in traded carbon values hitting this level by the end of the period.

than twice as high as in the counterfactual by the end of the period, reflecting the fact that only a limited range of abatement options would be incentivised at the auction reserve price. While there is uncertainty around the central projection, in all cases gross emissions are higher than in the counterfactual.

Net UK ETS emissions, i.e. gross emissions less the negative emissions associated with allowances from GGRs, would be the same as in the counterfactual. This is because the negative emissions from GGRs are exactly offset by the increased positive emissions from UK ETS sectors shown in the right panel of Figure 2. We can also infer from the results above that UK ETS auction revenues would also be lower than in the counterfactual, due to lower traded carbon values (and since the number of UKAs is the same as the counterfactual, so the quantity auctioned would be the same).

The impact on GGR developers would be a relatively weak price signal. This is because as GGR developers start to supply GGR allowances into the system, they lower prices and so undermine their own returns from doing so. As this effect would be known in advance, UK ETS integration with this cap option would likely be seen by GGR developers as a relatively weak demand signal.

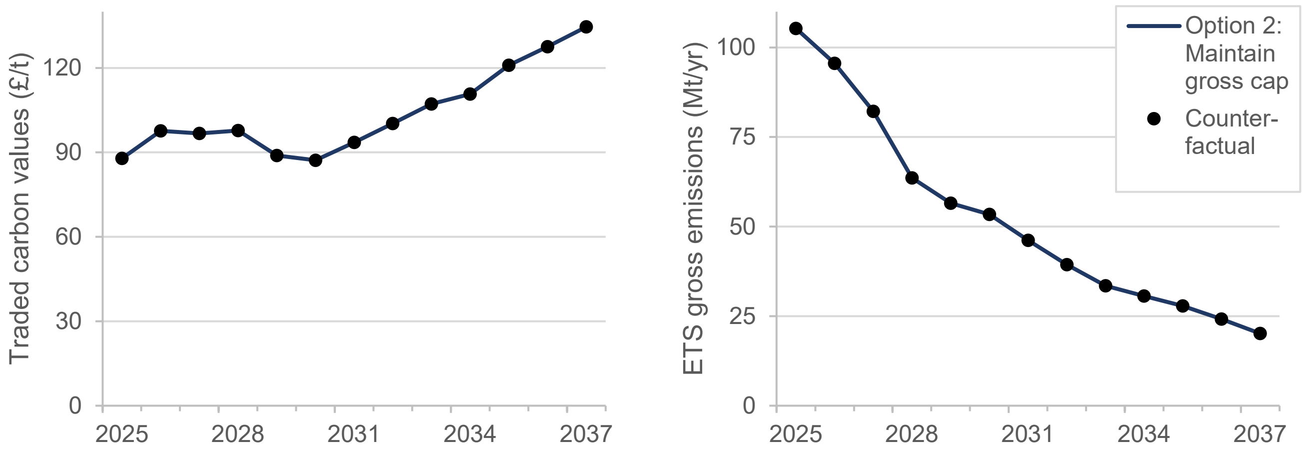
Option 2: Maintain the gross cap

The Authority’s proposal outlined in the consultation is to adopt a policy of maintaining the gross cap, at least initially if GGRs are integrated into the UK ETS. This option maintains the total number of allowances released to market participants at exactly the same level as they would be in the counterfactual of no GGR integration. To achieve this, for each extra GGR allowance awarded to a GGR operator, one fewer UKA is released at auction. The impact on the gross cap is illustrated in Figure 1.

Since UKAs and allowances from GGRs have the same value for compliance purposes, if the gross cap remains the same as in the counterfactual then we would not expect to see any impact on UKA prices. This is what we see in the left panel of Figure 3, with traded carbon values at exactly the same level for both GGR integration and under the counterfactual. We would also expect gross emissions to be unchanged from the counterfactual, as the gross cap is unchanged, and this is also what we see in right panel. Figure 3 also reveals another feature of this cap option, the elimination of the impact of GGR supply uncertainty on UK ETS outcomes. This is because when the supply of allowances from GGRs is higher or lower than expected, the number of UKAs is reduced or increased accordingly, so that the gross cap is maintained at the same level as the counterfactual whatever realised GGR supply turns out to be. This eliminates uncertainty in traded carbon values or gross traded sector emissions due to GGR supply uncertainty (many other sources of uncertainty of course remain).

Net emissions from UK ETS sectors plus the GGRs selling into the UK ETS would be lower than the counterfactual, since each additional allowance from GGRs makes no net contribution to emissions, and it displaces a UKA which does (see Box 1). Assuming that the reduction in UKAs relative to the counterfactual comes from reducing auctioned UKAs, auction revenues would be lower. When combining these price and quantity effects, we find that this option is projected to lead to higher UK ETS revenues than option 1. This is because the revenue implications of the fall in price due to an increase in allowance supply under option 1 outweigh the impact of the fall in auction quantities under option 2.

Figure 3. Modelled impacts of Option 2: Maintain gross cap.



Notes: The left panel shows traded carbon values and the right panel shows traded sector gross emissions (i.e. all positive emissions in the UK ETS with negative emissions from GGRs not included). The solid line is the central GGR supply scenario. There is no uncertainty band shown in this figure because the results for the high and low GGR supply scenarios are the same as the central scenario.

The impact of gross cap maintenance on GGR developers would be a strong demand signal. By maintaining the cap and therefore maintaining prices, rather than allowing the cap to rise and prices to fall (as in option 1), GGR developers are being given access to a market with a strong price signal.

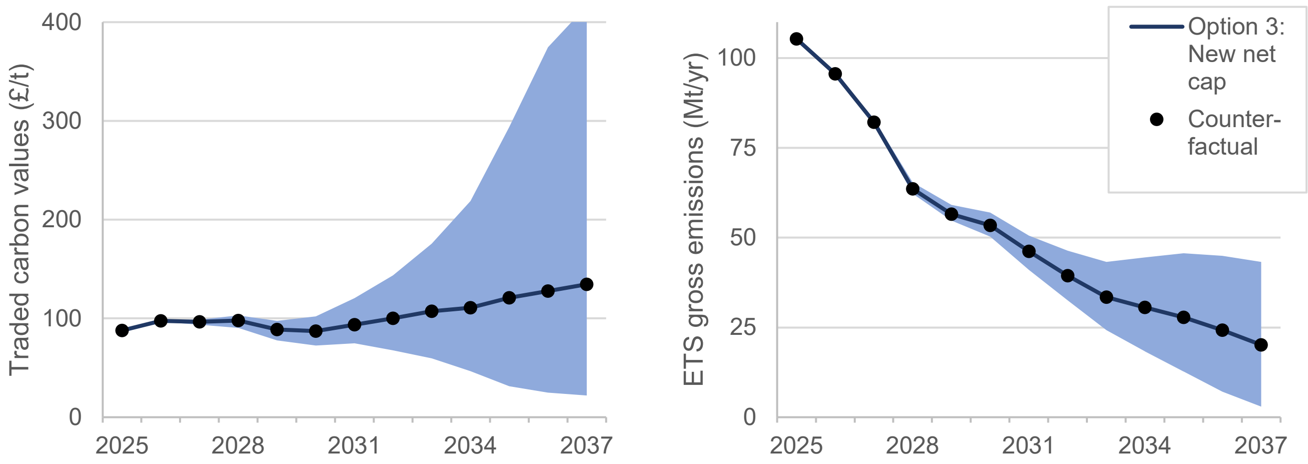
Option 3: New net cap

The Authority outlines the possibility of, in the longer run, transitioning to a policy of setting a new net cap (see Box 1 for an explanation of gross vs net cap). This amounts to setting a new, lower trajectory for the number of UKAs, as illustrated in Figure 1. The overall cap is equal to this number of UKAs plus the number of GGR allowances that GGR developers supply into the system, which would be uncertain at the time the UKA trajectory was set.

This option is the most sensitive to uncertainty in GGR supply. If the number of GGR allowances that actually enter the UK ETS is exactly equal to what was expected when the new net cap (i.e. the new UKA trajectory) was set, then the gross cap will be the same as in the counterfactual. Traded carbon values and traded sector emissions will both, therefore, be the same as in the counterfactual, which is what we see for the central scenario results in Figure 4. However, if GGR supply is lower than expected, then the gross cap will be lower than in the counterfactual. This results in higher traded carbon values, as shown by the upper edge of the band of uncertainty in the left panel of the figure. The modelling suggests that, given the quantities involved, the price effect could be large. In the same way, if GGR supply into the UK ETS is larger than expected, traded carbon values will be lower than in the counterfactual.

The impact on gross emissions is similarly uncertain. If GGR supply into the UK ETS is lower than expected, then higher traded carbon values will drive lower gross emissions. Likewise, the inverse would be true for higher GGR supply. This effect, where abatement and removals both respond to the same price in the UK ETS, and increases in one compensate for decreases in the other, has consequences. First, it introduces uncertainty into the UK ETS. All else equal, many UK ETS participants will not see this as advantageous. Second, this effect can be seen as a desirable property of an economically efficient system. It is an example of a market guiding efficient allocation of resources where economic agents, mediated by UK ETS prices, equalise their marginal costs of abatement and removals.

Figure 4. Modelled impacts of Option 3: New net cap.



Notes: The left panel shows traded carbon values and the right panel shows traded sector gross emissions (i.e. all positive emissions in the UK ETS with negative emissions from GGRs not included). The blue area indicates uncertainty and is calculated using the high and low GGR supply scenarios outlined above. The solid line is the central GGR supply scenario.

The attractiveness of the new net cap option, relative to maintaining the gross cap, involves balancing these two considerations. It is reasonable to conclude that while many GGRs are novel technologies and the uncertainties around their long-run supply are large, the risks associated with the new net cap option are large, and the maintain the cap option could bring more economic benefits. As GGR technologies mature over time and supply becomes less uncertain, the risks to the UK ETS from the new net cap option may fall. At the same time, the GGR market will get larger, and the economic efficiency benefits of the new net cap option, which should roughly scale with the size of the market, will grow. There is a rationale, therefore, for the new net cap option yielding greater economic benefits in the longer run. A future net zero UK ETS, for example, could be based on this option.

UK ETS auction revenue in the central scenario would be lower than in the counterfactual, as the UKA trajectory under a new net cap would be lower than in the counterfactual. However, if GGR supply were lower than expected, then prices would be higher, which would tend to increase revenue. For example, in the extreme case of the upper end of the uncertainty band shown in Figure 4, revenue is higher than in the counterfactual.

This option would send a very strong price signal to GGR developers to supply an amount of GGRs into the UK ETS. This is because if GGR supply was lower than expected, the price would rise, giving a further incentive to GGR developers to increase supply. In this option, the price will adjust in order to drive GGR deployment, unlike in the maintain the cap option, which is designed to avoid this dynamic.

Allowances

The consultation explores the option of differentiating between standard UKAs and GGR allowances. This section summarises the economic rationale for this proposal.

UKAs and GGR allowances would have exactly the same compliance value: both would allow an UK ETS compliance entity to emit 1 tCO2e. If this was the only value to be gained from purchasing allowances, then we would expect UKAs and GGR allowances to have the same price in the market.

However, it is possible that some private sector actors could derive additional value from an allowance from GGRs, over and above its compliance value. This is because a GGR allowance represents both the right to emit 1 tCO2e, and a high-quality, high-integrity removal of 1 tCO2e. Some private sector actors are already willing to pay significant sums for GGRs on a voluntary basis.[29] This is because they value carbon removal, for a variety of reasons. Some companies may want to pass on to their customers the chance to buy the removal,[30] some companies may want to lower their net emissions as this could give them greater access to finance,[31] and some companies want to lower their current net emissions or even address historical emissions for other reasons.[32]

If UK ETS compliance entities value GGRs for any of these reasons, then we could see a higher willingness to pay for allowances from GGRs than UKAs. The price of UKAs would stay the same as in a no-GGR-integration counterfactual (see Cap section), reflecting the compliance value of the allowance. The price of allowances from GGRs would equal the price of UKAs, i.e. the compliance value, plus the removal value to the marginal buyer. Hence, we could see a price premium in the market for allowances from GGRs.

While it is a theoretical possibility that there could be a price premium for allowances from GGRs, allowance differentiation could also result in no price premium. Even if some buyers of allowances from GGRs value the removals associated with the allowance, the marginal buyer may not. In this case, we would not expect to see a price premium in the market. It is ultimately an empirical question whether the price premium could emerge, and if so at what level. There is no conclusive empirical evidence to date. The consultation seeks to help to close this evidence gap.

The UK ETS Authority has no first-order interest in a GGR allowance price premium over UKAs, as it does not impact the core functioning of the UK ETS in matching demand with constrained supply for the right to emit. However, there are four secondary economic reasons to consider this proposal.

First, by differentiating between UKAs and allowances from GGRs, the Authority would allow market participants to satisfy any demand they have for high-quality, high-integrity removals

[29] For example, Frontier is a recent advance market commitment to purchase $1bn+ of GGRs, by corporate buyers including Alphabet, Shopify, Meta, and McKinsey.

[30] Many airlines, for example, already offer a related product, voluntary carbon offsetting of the emissions from their flight, to their customers (including British Airways, Ryan Air, and many others). Airlines (such as ANA) are beginning to move into GGRs, and it remains to be seen how this is incorporated into their business models.

[31] Some stakeholders have raised access to finance as one of the key drivers behind their internal business cases for net zero investments.

[32] For example Microsoft has committed to be net negative by 2030 and to have removed all its historical emissions by 2050.

over and above their compliance demand. This would allow for the formation of a market, matching economic agents willing to pay for something (UK ETS participants looking for removals) with economic agents willing to sell something (GGR operators looking to sell removals). The standard economic efficiencies from solving a missing market failure would result, in this case manifesting as increased GGR supply, voluntarily paid for (at least in part) by UK ETS participants.

Second, this proposal would move the scheme closer to the long-run destination of a net zero UK ETS. It would be transparent and clear to UK ETS participants that some allowances come from GGRs, which would allow a process of price discovery to see what the market is willing to pay for these allowances and in general allow the market to get used to this source of supply. The market would then be prepared for steadily increasing quantities of allowances from GGRs over time, smoothing the transition to GGRs as a significant and potentially eventually sole source of supply.

Third, the final benefit of allowance differentiation and the potential establishment of a price premium for allowances from GGRs is that it would have a positive impact on wider GGR supply and the policies that support it. For example, a potential future engineered GGR business model, in which a GGR operator signed a Contract for Difference with the government, could use the price of GGR allowances as its reference price rather than the price of UKAs. If this were higher, then for a given strike price, top up payments would be lower. This would reduce the cost to government of supporting a given quantity of GGRs, or allow the government to support more GGR supply for a given budget.

Fourth, allowance differentiation could impact on liquidity in the UK ETS. Allowance differentiation into UKAs and allowances from GGRs would split the market for allowances, so that there are now effectively two (closely related) goods trading the market, rather than one. Liquidity is not a simple function of the size of the market, so the quantitative impact on liquidity is difficult to predict.[33]

[33] See Evaluation of the UK Emissions Trading Scheme (2023), p 64-67, for a discussion of liquidity in the UK ETS.

Permanence

Economic valuation of carbon storage

Not all GGRs store carbon for the same length of time. This impacts the economic value of their activities. From a net emissions perspective, it can be helpful to think of GGRs in general as removing 1 tCO2e in year 0, and then potentially emitting that 1 tCO2e again in year x, where x is the duration of the storage or the permanence of the GGR. This captures the fact that permanence is continuous, not binary.

The permanence of a given GGR depends on both: the physical characteristics of the technology (for example the way CO2 is stored in a particular site under the North Sea, or the long run health of a particular woodland), and the social and legal institutions surrounding the activity (for example ensuring the seabed is not disturbed or that the woodland is not deforested).

If we know how permanent a given GGR's storage is, i.e. we know x, we can then ask what the economic value of that storage is. That is, what is the value to society over time of storing 1 tCO2e for x years? Herzog et al (2003) present a simple economic framework for calculating the value of impermanent carbon storage relative to permanent storage, as a function of storage duration x. They use the standard economic approach of discounting costs and benefits over time and use a social cost of carbon to summarise all relevant information on the value to society of avoiding putting carbon in the atmosphere in a given year.[34] In this framework, the value of storage depends on three factors. First, the length of time the carbon is stored for, x. Carbon stored for longer has a higher social value. Second, the social cost of carbon in the year it is released relative to when it was stored. Higher relative future social costs of carbon result in lower relative value of impermanent storage, since the release of carbon in the future is more socially costly. Third, the discount rate. A higher discount rate would result in a higher relative value of impermanent storage, as the social costs of releasing carbon in the future would have a lower value today.

Operationalising this framework for valuing carbon storage involves making assumptions about the three inputs to be used in the calculation, and the results are sensitive to the assumptions underpinning the inputs. First, we need to estimate the duration of the storage, which could be subject to considerable technological and policy uncertainty, since it involves assumptions about changes hundreds of years from now. The remaining two parameters, however, involve both positive and normative uncertainty – they incorporate value judgements as well forecasts about future states of the world. Estimating social costs of carbon generally involves using complex models, known as integrated assessment models, which are highly sensitive to debated assumptions, and there remains little consensus over which results should be used in policymaking.[35] There is also little consensus over the correct discount rate to use in the very long run, which involves making judgements about the relative moral value of future

[34] The relevant result from Herzog et al (2003) is their equation 3. This is $\eta = \frac{\sum_{t=0}^{\infty} p(t)a(t)(1+r)^t}{p(0)a(0)}$, where: η is the relative social value of storing carbon impermanently compared to permanently; $p(t)$ is the carbon value (the social cost of having 1 additional tonne of carbon in the atmosphere) at time t; $a(t)$ is the change in the carbon stock, so that $a(0) = -1$ if emissions are removed in year 0 and $a(x) = 1$ if the carbon is released in year x; r is the discount rate.
[35] See Pindyck (2013) for a critical summary of the debate.

generations compared to those alive today.[36] Given the long timeframes of carbon storage, the values of these inputs matter a lot for the resulting social value of storage.

There have recently been some attempts to quantitatively estimate the value of carbon storage of different degrees of permanence. Groom and Venmans (2023) provide a detailed numerical analysis of the economic value of GGRs of different storage lengths, consistent with the above framework. Their work suggests that carbon stored and then released after 100 years could be worth 66-70% of permanent storage. Prado and Mac Dowell (2023) estimate the ‘climate repair value’ of GGRs, which is different to their economic value, and reach similar qualitative conclusions but different quantitative conclusions. For example, under their preferred parameters, 100 year storage has a climate repair value of 8% of permanent storage. Given their methodology (in which there is no discounting over time, among other differences), it is to be expected they reach a lower value.

These studies are valuable early attempts to quantitatively address this issue. There is no external consensus on quantitative findings on which policy decisions can straightforwardly be based. There is, however, a consensus that less permanent carbon storage is still valuable to society, albeit less valuable than more permanent storage. This suggests there is a rationale for government to support impermanent storage, with the level of support dependent on the expected permanence at the time the carbon is stored.

Rationale for policy design addressing permanence

The UK ETS currently deals in allowances worth 1 tCO2e emitted. The policy design question when integrating GGRs is how to convert 1 tCO2e stored for potentially different lengths of time into an equivalent number of allowances such they have the same social value as 1 tCO2e of permanent removal. This in turn is equal to the value of 1 tCO2e of emissions avoided.

The consultation explores using three overlapping policy measures, in conjunction, to address this problem. Further details are given in the individual sections below, but the broad economic rationale for this policy framework is as follows. First, the consultation proposes using a liability measure to directly target the problem, which is the release of previously stored carbon. If carbon is released, the economic agent response for storing that carbon is liable for its release and must take actions that fully remedy the release (there are two options considered in the consultation for how this could work). Liability measures are a so-called ‘first best’ policy option: if there were no further limitations or imperfections in the implementation of the policy, then this would fully address the problem – as and when carbon is released, the economic agent responsible would make good the social cost of the release.[37]

However, there are at least three reasons to believe that liability measures will not, with certainty, work to perfectly and fully reverse all future releases of carbon. (1) There may be imperfections in the MRV process for some GGRs, such that releases are not measurable and therefore subject to liabilities. (2) Limited liability under UK law could mean that in the distant future the economic agent liable for carbon releases could declare bankruptcy rather than pay for remedying the release. (3) Finally, carbon will be stored over longer timescales (many hundreds of years) than the current liability policy might exist for. It is therefore uncertain

[36] See, for example, Stern (2006), Nordaus (2007), and Weitzman (2007).
[37] Edenhofer et al (2023) highlight the centrality of managing liabilities from non-permanent GGRs as one of the main policy design questions for governments supporting GGRs.

whether liabilities will continue to be enforced in the distant future. For these reasons, there is a role for further, so-called ‘second best’, measures to complement the liability measure.

The second measure outlined in the consultation is to set a minimum permanence threshold for GGRs entering the UK ETS. So long as the estimated permanence used at this point is not an underestimate, this guarantees a minimum level of permanence of GGRs in the UK ETS. The third component outlined in the consultation is fungibility measures. These measures adjust the number of allowances awarded to a GGR operator for storing carbon depending on how permanent that storage is expected to be, at the point the carbon is stored.

Both minimum permanence thresholds and fungibility measures are ex-ante solutions (addressing the problem in advance), compared to liability measures offering an ex-post solution (addressing the problem when it occurs). The rationale for using ex-ante measures is to mitigate the risks associated with relying exclusively on ex-post measures. Ex-ante measures, however, by construction fix a problem only to the exact extent it is forecast in advance. This could prove to be an under-estimate (with a negative impact on meeting carbon budgets), or an over-estimate (with a negative impact on GGR deployment). Finding the optimal mix of ex-post liability measures and ex-ante minimum permanence and fungibility measures involves, among other things, balancing the risks associated with permanence forecast errors against the risks that liabilities may not be met in the very distant future.

It is important to note that the permanence policy problem is unlikely to cause issues around the functioning of the UK ETS. If differences in permanence were not addressed, i.e. none of the measures outlined above were implemented, then the impact on the current functioning of the UK ETS would be small or zero. The cost of producing a GGR allowance could fall for some GGRs, which could marginally increase the supply of allowances from GGRs into the UK ETS. If this effect was concentrated in allowances from woodland, then the quantitative impact on the UK ETS would be small, since allowances from woodland are projected to make up a small share of the total (between 3-8% as shown in Figure 7). If maintaining the cap was the cap policy, then even this small change would result in no impact on the gross cap, and there would be no impact on the UK ETS. There would, however, be impacts on carbon budgets, since carbon released from storage, if unmitigated, has the same impact on carbon budgets as any other source of emissions. Permanence policy is therefore largely aimed at mitigating risks to future carbon budgets, not current ETS functioning.

Liability measures

The consultation explores the use of liability measures, that is creating an obligation for GGR operators to cover leaks of any carbon they store. There are two options outlined in the consultation for obligations on a GGR operator in the event they suffer a leak from the carbon they store: an obligation to buy ETS allowances or an obligation to fund replacement removals outside the UK ETS. This would apply to any GGR operator, whatever the expected permanence of their GGR technology. The remainder of this section summarises a qualitative consideration of these options from the point of view of: the incentives they create, their impact on carbon budgets, their impact on ETS market stability, and the very long-run durability of the policy.

The UK ETS allowance option ensures that GGR operators face an ongoing incentive to continue to store carbon equal to the market cost of emissions. Absent any other market failures, this is arguably the economically efficient incentive, and should avoid an outcome suffering from moral hazard where a storage operator is paid to bury carbon but then subsequently does not take efficient steps to ensure it remains buried. This liability measure would also efficiently manage the carbon budget risk from storing carbon. In the event of a leak, the resulting emissions would be covered by the UK ETS cap. The GGR operator would have to acquire and surrender allowances. This would result in fewer emissions elsewhere in the UK ETS. Leaks would therefore make no net contribution to the UK's emissions. There is also a potential interaction between the impact of a given liability measure and the GGR cap option in operation at the time of the leak.

A potential disadvantage of this option is that there could be adverse ETS market impacts in the unlikely case of large reversal events. By creating an additional source of demand for allowances, large leaks could increase the price in the UK ETS. While this is part of an efficient market response, depending on its magnitude it could also have adverse impacts on other ETS market participants. The likelihood of large leaks is judged to be low (see Case Studies in the consultation), so these impacts are considered unlikely to materialise on a large scale. As the stock of stored carbon grows over time, depending on how other components of the permanence policy framework are implemented, smaller-scale leaks with smaller-scale market impacts could become more likely.

A final consideration is the very-long-run durability of this option. We need to consider this because of the very-long-run nature of the policy problem – ensuring carbon remains stored for many hundreds, if not thousands, of years. The UK ETS may not exist over these timescales. In this case it would be necessary for future policymakers to implement new liability policies, or risk these storage liabilities being uncovered.

The second liability option, in which a GGR operator suffering from a leak would be required to buy GGRs outside of the UK ETS, could have broadly similar but not identical impacts. Assuming the obligation was to buy high quality GGRs, it would create a strong incentive on the GGR operator to keep their emissions stored. The strength of the incentive would be equal to the price of GGRs outside the UK ETS the operator can secure. Depending on how liquid this market is and how many other support policies are in place, this could end up being similar to the prevailing price in the UK ETS or it could be quite different. The impact on carbon budgets is less clear. If the purchasing of the GGR outside the UK ETS resulted in additional supply of GGRs, beyond what we would have seen without the leak, then the carbon budget risk would be addressed. However, it is difficult to forecast what the market conditions of non-ETS GGR supply might be like in the future.

This second liability measure could have a smaller impact on ETS market stability in the event of a large leak. This is because it would not contribute to additional demand in the UK ETS. It could only have a potential impact via allowance supply, since the GGR operator could purchase a GGR that would otherwise have been destined to be sold into the UK ETS. Under the cap option of maintaining the gross cap, this would not impact the gross cap and so there would be no market stability impacts. However, under the option of setting a new net cap, there could be negative impact on allowance supply and this could feed through into higher ETS prices.

The very-long-run durability of this liability option could be higher than the UK ETS allowance option – this is one of the key advantages of this option. Depending on the contractual design of the liability, it could outlast any particular policy framework. There are some contracts, for example a 999-year property lease, that do exist over the kinds of timescales relevant to carbon storage.

Minimum permanence measures

The consultation explores what should be the minimum period for which a GGR is expected to store carbon if it is to enter the UK ETS. So long as the estimated permanence used at this point is not an underestimate, this guarantees a minimum level of permanence of GGRs in the UK ETS. It therefore provides a minimum level of de-risking of the overall impacts of GGRs in the UK ETS to future net emissions.

If liability measures could be implemented perfectly and there was no risk of them being circumvented, then there would be no clear rationale for this measure. Any differences in permanence would be fully addressed at the point those differences materialised, i.e. at the time the carbon leak takes place. However, as outlined above, there are reasons to believe relying on liability measures alone would be a risky approach. A minimum permanence measure reduces this risk. It is a relatively crude measure; its rationale comes from its ability to address very long-run uncertainties in a simple, transparent and low-risk way.

We are not aware of a strong evidence base, let alone consensus, on which to base decision making when deciding on this threshold. The studies estimating the value of impermanent storage summarised above (see Economic valuation of carbon storage section) could be used as a guide to the social value of storage, but as noted there is no clear consensus around what the correct valuations would be, let alone what the right threshold would be, which involves making value judgements.

Fungibility measures

The consultation also explores the use of fungibility measures, so that an allowance from GGRs represents 1 tCO2e stored permanently, and is therefore of equivalent social value to 1 tCO2e of abatement. If this is achieved, allowances from GGRs are said to be fully fungible with UKAs.

If liability measures could be implemented perfectly and there was no risk of them being circumvented, then there would be no clear rationale for fungibility measures. Any differences in permanence would be fully addressed at the point those differences materialised, i.e. at the time the carbon leak takes place.

Consider for example a GGR operator who stores 100 tCO2e in a given year. However, they are considered at risk of losing 20 tCO2e in the form of leaks or reversal events over the relevant storage period. The policy design question is how many allowances should the operator receive for the 100 tCO2e that they put into storage. The consultation outlines two approaches.

The first approach is for the Authority to create a buffer pool, and require some GGR operators to contribute to the buffer pool to the extent their expected storage duration deviates from fully permanent storage. For example, they could be required to contribute 20 allowances into the buffer pool, leaving them with 80 allowances for each 100 tCO2e they capture and store.

The second approach is for the Authority to calculate an equivalence ratio between a given GGR and a permanent storage GGR. This ratio could be calculated following a standard economic framework in which costs and benefits are estimated using social costs of carbon (or their equivalent) and are then discounted over time. Groom and Venmans (2023) take this kind of approach and their results could be used to calculate equivalence ratios. In the example above, the expected storage length of the GGR would be an input into a calculation that outputted an equivalence ratio for that storage trajectory. The GGR operator would then be rewarded with some proportion (less than 100%) of allowances for their initial removal and storage based on the expected duration of storage it could provide. Permanent GGRs will receive 100% of their allowances under this ratio.

Both of these approaches are fundamentally similar, in that each results in certain GGR developers receiving less than 1 allowance for each 1 tCO_2e they store, as a function of how permanent their storage is. Both would be combined with liability measures. The approaches differ, however, in several other ways.

First, they are calculated differently, and so GGR developers could end up with different numbers of allowances under each option. Second, the buffer pool approach is more established and arguably better understood by carbon market participants, as it is commonly used in voluntary carbon markets including the Woodland Carbon Code. Third, calculating equivalence ratios requires making significant analytical judgements, including on pure time discount rates and climate modelling assumptions (either directly in the calculation or indirectly if quantities such as the Social Cost of Carbon are used as inputs). Fourth, buffer pools are arguably perceived as more transparent, because the Authority would hold a certain number of allowances in a clearly designated buffer pool, and could track the extent to which reversal events had exhausted the buffer pool or not. Equivalence ratios, calculated using complex formulae with debatable inputs, could be seen as less transparent. However, there is currently a lack of clear evidence on which buffer pool contribution rates could be set.

Box 2: Woodland Carbon Code permanence framework – a worked example

The following hypothetical example outlines how the current policy framework helps to achieve a high degree of permanence for carbon stored in Woodland Carbon Code (WCC) woodland.

A woodland owner in England enters the WCC in 2020, passing the WCC additionality test and plants their new 20 hectare woodland, which must meet high levels of woodland resilience in its design as set out by the UK Forestry Standard. This is done through a Woodland Creation Plan, and applying for a forestry Environmental Impact Assessment if the afforestation is likely to have a significant effect on the environment, and approved before woodland creation can begin. The WCC woodland is verified by independent assessors at year 5, 15 and 25 and produces verified woodland carbon units, of which 20% remain in the buffer and only 80% of the units can be sold.

Suppose in year 30 the woodland owner decides they want to undertake a development and build houses on 2 hectares of their woodland, and that this would result in the release of 200 tCO_2. They apply for planning permission, which will require them to be screened by the local planning authority under the Town and Country Planning (Environmental Impact Assessment) Regulations 2017, and to calculate the biodiversity of the woodland site as a baseline for Biodiversity Net Gain. They will then be required to buy biodiversity units to offset the biodiversity lost from the woodland. Since 30-year-old broadleaf woodland is high in biodiversity, these requirements are likely to impose significant costs.

If the landowner gains permission, goes ahead with the development, pays for biodiversity units, and fells the woodland, then they will be in breach of multiple contracts related to the WCC. They are contractually required by the WCC to report these breaches, and if they fail to do so this should be discovered at the latest at the next verification point in the contract (on-site verification visits by an independent verifier take place at least every 10 years). If they did not voluntarily report the breach, this would eventually be . A landowner of a WCC project has committed to a permanent land use change and to maintain the woodland as a carbon store. A loss of woodland due to development would be categorised as an 'avoidable loss' and dealt with by legal means. They will be required to reimburse the WCC buffer for all of the 200t of stored carbon released when the woodland is lost. This is a form of liability measure, of the kind outlined in the consultation.

The buyer of the original woodland carbon units, who purchased these up to 30 years ago, would be protected by the WCC buffer. 200 woodland carbon units from the buffer would be retired. This would ensure the buyer's original purchase was still directly associated with 200t of carbon removal, independent of the liability process of restocking the buffer described above.

Woodland

This section outlines evidence on two aspects of GGRs from the creation of new woodland: (1) a summary of the evidence on the potential permanence of UK woodland GGRs, (2) a summary of the evidence on costs and quantities of potential allowances from woodland GGRs, if these were integrated into the UK ETS.

These questions are relevant to the consultation because woodland GGRs are widely perceived to feature potentially lower degrees of permanence than engineered GGRs. There are also questions around wider land management impacts which are specific to woodland GGRs and do not apply to engineered GGRs.

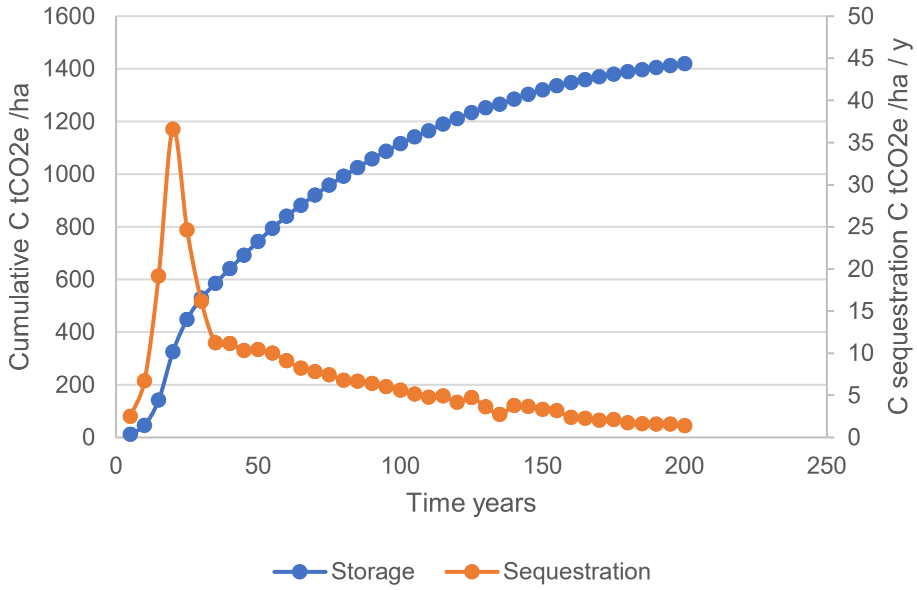
Permanence of woodland

The permanence of carbon stored in new woodlands depends on the long run health and existence of the woodland, rather than individual trees within it. The Forestry Commission, and successor organisations across the UK, have been monitoring and analysing woodland growth in the UK since 1919, and have produced a significant evidence base on which policies such as the Woodland Carbon Code (WCC) have been designed.[38]

Carbon removal and storage by a given hectare of woodland can be modelled, using WCC data, as shown in Figure 5. The orange line (sequestration) shows when and how much carbon is removed by the woodland, from the time it is planted. The rate of carbon removal peaks around 20-40 years after the woodland is planted, due to tree growth rates being at a maximum during that period. It continues to remove diminishing quantities of carbon throughout the period shown. The blue line (storage) shows how much carbon is stored in the woodland. This rises most rapidly during the maximum growth rate period, and then levels off, eventually reaching a steady state (not shown in the figure as the steady state for this woodland type is estimated to be reached around year 300). The key insight from this evidence is that if the woodland is not disturbed it reaches a steady state, and carbon continues to be stored when individual trees die, as the woodland is in a stable equilibrium.

[38] Prior to 2013, the Forestry Commission was responsible for England, Wales and Scotland. Scottish Forestry is now responsible for woodland in Scotland and Natural Resources Wales is responsible for woodland in Wales. Scottish Forestry manages the Woodland Carbon Code (across the UK).

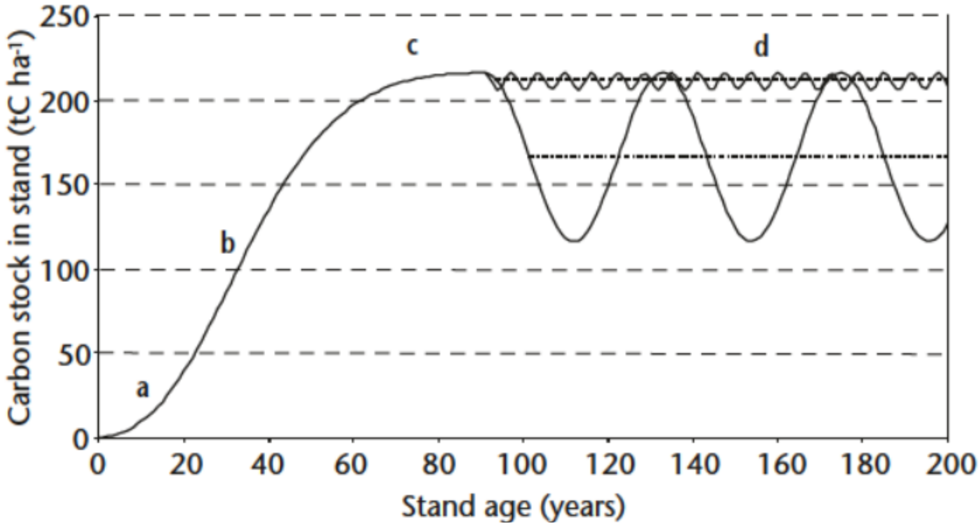
Figure 5. Woodland carbon removal and storage over time.



Notes. Source: Natural England (2021), p19. The figure shows a modelled trajectory of carbon sequestration (i.e. removal) and storage from new woodlands. Modelling based on Woodland Carbon Code data for un-thinned Yield Class 8 Oak in 5-year time intervals on a mineral soil with minimal soil emissions. The modelling of early growth is limited by a lack of data so the timing and height of the early peak should only be treated as illustrative.

The evidence, therefore, suggests woodland carbon storage is permanent if the woodland is not disturbed. We now summarise the evidence on how different types of disturbance could impact permanence. The general finding is that as long as the disturbance does not result in permanent loss of the woodland, then trees will re-grow, and the woodland will return to a steady state level of carbon storage. This is illustrated in Figure 6, which shows undisturbed woodland growth up to around year 100. It then shows the impact of repeated small or large disturbances. In each case the quantity of stored carbon recovers over time to its original level, before falling again due to another disturbance. The steady state carbon storage in each case is an average over time, with more carbon storage when disturbances are small (220t) than when they are large (170t).

Figure 6. The impact of woodland disturbance on carbon storage.



Notes. Source: Forestry Commission (2003). The figure shows modelled carbon storage over time for a stand of general yield class 12 Sitka spruce. (Note that this tree species is faster growing than the oak trees in Figure 5, hence this woodland reaches a steady state sooner.)

The amount of carbon the woodland is permanently storing, therefore, is adjusted downwards depending on the size and frequency of the disturbances. We look at the following kinds of disturbance of woodlands: (1) commercial felling of trees, (2) loss of woodland due to development, (3) loss of woodland to other uses, (4) natural disturbances such as disease, storms, floods and wildfires.

Commercial felling of trees

Woodland is often managed for the commercial growth and felling of trees, so that income from timber sales can be earned. Felling and re-growing trees impacts the average quantity of carbon stored in the woodland, in a similar way to the disturbances shown in Figure 6. Under the WCC, the schedule of tree felling is agreed in advance, and the number of woodland carbon units the landowner can claim is adjusted downward accordingly. So long as these adjustments are made to the quantity of carbon storage claimed, commercial management of woodland is consistent with permanent carbon storage.

Loss of woodland due to development

Woodland can be replaced by development, for example building new houses. This is a disturbance unlike those shown in Figure 6, because trees are felled but not re-grown, so previously stored carbon is released and not re-stored.

Rates of woodland loss to development in the UK are currently very low. Data from the Forestry Commission suggests currently around 0.03% of woodland in England is lost each year to development.[39] (Statistics for devolved governments are not available for some metrics. Defra figures for England are used where this is the case.) This rate may not remain the same in the future – it is possible it could either decrease or increase over the very long run. There is good reason to believe the rate could fall as a result of the introduction of

[39] This estimate is based on Forestry Commission (2023) data for England, averaged over 2013-21.

Biodiversity Net Gain requirements from 2024, as described in the woodland case study in the consultation. It is also possible that in the very long run increased pressure from development could result in the rate rising. There is currently no substantive evidence on how this rate is likely to change over the long time periods relevant to carbon storage.

As an illustrative exercise, we can extrapolate into the future using the current rate of woodland lost to development. This is not a forecast, for the reasons outlined above, but it gives an indication of the potential degree of permanence of UK woodland, based on current rates. At an annual rate of loss of 0.03%, 97% of new UK woodland would still exist after 100 years, and 75% would still exist after 1,000 years.[40]

Finally, it is also possible that woodland covered by the WCC will have a lower rate of loss to development compared to average UK woodland. Evidence consistent with this hypothesis is that to date, the WCC buffer has not been used for any purposes, including woodland lost to development. (See Box 2 for an example of how this would work.)

Loss of woodland due to other uses

Current data suggest that UK woodland of the kind supported by the WCC is not lost to uses other than development. Forestry Commission data suggest that currently woodland is lost only to development or to habitat restoration.[41] Habitat restoration occurs on sites where commercial timber forests were in the past planted on biodiverse heathland, peatland and wetland. Removing these forests and restoring the land's previous habitat has significant environmental benefits. This is unlikely to apply to new woodland planted under the WCC, which would effectively prohibit woodland creation on these habitats.

It is a theoretical possibility that woodland could be lost to other uses in the distant future, for example to agriculture. Currently in the UK, no woodland is legally lost to agriculture. There is no evidence we are aware of on potential future rates of loss of this kind.

Natural disturbances such as disease, storms, floods and wildfires

Woodlands can be impacted by natural disturbances, including disease, storms, floods and wildfires. There is a relatively strong evidence base on the prevalence of many of these disturbances in the past and current data. Natural disturbances in the UK are estimated in the National Forestry Accounting Plan of the United Kingdom 2021-2025. Wildfire, extreme weather, geological disturbances, and insect pests and diseases are all considered and result in an annual average loss of woodland to natural disturbance of 0.14% per year. The vast majority of woodlands are restocked after a natural disturbance. If the average impact of disturbances is incorporated into storage estimates in advance, this means that rather than causing a permanent loss, these disturbances slightly reduce the long-term carbon stock average of UK woodlands.[42]

Where these disturbances do not impact the long-run health of the woodland and where their impacts are already anticipated in quantities of carbon claimed to be stored, they would not reduce the permanence of the carbon stored in the woodland. There is currently a lack of

[40] These figures can be compared to estimates of carbon storage for engineered GGRs of >99.9% after 100 years and >99% after 1,000 years, as described in the Geological storage in the UK case study in the consultation.
[41] See Forestry Commission (2023).
[42] See UK National Forestry Accounting Plan 2021-25. Losses from are estimated to average 4,500 hectares per year.

comprehensive quantitative evidence on the impact of these disturbances on the permanence of carbon storage.

All of these disturbances are expected to increase as a result of climate change.[43] However, there is currently no evidence quantifying the potential impact of future changes on the permanence of carbon stored in woodlands.

Cost and quantities of woodland

In this section, we summarise evidence on the costs and quantities of woodland GGRs relevant to ETS integration.

The Woodland Carbon Code (WCC) is a government-backed, voluntary carbon market for UK woodland GGRs. It has been in operation since 2011. For the most recent year of available data (2022/23), it incentivised new woodland creation that will remove and store 0.04 Mt per year on average over the next 100 years.[44] This falls short of our woodland carbon targets, which are estimated to require woodland creation resulting in the storage of 0.78 Mt per year by Carbon Budget 6 (2033-37).[45]

In 2023 the average carbon price in the scheme was £25/t, up from £19/t in 2022.[46] However, woodland creation under the scheme is also incentivised by other payments, including significant up-front government grant income.[47] The effective carbon price, if the grant income were converted to a carbon price equivalent, is therefore considerably higher than the headline carbon price under the WCC. The present value of expected future carbon payments under the WCC for typical woodlands in England, Wales and Scotland is estimated at £1,400-1,600 per hectare.[48] This compares to grants which were £13,400 on average in 2022/23 in England,[49] up to £12,000 per hectare in Wales,[50] and up to £7,500 per hectare in Scotland[51]. On average, the WCC carbon price is therefore estimated to make up only up to 19% of the total income from carbon sequestration plus grants. We can also compare WCC carbon income to total costs of woodland creation, which are estimated at £7,000-£10,000 per hectare.[52] This

[43] See Forestry Commission (2010).
[44] See Woodland Carbon Code, Statistics. In the year ending Mar 2023, there were 377 additional WCC projects validated or awaiting validation. Projected carbon sequestration for these projects is 4.2 MtCO2 over 100 years.
[45] This figure is an internal Defra estimate, based on Carbon Budget Delivery Plan projections for England, scaled up to the UK.
[46] See Woodland Carbon Code, UK Carbon Prices, 'Volume Weighted Average Price per PIU – Nominal Terms' for 2022 and 2023.
[47] Woodland creation can also result in income from commercial timber sales. However, payments for removing and storing carbon under the Woodland Carbon Code are adjusted depending on how a woodland's trees are managed. If they are to be periodically commercially felled (to an agreed schedule), then carbon payments are adjusted downwards to reflect the reduced steady-state carbon storage the woodland provides.
[48] These are internal Defra estimates, using Woodland Carbon Code parameters to calculate carbon storage over time by woodlands with representative species mixes and management practices. Woodland in England and Wales is assumed to be 70% broadleaf and 30% confier, generating on average 115 carbon units over 20 years (after a 20% contribution to the WCC's buffer). In Scotland the woodland mix is assumed to be 40% broadleaf and 60% conifer, reflecting different average mixes observed in the past, resulting in 130 carbon units over 20 years. The present value figures are calculated over a 20 year period using the standard Green Book discount rate of 3.5%.
[49] See England Woodland Creation Offer.
[50] See Woodland Creation Grant: overview.
[51] See Woodland Creation.
[52] Defra analysis of evidence of from existing England Woodland Creation Offer funded sites . The costs of woodland creation include: (1) costs of planning, establishment, and maintenance, including tree saplings,

suggests WCC carbon income is equivalent to up to 17% of the total estimated costs of woodland creation.

If carbon pricing was the only policy intervention supporting woodland creation, then the above estimates suggest that the price would need to be significantly higher than the current Woodland Carbon Code price of £25/t, to make up the gap currently filled by grant income.

There is a second reason we could expect higher carbon prices for woodland in the future. As outlined above current woodland planting rates would have to increase significantly to meet woodland creation targets. In England, for example, planting rates would need to increase 5-fold, from their current rate of around 2,000 hectares per year to around 10,000 hectares per year.[53] If the cost curve for woodland planting is upward sloping, then we would expect higher costs at these significantly higher levels of supply. For example, it is possible that landowners may require higher incentives to plant trees in the future, to overcome barriers such as cultural attitudes to tree planting and increased competition for land.[54]

This evidence suggests that, if UK ETS prices were to follow the published DESNZ traded carbon value projections, then UK ETS integration alone would not lead to woodland targets being exceeded.

shelters, fencing and labour costs; (2) costs associated with selling carbon, including registry fees, validation of the project, and verification of carbon sequestered by the woodland over time; (3) insurance costs to protect against extreme weather events or Public Liability insurance to cover costs of claims made by third parties; (4) timber production and harvesting costs, including removal of wood material. Costs vary depending on geographical factors and the type and size of the woodland being created.

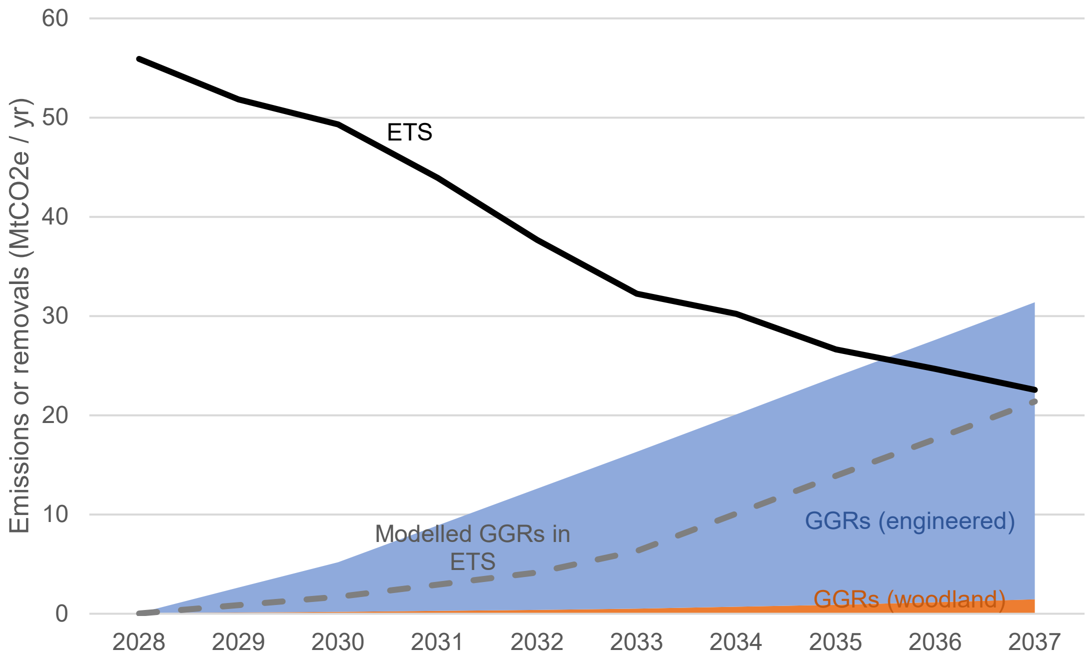
[53] See Impact Assessment for Environment Act Targets – Tree Canopy and Woodland cover target (2022).

[54] We would expect an upward sloping cost curve if woodland creation initially came from land with low direct costs of woodland creation (planting the trees) and also low opportunity costs (less productive farmland). If, as more woodland was planted, both the direct and opportunity costs rise, then we would see an upward sloping cost curve.

Pathways

The consultation sets out options for a pathway for integrating GGRs into the UK ETS. Figure 7 illustrates the quantitative context for these policy decisions, for 10 years from the earliest possible date of integration, 2028. It reproduces the relevant pathways quantities of removals from GGRs (engineered and woodland) and emissions by UK ETS sectors from the Net Zero Strategy (2021).[55] We would not expect all GGRs in the NZS to enter the UK ETS, for example voluntary carbon markets already support some UK woodland GGRs and their role is likely to grow. However, the figure illustrates the potential dynamics of the sectors involved in these policy decisions. It does not include any GGR supply or demand controls.

Figure 7: Illustrative net zero strategy pathways for GGRs and UK ETS emissions.



Sources: Net Zero Strategy (2021) and internal DESNZ modelling. UK ETS emissions after 2030 are projections consistent with the net zero strategy, not based on legislated annual caps. Figures do not include any UK ETS scope expansion. GGR trajectories are illustrative pathways subject to considerable uncertainty. For a description of assumptions underpinning Modelled GGRs in UK ETS, see section 'Modelling methodology' above.

No decision has yet been made around when GGRs would be integrated into the UK ETS, but the consultation outlines 2028 as the earliest possible date this could happen. Figure 7 suggests that there are likely to be only small quantities of GGRs in the UK at that time. If GGRs were integrated in 2028, this could lead to a gradual increase in GGRs, with effectively a natural pilot period at the start before more significant growth picks up. If GGRs are integrated at a later date, this gradual phase in would not be so possible without additional supply controls, as mentioned in the consultation.

[55] See footnote 22 for a description of how the total GGR trajectory was constructed, and footnote 23 for a description of the modelled GGRs in UK ETS trajectory.

The consultation also considers the role additional demand or supply controls as part of a pathway to GGR integration. The consultation proposes that such controls are not needed for the purposes of so-called mitigation deterrence, the risk that UK ETS emissions could increase relative to a counterfactual of no GGR integration. As outlined in the Cap Section, if the Authority implements their minded-to position of maintaining the cap, then this eliminates the potential for mitigation deterrence. There is no clear economic rationale remaining for demand or supply controls to address this issue. As outlined in the consultation, there may be other secondary reasons to adopt demand or supply controls.

When considering both the timing of integration and demand or supply controls, there is an economic cost to delaying GGR integration or quantitative controls. Both types of measures reduce the strength of the demand signal given to GGR investors, and proportionately reduce the benefits of intervention outlined in the Economic rationale section.

Analysis for the Government Response

The Government Response to this consultation will develop further evidence of three broad types. First, it will explore development and refinement of the preliminary analysis presented above of potential impacts of GGR integration on the UK ETS market. This will support decision making that maintains market integrity and safeguards the central role of the UK ETS in the UK's approach to net zero.

Second, it will present a cost-benefit analysis of integrating GGRs into the UK ETS. This cost-benefit analysis will include the following impacts:

- **Negative GHG emissions (monetised benefit):** integrating GGRs into the UK ETS will support GGR supply, leading to negative emissions, which are a social benefit.
- **UK ETS gross emissions (monetised benefit):** UK ETS gross emissions could be impacted by GGR integration, depending on the cap option adopted. Emissions reduction is a social benefit.
- **Technological innovation (non-monetised benefit): UK** ETS integration is likely to accelerate GGR supply. Given many GGRs are novel technologies, this is likely to result in innovation in the form of learning-by-doing cost reductions. These cost reductions will lower the cost to society of procuring future GGRs, so they represent a social benefit.
- **Purchasing allowances (monetised transfer):** UK ETS compliance entities need to purchase allowances from the government and GGR suppliers. This is a transfer not an economic cost or benefit.
- **GGR supply costs (monetised cost):** GGR supply incentivised by UK ETS integration has an economic cost equal to the cost of supplying GGRs.
- **UK ETS abatement costs (monetised costs):** if UK ETS gross emissions are impacted by GGR integration, then this will impact abatement costs.
- **Administrative costs (non-monetised cost):** there are costs, for example associated with MRV or the sale of allowances on the secondary market, that GGR suppliers selling into the UK ETS would incur.
- **Wider impacts of woodland creation (monetised benefit)**: non-carbon benefits of woodland creation include biodiversity, recreation, air quality, and water quality improvements.

The approach to quantifying both market impacts and monetizable benefits, costs and transfers outlined above will be based on using the Carbon Market Model.[56] We can use the standard version of the model and augment it with an assumed exogenous pathway for GGR supply (as presented in this annex). We will also explore the feasibility of developing modelling of endogenous GGR supply pathways, where supply responds to traded carbon values in the model. Either approach will give a pathway of GGR supply, traded sector emissions and abatement, and traded carbon values. These quantities can be used to estimate many of the benefits and costs identified above. When estimating the monetised wider benefits of woodland

[56] See DESNZ Traded carbon values used for modelling purposes (2023).

creation, we would follow Enabling a Natural Capital Approach guidance.[57] For the non-monetised benefits and costs, a qualitative assessment will be given.

Third and finally, the Government response will present further evidence on the permanence of different types of GGRs. This will include attempting wherever possible to fill the evidence gaps identified in the Woodland section of this annex.

[57] See Enabling a Natural Capital Approach guidance (2020).

This consultation is available from: www.gov.uk/government/consultations/integrating-greenhouse-gas-removals-in-the-uk-emissions-trading-scheme

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