Analytical Annex to Integrating Greenhouse Gas Removals in the UK Emissions Trading Scheme: Main Response

July 2025

Contents

Introduction and Purpose

The UK Emissions Trading Scheme (UK ETS, hereafter) Authority conducted a comprehensive consultation on the integration of greenhouse gas removals (GGRs, hereafter) into the UK ETS in May 2024. The Authority has now responded to the consultation, reflecting the feedback received and outlining the next steps in this policy area.

This analytical annex provides a detailed summary of the analysis that underpins the decisions regarding the integration of GGRs into the UK ETS. This annex aims to present the evidence, methodologies, and rationale behind the proposed changes, ensuring transparency and clarity in the decision-making process. By doing so, it seeks to inform stakeholders and the public about the analytical foundations of the policy decisions.

The scope of this analysis encompasses several key areas critical to the integration of GGRs into the UK ETS:

1. Cap: Examination of how GGRs will be incorporated into the existing cap and trade system.
2. Allowance Design: Considerations on the design of allowances and their distribution.
3. Pathways: The benefits inclusion can bring to GGRs operators through providing investment certainty.
4. Permanence: Analysis of the permanence of GGRs, ensuring that the removals are long-lasting and contribute effectively to the UK's net-zero targets.

Evidence on the role of woodland and forestry as a GGR technology in the UK ETS including the potential for afforestation and reforestation projects to contribute to long-term carbon sequestration, is covered in the Woodland Evidence Annex.

It is important to note that this analysis does not include a cost-benefit analysis at this stage. A detailed cost-benefit analysis will be produced in conjunction with a response to a subsequent technical consultation. This phased approach allows for a more thorough examination of the economic implications of integrating GGRs into the UK ETS. We welcome input from stakeholders in developing that cost-benefit analysis.

Background and Policy Context

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[1] within the cap are distributed to participants primarily via auctioning, with a proportion given out through free allocation.[2] The system 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 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-wide Net Zero Strategy and the Carbon Budgets of Scotland, Wales, Northern Ireland, and the UK.[3] The Net Zero Strategy has a trajectory based on each sector in the economy, and when summed over all sectors these give the total permitted emissions each year. UK ETS participants are spread over several sectors[4], with the UK ETS cap consistent with the share of expected future emissions under the net zero strategy for the covered sectors.

The UK ETS covered around 25% of UK territorial emissions in 2023.[5] The Authority is developing proposals to expand the scope of the UK ETS to include energy from waste and maritime emissions.[6] 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.[7]

Problems Under Consideration and Rationale for Intervention

Introduction to Greenhouse Gas Removals (GGRs):

GGRs are technologies or processes which remove greenhouse gases from the atmosphere.[8] Broadly two types of GGRs exist: nature-based (such as woodlands) and engineered (such as

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[1] Each allowance represents a permit to emit one tonne of CO_2 equivalent (tCO_2e).

[2] Free allocation is given to businesses deemed at risk of carbon leakage (offshoring emissions as the result of UK policies being stricter that in other jurisdictions)

[3] 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.

[4] Including 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

[5] DESNZ analysis based on Provisional UK greenhouse gas emissions https://www.gov.uk/government/statistics/provisional-uk-greenhouse-gas-emissions-national-statistics-2023

[6] See consultations on UK ETS Waste (May 2024) and Maritime (November 2024)

[7] See The long-term pathway for the UK ETS (December 2023).

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

Direct Air Carbon Capture and Storage). This document focuses on engineered GGRs and evidence around nature-based GGRs is discussed in the Woodland Evidence Annex. The use of 'GGR' in this document refers specifically to engineered GGRs only.

UK GGRs are projected to play a key role in the way nations across the UK reach net zero.[9] The Net Zero Strategy projects the need for between 75Mt and 81Mt of removals per year by 2050.[10]

GGRs are essential in addressing the residual emissions[11] that are difficult to eliminate through direct emission reductions. They provide a critical pathway to achieving the UK's legally binding net zero targets by 2050. There are a wide range of engineered GGR technologies, and we aim to support a mix of technologies to help them achieve commercial viability. We believe this will be essential to reduce reliance on any single technology, allow innovative and highly-scalable solutions to demonstrate cost reductions, and spur the growth of a resilient market that can support decarbonisation at the lowest cost to business while maximising the benefits to the UK economy.

Examples of Engineered GGRs:

- Direct Air Carbon Capture and Storage (DACCS) technologies extract CO_2 directly from the atmosphere at any location. The CO_2 can be permanently stored in deep geological formations.
- Bioenergy with carbon capture and storage (BECCS) technologies can combine the conversion of sustainable biomass, biogas and biogenic wastes into electricity, heat, hydrogen or fuels while also capturing a high percentage of the CO2 emissions contained in that biomass in long-term storage in geological sequestration.

While GGRs offer significant potential, they also face challenges such as high costs, high energy requirements, and the need for robust regulatory frameworks.[12] However, ongoing research and development are paving the way for more efficient and cost-effective solutions.[13]

The UK government is actively supporting the development and deployment of GGR technologies through various initiatives and funding programs. This includes the integration of GGRs into the UK ETS and designing business models to incentivise private investment in GGR projects. The GGR business model is based on a contract for difference (CfD, hereafter) style structure.[14] Subsidies under a CfD contract are determined by the difference between a 'Strike Price' reflecting the cost of producing removals and a 'Reference Price' reflecting the market value of the removal. The key priorities for support are to provide revenue certainty for developers, to stimulate the market for removals, and to deliver GGRs cost effectively.

Rationale of Integrating GGRs into the UK ETS:

GGRs are a group of methods that actively remove greenhouse gases, predominantly CO2, from the atmosphere for highly durable storage, achieving negative emissions; this is their output. Importantly, GGRs remove more greenhouse gases than they emit through their lifecycle achieving negative emissions. Given that everyone benefits from the reduction of

[9] See Carbon Budget Delivery Plan (March 2023) and CCC Carbon Budget 7 (February 2025)
[10] Net Zero Strategy: Build Back Greener (October 2021)
[11] Emissions in the most hard-to-abate sectors that cannot be decarbonised completely.
[12] See DESNZ government response to consultation on GGR business model (June 2023)
[13] DESNZ Greenhouse gas removal methods: technology assessment report (October 2021)
[14] See DESNZ government response to consultation on GGR business model (June 2023)

damages from climate change provided by this output, and nobody can be excluded from the benefits, GGRs are deemed a pure public good. However, this presents a challenge, the so-called 'free-rider problem.' Since everyone benefits from GGR outputs, some may not feel the need to pay for it themselves expecting others will cover the cost. This leads to fewer parties paying for the technology and so less carbon is removed from the atmosphere than needed. This provides the rationale for intervention because deployment of GGR technology is widely considered necessary for the UK to achieve its net-zero targets.

Some GGRs, like power BECCS, produce a private benefit (electricity) alongside a positive externality by removing carbon dioxide from the atmosphere, which leads to a social benefit through the reduction of damages from climate change. However, private markets often fail to fully recognise this benefit because it is not directly reflected in the market price. This means that the true value of the benefit is not accounted for. As such, demand will be lower than optimal for society, and therefore lower quantities will be produced, leading to a less-than-optimal outcome for society.

These issues can be addressed by creating increased demand for the removals (either through direct government support or through the creation of a market like the UK ETS) to encourage greater production by GGR operators. The Government has confirmed its intention to progress work on business models based on a 'CfD' structure, where the reference price represents the sales price achieved by the developer in whichever market(s) they are permitted to sell into – whether that is a voluntary market or a compliance market such as the UK ETS.

Voluntary Carbon Markets (VCM)[15] exist where private firms and individuals can purchase removals credits. Integrating GGRs into the UK ETS will create an additional market for GGRs that is based on compliance obligations under the UK ETS rather than voluntary purchase. Creating market demand for GGRs reduces the level of direct government intervention necessary and provides long term certainty above direct subsidies. This helps to address some of the main market failures associated with GGRs by generating additional demand for GGRs, improving investment certainty, and increasing the potential for innovation spillover effects[16] for future technological development.

Removal allowances in the UK ETS would provide additional potential benefits for UK ETS participants. These allowances would cover their compliance obligations and additionally offer offsetting benefits like those provided by credits from Voluntary Carbon Markets, such as aligning with Corporate Social Responsibility (CSR) commitments. In the long run, removal allowances could also act as additional decarbonisation options for UK ETS participants with very high alternative abatement costs.

We are clear that the purpose of GGRs is to balance the residual emissions from sectors that are unlikely to achieve full decarbonisation by 2050. It is not a substitute for decisive action across the economy to reduce emissions, often referred to as mitigation deterrence.

In the long run, including GGRs in the UK ETS is a necessary condition for moving towards a potential net-zero or net-negative UK ETS.[17] This has further long-run economic benefits by matching supply and demand for decarbonisation options. A net-zero or net-negative UK ETS

[15] A voluntary carbon market is a system where companies or individuals buy carbon credits to offset their greenhouse gas emissions on a voluntary basis, outside of regulatory requirements.
[16] Innovation spillover occurs when an entity benefits from the innovation of another party even if it did not directly invest in that innovation.
[17] ICAP, ETS, Reloaded? Designing Emissions Trading for Net-Zero and Net-Negative Societies, 2025

would have a cap where all emissions are matched or exceeded by removal allowances. In the future, all allowances in the system could come from GGRs, in which case all residual emissions from compliance entities are matched by a removal, leading to net zero emissions from the system overall. We would only do this once removals deployment is more established (giving us a better understanding of future deployment) and we have made significantly greater progress towards residual emissions (i.e. when the only remaining emissions are those that are hard to abate, for example due to technical or economic constraints). This could be the long-run future direction of the scheme, as it would underpin an economically efficient approach to net zero.

Objectives

The Authority outlined several guiding principles for policy design for integrating removals into the UK ETS. Four key principles are: to drive the efficient long-term deployment of GGRs; maintain the incentive to decarbonise; ensure fiscal impacts maximise value-for-money for the taxpayer; and maintain market integrity.

The government is minded-to differentiate UK ETS allowances and has decided to maintain the cap. These impacts are discussed further in the Costs and Benefits of Policy Decisions section with due regard to this position.

Cost and benefits of policy decisions

This analytical annex supports the government response to the May 2024 consultation.[18] Analysis used to inform policy decisions made in response to this consultation is set out below.

Benefits will primarily accrue to society through reduced levels of greenhouse gas emissions in the atmosphere and corresponding lower global warming impacts, as well as to GGR operators through the value achieved from their sales and UK ETS participants who value GGRs above UK Allowances (UKAs) if allowances are differentiated. The costs will primarily include reduced revenues from a lower number of UKAs being auctioned and risks of negative UK ETS market impacts such as liquidity.

Benefits

The main benefits of integrating GGRs into the UK ETS come from lowering overall net UK emissions and the increased demand for GGRs compared to not integrating GGRs into the UK ETS. Further benefits to GGR operators exist from improved investment certainty and the potential realisation of a price premium for removals credits.

Removal of Emissions

Integrating GGRs into the UK ETS will allow sales of removal allowances into a new market and create additional demand, creating a positive price incentive for additional GGR deployment. The level of expected deployment of GGRs is highly uncertain due to the nascent nature of the technology and current development of supporting policy framework.[19]

An estimate for their integration into the UK ETS was presented in the 2024 analytical annex,[20] assuming around 1/3rd of overall GGRs credits sell into the UK ETS. We are continuing to develop our understanding of the level of GGRs and will quantify the removal benefits in an impact assessment at a later date. For further information, please refer to the Further Planned Analysis section.

Investment Certainty

The Authority will aim to legislate to integrate removals in the UK ETS by the end of 2028, aiming for integration to be operational by the end of 2029, subject to further consultation, bringing investment certainty for projects, while taking into account the feasibility of adjusting the UK ETS to accommodate the change.

GGR integration into the UK ETS will help to create a new market for removals to sell in to. Providing increased revenue certainty for GGR operators by offering UK ETS integration could lower the cost of capital, reducing project costs and any related fiscal support, such as through any interaction with subsidies via the GGR business model or power BECCS business model.[21]

Investment risks for GGR operators can be reduced by providing a reliable market for GGRs to sell into. Reducing these risks can lower hurdle rates for investments, which in turn can greatly reduce the overall cost of a project.

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[18] Integrating greenhouse gas removals in the UK Emissions Trading Scheme (May 2024)
[19] See Update on the design of the Greenhouse Gas Removals (GGR) Business Model and Power Bioenergy with Carbon Capture and Storage (Power BECCS) Business Model (December 2023)
[20] Integrating greenhouse gas removals in the UK Emissions Trading Scheme (May 2024)
[21] Business model for power bioenergy with carbon capture and storage (Power BECCS) - GOV.UK

The hurdle rate is the minimum acceptable rate of return on an investment. When risks are reduced, investors require a lower return to compensate for the perceived lower risk, leading to overall cost reductions for the project.

This reduction in project costs could result in potentially large savings for GGR operators and reduce the risk for any related government support. By lowering investment risks in this way, benefits could span across GGR investments in both the UK ETS and the VCM.

Estimates of the impact of policy certainty on the cost of capital found a 140-320 basis point reduction for offshore wind when revenue stabilisation, via CfDs, was introduced relative to a position where no revenue stabilisation was being provided. [22] [23] These are different markets to GGRs but give an illustration of potential benefits from increased certainty.

Potential for Price Premium Through Differentiated Allowances

There are potentially significant benefits to differentiating allowances. These benefits are in the form of increased transparency and the potential for price discovery. These must be carefully balanced against introducing any new risks to the scheme, principally in the form of potential impacts on the liquidity of the UKA market. The issues are discussed in further detail below.

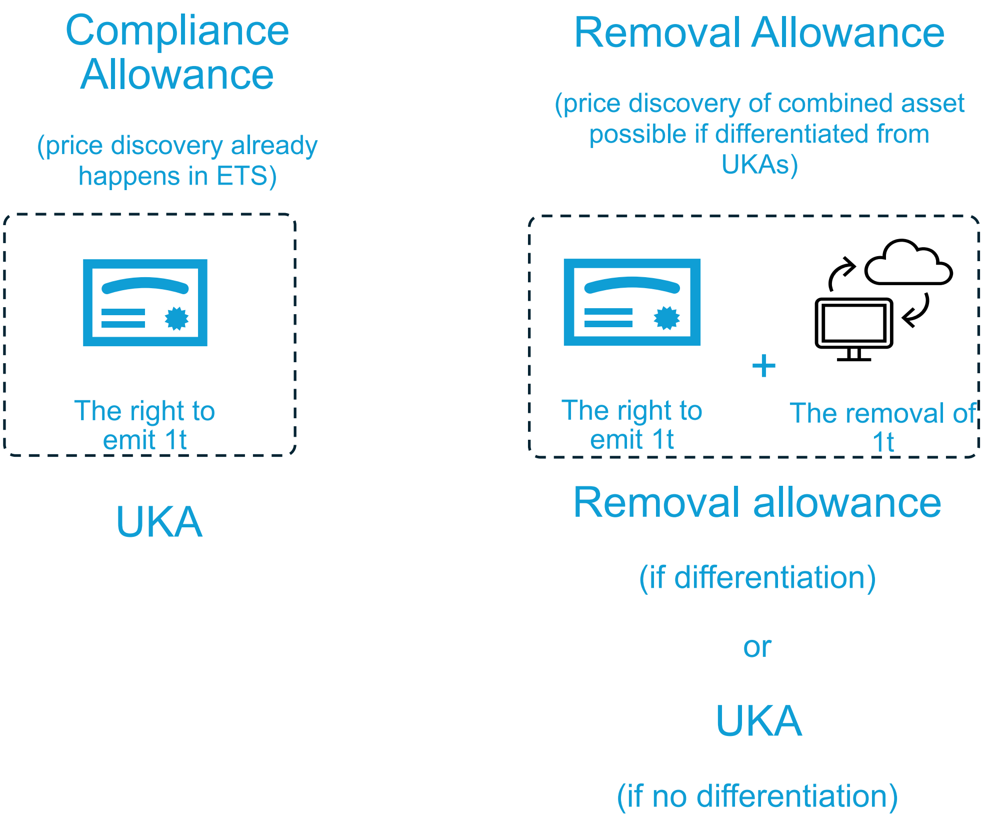
Policy options not to create a new type of allowance, or to differentiate removal allowances by technology type have also been considered. Not creating a new type of allowance would reduce the potential benefits discussed below to materialise but would limit risks to market integrity, while differentiating removal allowances by technology type could allow for further price discovery, but poses further risks to ETS liquidity in a way that could have negative market integrity impacts.

Price Discovery

In general, price discovery is defined as being able to find an accurate, efficient price for buying or selling an asset at a given point in time.[24] In the context of GGRs, we take price discovery to mean the market being able to find an accurate, efficient price for assets traded in the UK ETS with GGRs.[25] As shown in Figure 1, these assets have two components: compliance with UK ETS regulations, and the removal of CO_2.

[22] ARUP, Cost of Capital Benefits of Revenue Stabilisation via a Contract for Difference (2018)
[23] One basis point is 0.01%. Therefore 140 – 320 basis points is 1.40% - 3.20%
[24] Evaluation of the UK Emissions Trading Scheme: Phase 1 report
[25] In this context, an efficient price refers to a price that accurately reflects the true value of the asset, considering both its compliance with UK ETS regulations and its contribution to the removal of CO_2.

Figure 1: Illustration of UK ETS allowances under differentiation and non-differentiation



It may be that UK ETS market participants value UKAs and removal allowances differently as removal allowances provide an additional benefit of removing 1 tonne of CO_2. As such, purchases of removal allowances could be considered a strategic premium for operators.[26] If removal allowances are valued more highly, then price discovery in a market with differentiation could lead to a price premium for removal allowances, over and above the UKA price. This would have two benefits:

1. It would lead to an efficient market outcome. Higher prices for removal allowances could (in the long run) incentivise higher GGR deployment. This would benefit UK ETS participants who value GGRs, as well as benefiting UK carbon budgets, and GGR operators. Without differentiation it would not be possible to realise this price difference.
2. It may lower the fiscal impact of other potential policies supporting GGR deployment. If a price premium is established, this higher achieved sales price for GGRs would decrease the difference between the strike price and reference price in a business model based on a 'CfD' structure, lowering the cost to government.

There is limited evidence on the extent that UK ETS participants would value removal allowances above UKAs, though 76% of consultation respondents said they thought that differentiated allowances would attract higher prices than existing emissions allowances.

One source of evidence outside of the UK ETS comes from New Zealand where the government allows the use of allowances from removal activities mainly generated in the forestry sector.[27] My Native Forest Limited is a NZ-based company that operates a platform

[26] A strategic overpayment that enhances intangible aspects like brand image but does not directly improve profits or the balance sheet.
[27] https://www.mpi.govt.nz/forestry/forestry-in-the-emissions-trading-scheme/

which connects landowners with carbon buyers across New Zealand and follows the prices of New Zealand Units (NZUs)[28] and Verified Carbon Units (VCUs). VCUs are an NZU that My Native Forest has verified as coming from a permanent native forest and are effectively the same as Asset 2 in Figure 1 above.[29] Data from My Native Forest shows that VCUs have around a 20% price premium on NZUs, suggesting that New Zealand ETS participants value the removals element of the assets as an additional positive element to the compliance element.[30]

An alternative risk is that removal allowances could see a price discount compared to compliance allowances. Fundamental aspects of GGR integration into the UK ETS, such as seller liability and no demand controls, limit the risk of price discounts occurring in the UK ETS.

- Seller Liability: This ensures that the responsibility for the integrity of the removals credits lies with the seller, which can enhance market confidence and reduce the risk of price discounts.
- No Demand Controls: By not imposing strict demand controls, such as limiting the number of removal allowances that can be surrendered, the UK ETS aims to create a more flexible and responsive market, which reduces the risks of low demand dampening prices.

These fundamental differences are designed to limit the risk of price discounts occurring in the UK ETS, making it a more robust and reliable system for integrating GGRs.

Costs

While significant benefits are expected, there are risks to integrating GGRs to the UK ETS. These primarily focus on market impacts for UK ETS participants. Revenue risks are considered in the Fiscal Impacts section. Additionally, the Authority intends to implement transitional supply controls to ensure market stability and overall value for money during integration.

Price Risks from Integration

Evidence was provided in the May 2024 analytical annex[31] on potential impacts from cap options. That analysis remains the key evidence used by the Authority to decide that maintaining the gross cap[32] is how GGRs will be integrated into the UK ETS.

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 overall long-term impact on UKA prices (though specific price risks are discussed in the following sections). Figure 2, below, shows different sensitivity scenarios of projected carbon values in the UK ETS under the baseline of not integrating GGRs. It also shows carbon values under the 'maintain the cap' policy option, resulting in traded carbon values at the same level for both GGR integration and under the baseline for corresponding sensitivity scenarios. We

[28] NZUs are the primary unit of trade in the New Zealand Emissions Trading Scheme (NZ ETS). Each NZU represents one tonne of CO_2e. Participants must surrender NZUs to cover their greenhouse gas emissions.
[29] One VCU corresponds to one metric tonne of carbon dioxide-equivalent emissions that have been sequestered by a native forest.
[30] https://www.mynativeforest.com/carbon-price-nz
[31] Integrating greenhouse gas removals in the UK Emissions Trading Scheme (May 2024)
[32] Gross cap is defined as the sum of compliance allowances and removal allowances.

would also expect gross emissions to be unchanged from the counterfactual, as the gross cap is unchanged.

When compared to increasing the gross cap or setting a new net cap, another feature of this cap option is the elimination 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[33] whatever GGR supply is realised. This eliminates some uncertainty in traded carbon values or gross traded sector emissions due to GGR supply uncertainty.

Net emissions (emissions from UK ETS sectors plus the GGRs selling into the UK ETS) would be lower than the counterfactual. When a removal allowance is created, emissions in the atmosphere fall through two mechanisms. Firstly, each removal allowance is only created once a net removal has been verified as having been delivered, reducing the level of CO_2 in the atmosphere. Secondly, as a result of our decision to maintain the UK ETS gross cap, the Authority will correspondingly reduce the number of compliance allowances, meaning covered installations emit 1 tCO_2 less than they would have otherwise. Any reduction in auctioned UKAs would result in lower auction revenues.

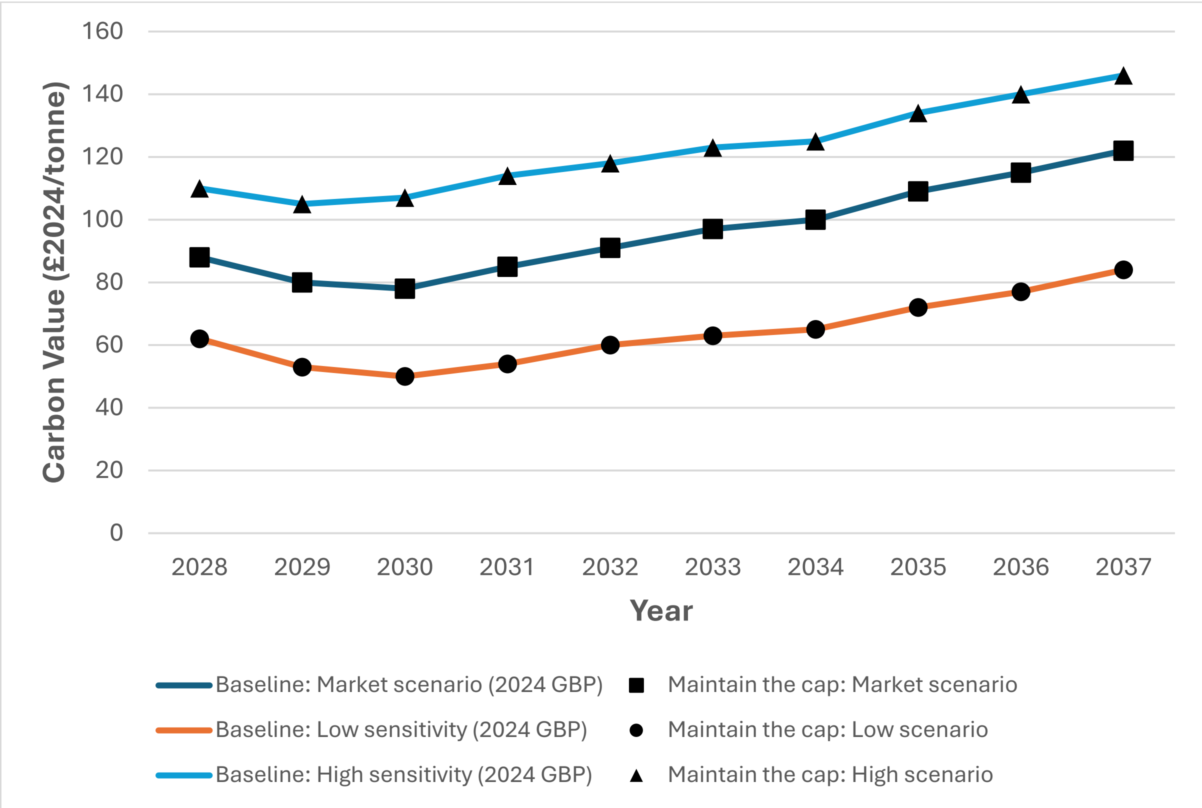
Maintaining the gross cap is considered the best option as it maintains the incentive to decarbonise, reduces fiscal impacts compared to increasing the cap[34], and maintains the market integrity of the UK ETS by reducing risks arising from uncertainty supply of GGRs.

Other policy options considered were increasing the gross cap, and creating a new net cap. Increasing the gross cap would increase total emissions and would not be compatible with Carbon Budgets and the policy objective to maintain the incentive to decarbonise. The increase in supply of allowances was also expected to reduce allowances prices significantly, resulting in higher revenue losses than maintaining the gross cap, which is inconsistent with the policy objectives to deliver value-for-money of any fiscal impacts. A new net cap has advantages around matching supply and demand but risks significant market impacts in the near term while the GGR market continues to develop, risking the policy objective to maintain market integrity.

Further analysis of the alternative options can be found in the May 2024 analytical annex.[35]

[33] The counterfactual relates to the UK ETS cap without integration of GGRs.
[34] Modelling from the 2024 Analytical Annex showed the decrease in price from increasing the cap outweighed the volume effect from additional allowances being auctioned.
[35] See Integrating GGRs in the UK ETS Analytical Annex (May 2024)

Figure 2: Modelled impacts of maintaining the gross cap under market, low and high sensitivity scenarios, £/tonne (real 2024 prices)



Note: Market scenario assumes some unobservable market factors that affect the carbon value dissipate over four years, the extent of foresight in the models, returning to the underlying fundamentals reflected above. Low Sensitivity = High Fossil Fuel Prices and Low Economic Growth. High Sensitivity = Low Fossil Fuel Prices and High Economic Growth. Maintain the cap option maintains the gross cap (compliance allowance + removal allowances) by removing one compliance allowance for every removal allowance.

Price Risks from Differentiation – impacts via auction order

With differentiation, the price impact on UKAs would depend on how the marginal buyer[36] of UKAs is affected. It is possible removal allowances could affect UKA prices if the marginal buyer of UKAs switches to purchasing a removal allowance instead.

Exact decisions on how allowances will be auctioned will be considered in the technical consultation. Figure 3 below depicts a stylised sealed-bid auction for UKAs where each bid represents demand for a single UKA and we analyse the impact of introducing a single removal allowance of the UKA price.

In this framework, bids are ordered by decreasing bid price. Each auction has a fixed limit (or cap) on the quantity of allowances available for purchase. The bid which satisfies or spans the final available UKA – corresponding to the auction volume limit - sets the market price that all bids will pay and this bidder is the ‘marginal buyer’. Under the one-in, one-out system of maintaining the cap, if a removal allowance enters the market, then a compliance allowance (UKA) must exit.

[36] The marginal buyer is the consumer who is willing to purchase the next or last unit of a good or service. They are the buyer who is most sensitive to price changes and their willingness to buy that good or service at a specific price. Their bid will be the lowest accepted price and this bid sets the market value in the auction.

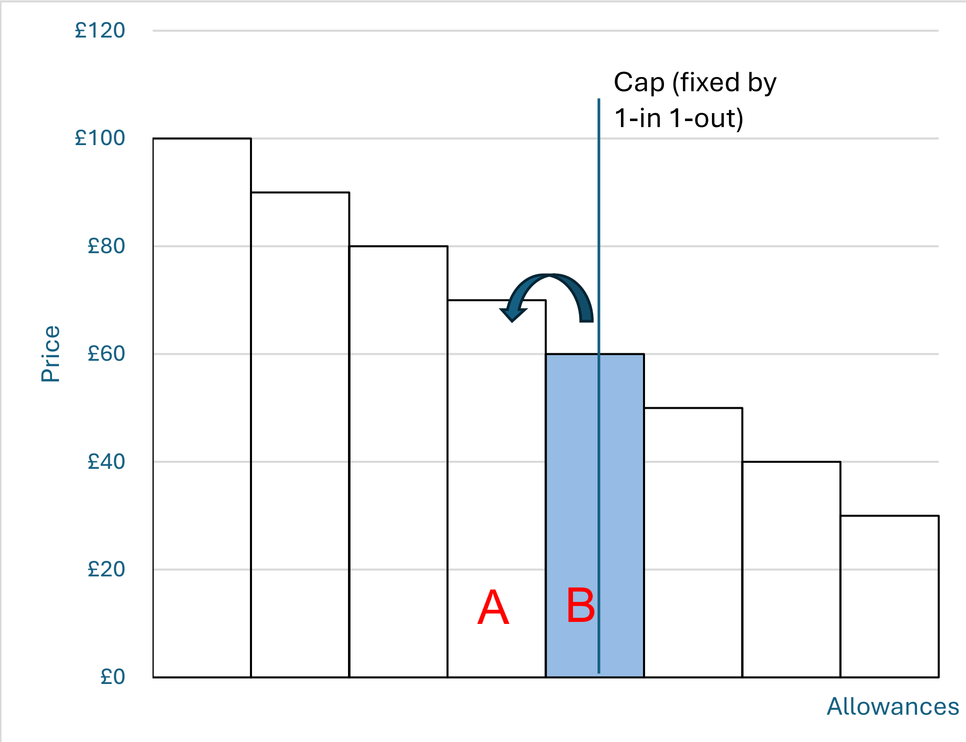
In figure 3, bidder B is the marginal buyer of UKAs. If bidder B instead purchased a GGR allowance, then the counterfactual bid B would be removed from the auction. Then all bids with lower prices (positioned to the right of B) would shift one position to the left. By introducing a single removal allowance in this example, and as a consequence of maintaining the cap, the quantity of UKAs available in the auction falls by one and so the black line in figure 3 also shifts to the left one place. Consequently, bidder A would become the new marginal buyer setting a higher market price for UKAs.

However, if a bidder with a higher bid than the marginal bid (e.g. bidder A) were to purchase a removal allowance then the dynamic changes slightly. A's bid is withdrawn from the auction and all lower bids (including the marginal bid) shift to the left one place. The cap would still be reduced by one unit and the relative position of the bids and cap would be preserved. Therefore, B would remain the marginal buyer and the market price would remain unchanged.

It is unlikely that the purchaser of a removal allowance would typically be the marginal buyer of UKAs. When preparing their bids, emitters weigh the cost of abatement against the price of allowances. Emitters with access to low-cost abatement options would place lower bids, while those facing higher abatement costs would place higher bids, reflecting a greater willingness to pay for compliance. Accordingly, such bids are likely to be placed higher in the order and are less likely to be the marginal buyer.

Given the offsetting nature of removal allowances, they are likely to hold greater value for buyers with limited or costly abatement options. As discussed in the price discovery section, these buyers may be willing to pay a strategic premium for such allowances. It follows, therefore, that purchasers of removal allowances are unlikely to also be the marginal buyers of UKAs. Consequently, if differentiated allowances were introduced, the auction order impacts on UK ETS prices is expected to be minimal.

Figure 3: Stylised ETS auction order for compliance allowances



Price Risks from Differentiation – impacts via allowance route to market and market participants behaviour

As explained earlier, on average we expect minimal price impacts over the long run for businesses due to the Authority's decision to maintain the cap. However, impacts could be possible due to temporal changes in auction supply. Such changes could materialise through the design of how removal allowances enter the market via auctions or market participants behaviour such as withholding allowances.

Carbon prices are sensitive to changes in the supply of allowances. The 'maintain the cap' options will hold the total number of allowances in the UK ETS at the same level as the counterfactual of not integrating GGRs into the UK ETS. Below we have modelled changing the overall supply to illustrate how sensitive modelled carbon values are to changes in supply such as the temporal risks identified earlier.

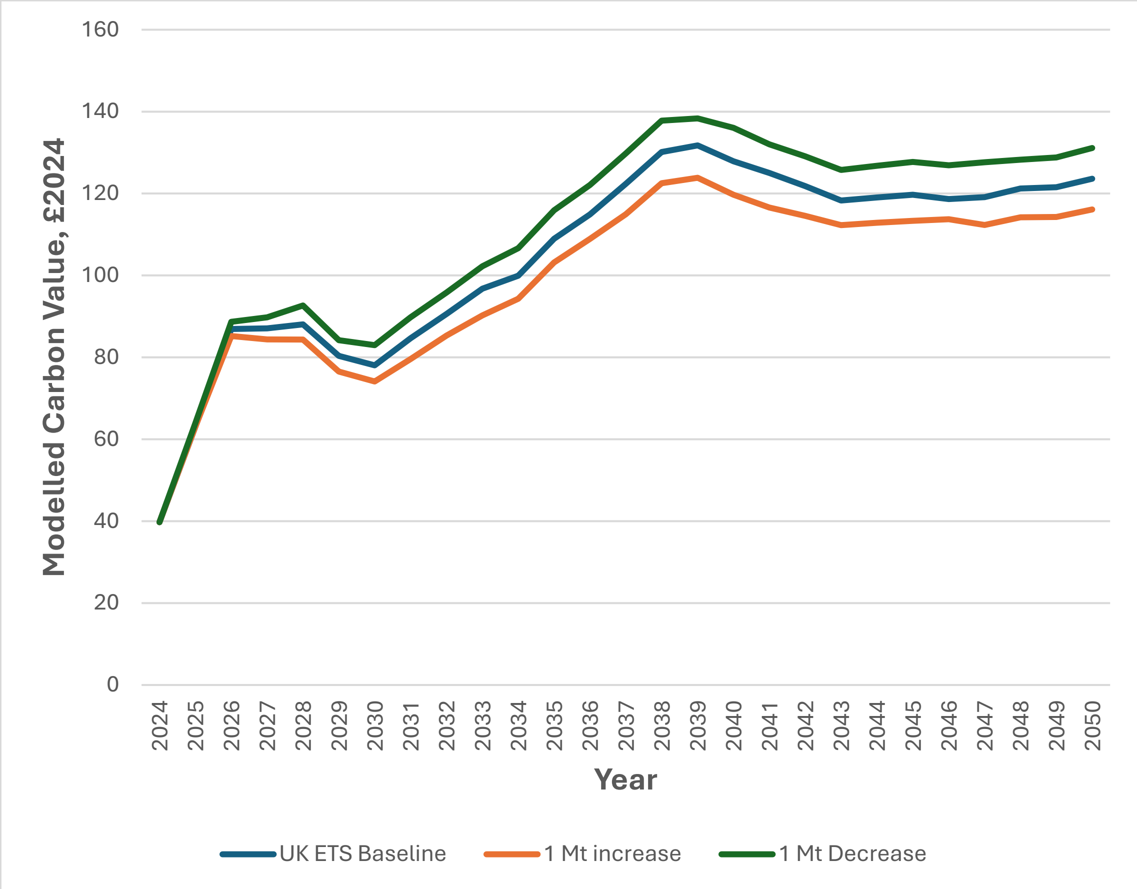
Figure 4 below shows carbon values under the UK ETS baseline level of allowances in the market (blue line). The orange and green lines model the effect of adding and removing 1 Mt worth of allowances per year respectfully compared to the baseline.

In earlier years the impact is smaller as the change in supply makes up a smaller proportion of total supply. In 2028 carbon values change by around ± £4/t. However, in later years the impact grows as the modelled change in allowances makes up a greater proportion of total allowances due to the overall cap falling. By 2050 the impact is ± £8/t.

This analysis is designed to show how the release of allowances can impact price. There is no change to the overall number supplied. This is not an expectation, but simply an exploration of risks.

Decisions on the technical details of how allowances enter the market will be considered in a technical consultation in due course and will be designed to limit market disruption.

Figure 4: Sensitivity of modelled carbon values from changes in allowances supply, £2024/t



Liquidity Impacts

A well-functioning financial market is characterised by its ability to offer a reliable and trusted price discovery mechanism and ensure liquidity in both regular market conditions and times of heightened uncertainty.[37] Price discovery is a process of incorporation of available information (both private and public) into prices. The main goal of this process is to achieve informational efficiency when all relevant information is reflected in the prices. [38]

Liquidity here refers to whether transactions in the secondary markets for all allowance types (i.e. both UKAs and removal allowances) can be executed promptly without generating significant or enduring price impacts.[39] Two counter-opposing effects are possible from allowance differentiation:

1. Splitting the market - If the market divides into different products, the size of each individual market will decrease. While liquidity is not a simple function of quantity of allowances available, this has the potential to decrease liquidity.
2. Volume of trading - Differentiated allowances might lead to higher trading volumes, as new participants are attracted to the market for allowances because of GGRs. This could increase liquidity.

[37] O'Hara, M. (2003) Presidential Address: Liquidity and Price Discovery. The Journal of Finance, 58(4), 1335-1354.
[38] 39 Ibikunle, G (2023). Market quality in emissions trading schemes: a literature review. Presented in Annex 3.
[39] Evaluation of the UK Emissions Trading Scheme: Phase 1 report

Evidence from commodity markets can illustrate how differentiated products can still maintain liquidity in the main market product. The trading of futures contracts related to differentiated products tend to use a benchmark product,[40] resulting in increased liquidity of that benchmark product. If the Authority decides to differentiate, it is possible that creating removal allowances could therefore support liquidity in UKAs for this reason.

Residual risks to liquidity for UKAs still exist. Hedging against a benchmark product relies on the two products maintaining a correlation between each other. If the two products become uncoupled then the benchmark product becomes a poor hedge, which could lead to the market splitting into two separate markets. This is considered relatively unlikely, as it would effectively require such a large price premium that the market saw no link between removal allowances and their value as a compliance instrument.

A further risk exists from the use of offtake agreements. Removal allowances buyers and sellers could manage their risk outside of the UKA market by signing bilateral offtake agreements without the need to hedge with UKA futures. We expect in the short run the number of offtake agreements in the UK ETS will be small as GGR deployment develops and are unlikely to be significant enough to affect the overall liquidity of the market. As removal allowances make up a greater share of total allowances over time, the impact of offtake agreements could rise. This will be explored further in the technical consultation.

[40] Brent Crude oil serves as a major benchmark for pricing oil worldwide

Additional analysis

Defining a Minimum Storage Period

Selecting a suitable a timeframe for the minimum storage period was complex. There is little academic or scientific consensus on a definition for permanent carbon storage periods (The State of Carbon Dioxide Removal - 2nd Edition, 2024).[41] The Authority will require projects to demonstrate a minimum storage period for carbon of 200 years before they are eligible for entry into the UK ETS. This enables a variety of removal technologies to enter the UK ETS recognising the need for a diverse portfolio of approaches to tackle net zero including those which are nature-based solutions (NBS). Enabling NBS, such as woodland, to enter the UK ETS would align with the *Oxford Principles for Net Zero* (2024)[42] where the authors support biological storage's role as a durable carbon store if properly managed. The potential inclusion of NBS opens the possibility of other co-benefits, for example habitat creation and subsequently supporting biodiversity.

There is modelling within the academic literature that cautions against the use of storage with less-than 1000-year durability (Brunner 2024,[43] Matthews 2022[44]). Impermanent storage can delay warming and limit peak temperatures but not abate it. Therefore, the use of impermanent storage still results in continuous warming over several centuries. Matthews (2022)[43] concluded that to achieve net-zero, temporary nature-based removals should only be implemented in conjunction with a drive for rapid reductions in fossil fuel emissions. This is supported by Allen *et. al.* (2022)[45] who argued that within a few decades any continuing fossil fuel emissions should be matched by permanent (geological) storage of carbon in a like-for-like principle in order to achieve net-zero.

Temporary carbon sequestration can reduce the risk of exceeding climate tipping points (Brandão, 2013).[46] Whilst climate modelling indicates that longer duration storage (1000 years or more) is the better option for mitigating climate change, the delayed release of carbon, for at least 200 years, will still provide a climate benefit, in addition it will enable a variety of technologies to enter the UK ETS.

There are pre-existing international compliance schemes which define permanent storage periods. These range from 50 to 200 years (Table 1). Not all these compliance schemes require a minimum storage period per se, for example Quebec has an innovative method which focuses on the climate benefits of carbon sequestered over a 100-year period.

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[41] Smith, S. M.-H. (2024). *The State of Carbon Dioxide Removal - 2nd Edition.*
[42] Axelsson, K. W.-L. (2024). *Oxford Principles for Net Zero Aligned Carbon Offsetting (Revised 2024).* Oxford: Smith School of Enterprise and the Environment, University of Oxford.
[43] Brunner, C. H. (2024). Durability of carbon dioxide removal is vital for Paris climate goals. *Communications: Earth & Environment, 5*, 645.
Groom, B. V. (2023). The social value of offsets. *Nature, 619*, 768-773.
[44] Matthews, H. D.-M. (2022). Temporary nature-based carbon removal can lower peak warming in a well-below 2 °C scenario. *Communications: Earth & Environment*. doi:10.1038/s43247-022-00391-z
[45] Allen, M. R., Friedlingstein, P., Girardin, C. A., Jenkins, S., Malhi, Y., Mitchell-Larson, E., . . . L., R. (2022). Net Zero: Science, Origins and Implications. *Annual Review of Environment and Resources, 47*, 849-887.
[46] Brandão, M. L. (2013). Key issues and options in accounting for carbon sequestration and temporary storage in life cycle assessment and carbon foot printing. *The International Journal of Life Cycle Assessment, 18*, 230-240.

Environmental integrity is crucial across various ETS schemes to ensure the long-term climate benefits of carbon removals. California mandates a 100-year durability period for carbon sequestration projects, based on scientific research and modelling that demonstrates the need for long-term carbon sequestration. New Zealand commits forest owners to a 50-year sequestration period, aligning with its net-zero goal by 2050. Quebec's approach, based on climate science, values CO_2 removals by their equivalent actual climate benefit, calculated over a 100-year period.

Scheme	Minimum Storage Period	Buffer Pool or Equivalence Measures	Liability Measures
New Zealand	NZUs created by forestry can be classified as two types for forests post 1989: - **Standard forestry**: Intended for forests that you want to regularly harvest and replant, such as commercial plantation forests. - **Permanent Forestry**: Forests that will not be clear-felled. *They must remain in permanent forestry for at least **50 years**.*	NA	When deforestation occurs on either forestry type, the forester must surrender NZUs equivalent to the carbon lost from the forest. Deforestation is when the land is permanently cleared of trees, or if trees aren't restocked or grow fast enough after felling. If permanent forestry is clear felled NZUs must be surrendered. Total liability is capped at the net number of NZUs the forester received for the carbon removed.
Quebec	NA *Projects must demonstrate the climate benefit of removing 1 tonne of CO_2 (or CO_2 equivalent), quantified over 100 years.*	Administrators don't need to manage credit invalidation and replacement. Fungibility occurs though carbon sequestration demonstrating a net atmospheric effect over 100 years equivalent to not emitting 1 tCO_2e.	Under Quebec's method, there is no need to cancel or invalidate credits, as it focusses on the real climate benefit which has occurred.
California	California Air Resources Board (CARB) requires permanent for a minimum of 100 years for forest projects	California maintains a forest carbon buffer pool to ensure the permanence of its offsets. In the event of unintentional reversals, projects are required to measure and report losses to CARB, which then retires buffer pool credits equivalent to the amount of CO_2 lost.	Buyer liability is applied. CARB can invalidate forestry credits if a projects regulatory requirements are not met. A substitute compliance instrument must be purchased (by the original buyer) in its place.

Liability measures, such as the case with New Zealand ETS, ensure that any carbon releases are accounted for, and the overall balance of emissions is maintained. When deforestation occurs, foresters must surrender NZUs equivalent to the carbon lost or receive fines. This measure incentivises long-term carbon removal and permanent storage.

California maintains a buffer pool to ensure the permanence of its offsets. In the event of reversals, projects must measure and report losses, and buffer pool units are retired. This acts as a long-term safeguard, ensuring that unintentional carbon release is accounted for through social pooling of units. This protects the market from potential reversal event shocks and maintains overall environmental integrity of the scheme. Further, to ensure overall environmental integrity of their program, the principle of buyer liability is implemented. CARB may invalidate a forestry credit if it later determined to not have met requirements, and the entity that surrendered the credit for compliance must then substitute a valid compliance instrument for the invalidated credit.

The societal value of impermanent storage

Carbon that is stored and rereleased into the atmosphere at a later date is less valuable than carbon that is stored permanently. Some removals technologies have a higher risk of releasing the carbon that has been stored. To understand the significance of this risk, we have considered the societal costs and benefits of temporary storage in accordance with the Green Book.[47] Other sources in the literature have followed similar approaches in using the social cost of carbon and applying discounting techniques, such as those discussed by Parisa (2022),[48] Balmford (2023)[49] and Groom and Venmans (2023).[50]

Two counter-opposing factors are considered in this analysis:

1. Increasing carbon values[51] – carbon values are based on setting the value of carbon at the level that is consistent with the cost of marginal abatement to reach the targets that the UK has adopted at a UK and international level. These carbon values increase over time to reflect increased emissions reductions targets.
2. Societal discount rates[52] – Discounting in appraisal of social value is based on the concept of time preference – that generally people prefer to receive goods and services now rather than later. The rate that society values the present compared to the future is known as the ‘social time preference rate’ (STPR) and has two component parts:
    a. ‘Time preference’ – the rate at which consumption and public spending are discounted over time, assuming no change in per capita consumption. This captures the preference for value now rather than later.
    b. ‘Wealth effect’ – this reflects expected growth in per capita consumption over time, where future consumption will be higher relative to current consumption and is expected to have a lower utility.

In 2021, HM Treasury published the conclusions of an expert, external review[53] to examine the application of this discount rate to environmental impacts. The review concluded that the Green Book should not change the discount rate for environmental impacts as this would be an

[47] The Green Book (2022) (updated May 2024)
[48] Parisa, Z. M. (2022), The time value of carbon storage. Forest Policy and Economics, 144, 102840.
[49] Balmford, A. K. (2023), Realising the social value of impermanent carbon credits. Nature Climate Change, 13, 1172-1178.
[50] Groom and Venmans, The social value of offsets, 2023.
[51] Carbon values are used across government for valuing impacts on GHG emissions resulting from policy interventions. They represent a monetary value that society places on one tonne of carbon dioxide equivalent (£/tCO_2e). They differ from carbon prices, which represent the observed price of carbon in a relevant market (such as the UK Emissions Trading Scheme).
[52] Discounting is a technique used to compare costs and benefits occurring over different periods of time on a consistent basis.
[53] https://www.gov.uk/government/publications/green-book-supplementary-document-environmental-discount-rate-review-conclusion

imprecise way of accounting for effects. Effects can already be adequately accounted for in the Green Book methodology through relative price adjustments and the uprating of values over the appraisal period.

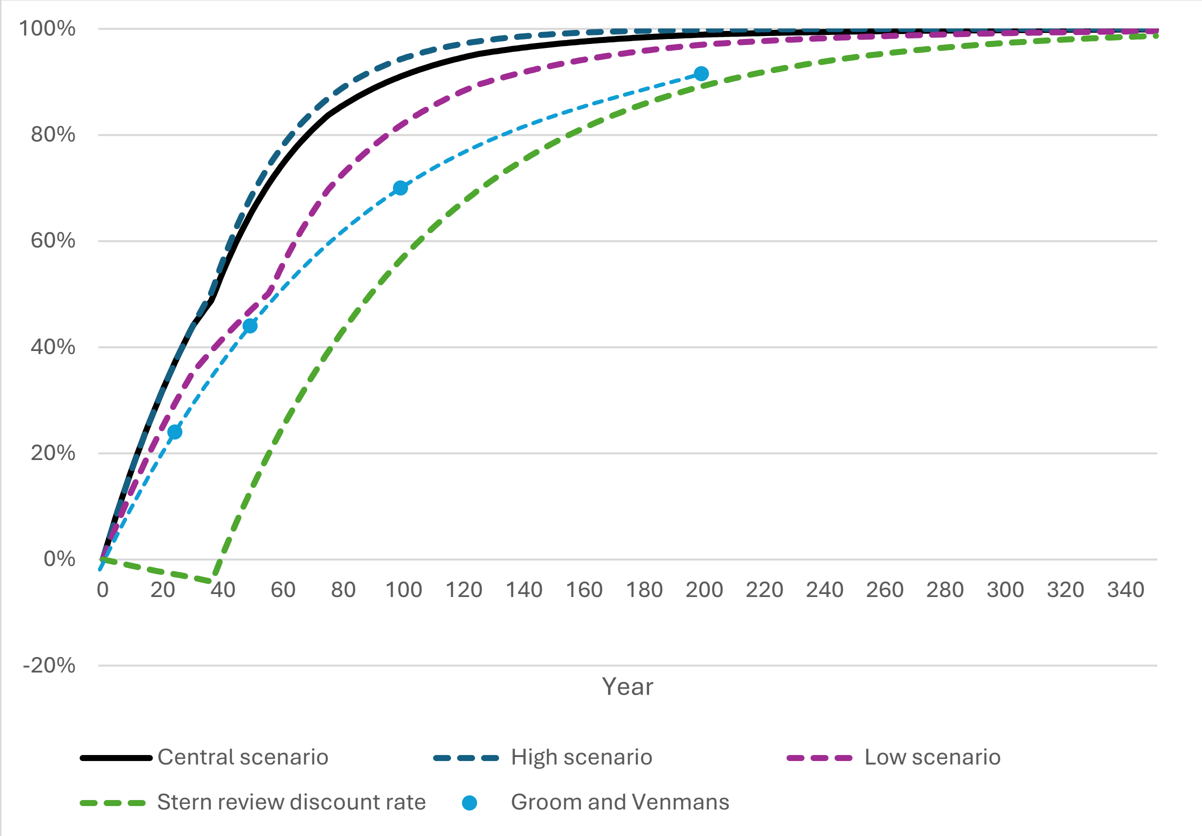
Figure 5 shows how the societal value of stored carbon that is released at a later period compares to infinite storage for several scenarios. Over time the discount rate effect dominates. The value to society of carbon that is stored for 200 years and then rereleased has around 99% of the societal value of infinite storage in the central HM Treasury Green Book consistent scenario. While this non-infinite technology is not as effective as infinite storage, it is close to as effective from a societal perspective today. This suggests that technologies that can store carbon for significant but not infinite periods of time (e.g. 200 years) are valuable decarbonisation options for society. This method can also be used to value removals with specific estimated reversal risks.

Sensitivity scenarios have been included varying the discount rates and carbon values applied. The central scenario assumes a falling discount rate over time in line with green book guidance on intergenerational wealth transfers and social discounting[54] and central carbon appraisal values.[55] The high scenario assumes a flat discount rate of 3.5%. The low scenario assumes a falling discount rate excluding social time preference, high carbon appraisal values[56] and increases the carbon appraisal values cap to £1000/t. The Stern review[57] discount rate scenario applies a very low discount rate of 1.4%. The methodology in Groom and Venmans[58] offers an independent assessment of the value of temporary carbon storage, with separate assumptions and find a similar pattern overall, though at a slightly lower level.

In all scenarios the value to society of carbon that is stored for 200 years and then rereleased is in the range of 89.3%-99.8% of the societal value of infinite storage.

[54] Green Book supplementary guidance: discounting - GOV.UK
[55] These are grown via their average growth rate and capped at £500/t to illustrate a conservative estimate of DACCS costs as a mitigation backstop.
[56] https://www.gov.uk/government/publications/valuation-of-energy-use-and-greenhouse-gas-emissions-for-appraisal
[57] The Economics of Climate Change: The Stern Review - Grantham Research Institute on climate change and the environment
[58] Groom and Venmans, The social value of offsets, 2023

Figure 5: Net Present Value of carbon stored in year 0 and released in year T compared to infinite storage



Fiscal impacts

UK ETS revenues are made up from the allowance price and the number of allowances sold. As discussed earlier the decision to maintain the cap should result in no significant impacts on UK allowance prices. However, for every removal allowance integrated into the UK ETS, one UK allowance will be removed. This represents foregone revenues to the government.

On the other hand, fiscal benefits may arise due to improved investment certainty and learning-by-doing benefits that can reduce the need for additional fiscal support. These are discussed in the economic rationale and price premium sections earlier.

Further Planned Analysis: Cost Benefit Analysis and Impact Assessment

Due to the ongoing development of supporting policies on GGRs, there is uncertainty regarding the expected level of GGR deployment into the UK ETS. The scale of impacts will be directly related to the deployment of GGRs. Under these circumstances, conducting a robust impact analysis of GGR integration into the UK ETS is challenging. The Authority will consult further on technical and implementation options in due course. In responding to that consultation, the Authority will present a cost-benefit analysis of integrating GGRs into the UK ETS.

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