Estimating the future prices and scale of engineered GGRs in voluntary carbon markets

Summary report

RAF028/2425

April 2026

Acknowledgements

This report was funded by the UK Government’s Department for Energy Security and Net Zero (DESNZ) and written by the following AlliedOffsets team members: Pranav Balaji, Antonia Drummond, Lars Kroijer, and Anton Root.

We thank the DESNZ team for their feedback and contributions to the report. We also thank Josh Burke of the LSE Grantham Institute and Luca Taschini of the University of Edinburgh for providing comments on the forecast model’s methodological approach.

Views expressed in this report are those of the researcher and not necessarily those of the UK Government.

Contents

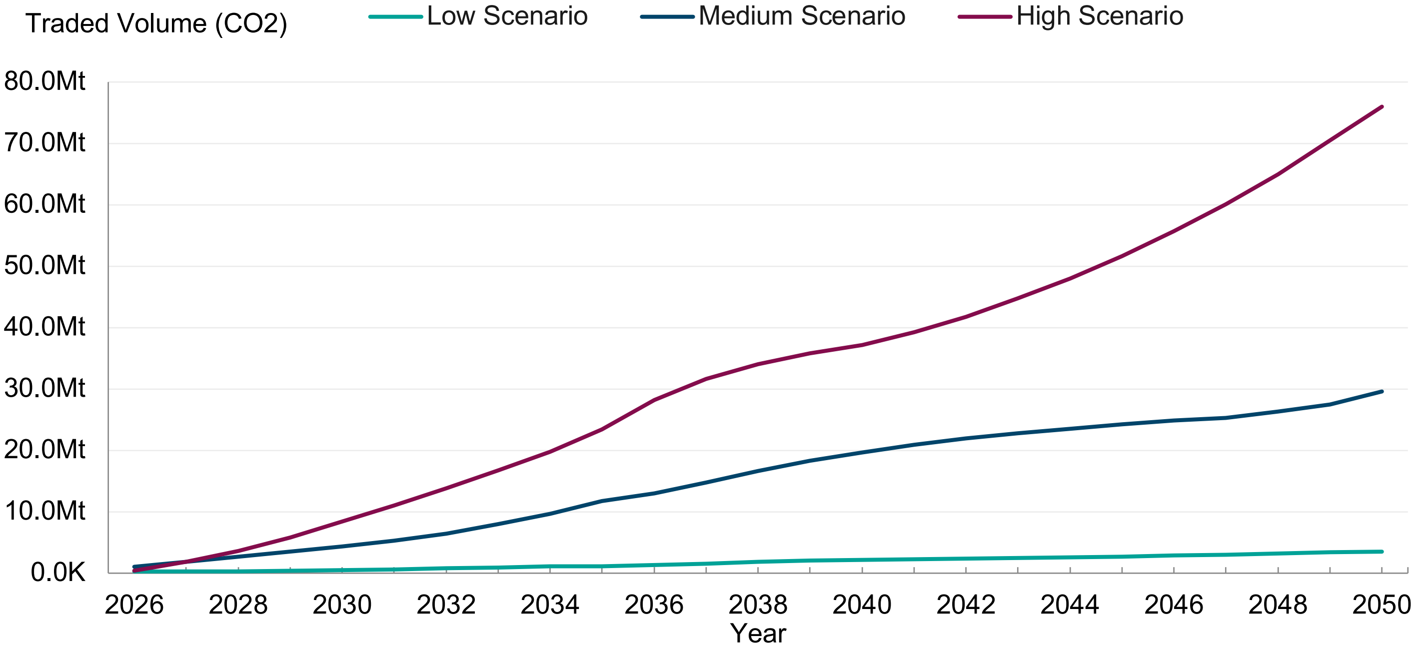
Executive Summary

This research forecasts prices and traded volumes of greenhouse gas removals (GGRs) in the UK between 2026 and 2050, both in the voluntary market and in UK ETS. To reflect uncertainty in both corporate demand and technological progress, we model three scenarios for the UK, supplemented by a "VCM failure" case in which the UK ETS is the sole source of demand.

The analysis uses the AlliedOffsets Forecast Model, which integrates supply- and demand-side assumptions derived from literature and the AlliedOffsets proprietary database. It covers six GGR pathways: direct air capture, biochar, enhanced rock weathering, and three forms of BECCS (power, hydrogen, and energy from waste).

Our modelling shows that in the low scenario, high project setup costs constrain UK market growth under low demand. Medium and high scenarios highlight the importance of strengthening demand signals, with voluntary market expansion remaining the primary driver of outcomes.

Figure 1: Forecasted traded volumes of UK GGRs in voluntary and compliance markets under three scenarios



Between 2026 and 2050, UK projects are estimated to cumulatively generate 47.8 Mt (million tonnes) (in the low scenario), 325.6 Mt (medium), and 851.8 Mt (high) of traded GGR credits, with corresponding prices of £164/tonne, £206/tonne, and £284/tonne. Across all scenarios, technologies with the lowest levelized setup costs (biochar, ERW, and BECCS – EfW) dominate in the early years, while higher-cost technologies only become profitable closer to mid-century. In the "VCM failure" case, UK ETS-only demand could stimulate 175 Mt (medium) to 473 Mt (high) of cumulative traded GGRs by 2050. In the low scenario, however, depressed UK ETS prices prevent GGR projects from operating profitably, resulting in no new project deployment through 2050. These findings underline the importance of ETS integration in providing a strong and predictable long-term incentive for market growth.

As GGR technologies and markets remain in an early stage of development, parts of the analysis rely on highly theoretical inputs, such as projected future levelized setup costs. In addition, the primary driver of demand (voluntary corporate decarbonisation targets) remains unstable and may increase or decline relative to current trends. For these reasons, the results of this analysis should be interpreted as indicative rather than predictive.

Research Questions

- Research Question One (RQ1): What are the factors that will influence the global demand and supply of engineered removal technologies out to 2050, and how will they influence them?
- Research Question Two (RQ2):
  - What are the predicted prices (in £/tonne CO_2e) and quantity (in $MtCO_2/y$) of engineered removals sold in the voluntary carbon markets, split by technology type and presented in yearly intervals from 2025 to 2050 globally?
  - How much of this quantity traded in the VCM is supplied by UK-based engineered GGR projects?

Introduction and Scope

This report forecasts the potential future price and scale of engineered greenhouse gas removal (GGR) technologies within the UK. The data collection, literature review, modelling, and report drafting was undertaken by AlliedOffsets.

AlliedOffsets captures data on more than 35,000 voluntary carbon market projects globally, including those in the engineered GGR sector. We have tracked tens of millions in offtake agreements signed by GGR project developers to supply credits to buyers, including the price point per tonne and the volume of the transaction.

To answer the research questions above, the team employed the AlliedOffsets Forecast Model, developed prior to this project and adapted to this research. It is a Python-based model that allows users to project the price of carbon credits, by sector and geography, into the future. It relies on a series of assumption inputs to generate price projections for the voluntary carbon market. Off-model adjustments were made to project the interaction of the VCM with the UK ETS.

The sectors selected by DESNZ to be covered as part of this analysis are the following:

- Direct air carbon capture and storage (DACCS): facilities that capture and store carbon dioxide from ambient air
- Power bioenergy with carbon capture and storage (BECCS): projects that generate power from biomass through combustion or gasification, and incorporate carbon capture with permanent storage.
- Hydrogen BECCS: Projects that produce hydrogen by removing carbon from biomethane or through biomass gasification, where biomass is heated without

combustion to create syngas that can be used for heat and power or upgraded into hydrogen.

- Biochar: projects that heat biomass in the absence of or restricted oxygen (via pyrolysis or gasification) to produce biochar, preventing the carbon captured during growth from being released into the atmosphere.
- Enhanced rock weathering (ERW): projects that accelerate the natural weathering process in order to capture carbon dioxide.
- Energy from waste (EfW) with CCS: projects that use part-biogenic waste as feedstock, combusting or gasifying it to generate energy while capturing and storing CO2. Compared to landfill, these projects cut emissions, avoid methane from waste degradation, and deliver negative emissions alongside waste management benefits (only to the extent of biogenic waste used as feedstock).

The variables that serve as inputs into the Forecast Model include data points including the current number of projects by sector, the number of credits generated by a project in a given sector, the crediting period length, the levelized cost of generating a carbon credit, buyer willingness to pay premium for credits from a specific sector, and others. These inputs align with the research questions posed by DESNZ, and therefore the literature review and data collection conducted for this project as part of RQ1 focused on identifying relevant inputs into the model.

In order to answer RQ2, we adapted our Forecast Model to include all of the sectors above and created a list of UK-specific assumptions and inputs into the forecasting model, allowing us to forecast UK GGRs under various scenarios. This report summarises the work undertaken in order to answer the two research questions.

Model Overview and Framework

In order to answer this question, we conducted a literature review and data collection exercise. We split this question into two interrelated parts: supply and demand. The literature review focused on the above sectors, both in the UK and globally. We reviewed 12 papers, 3 of which focussed on the UK; the summary of the literature review is reproduced in the appendix. The findings of the review fed into the Forecast Model as key assumptions underpinning the supply side of the model. To supplement the research, we reviewed data on projects and transactions collected by AlliedOffsets. Significantly, this includes data on prices of credits purchased by companies for credits issued via the above pathways, the volumes of purchases, and the current number and profiles of projects (i.e., their location, number of credits issued or sold per year, and facility readiness).

At a high level, **supply** of engineered removal credits to 2050 will be determined (among other factors) by the cost of capturing 1 tCO2e from the atmosphere by technology, the reduction in cost over time, the potential scale of CO2e removal by technology, technological efficiency gains, the lifetime of the CO2 capture facilities, and other variables. Voluntary **demand** for credits is influenced by the number of companies with emission reduction targets, the success rate with which companies can meet targets, the amount of the target emission reductions missed, and the rate at which companies set targets, among other factors. Compliance demand is driven by UK ETS allowances in the market, as well as projections for CORSIA.

Due to the nascent nature of the technologies modelled, there is a lack of consensus in the literature regarding the above data points. Indeed, the limited amount of research on these topics means that there is no consensus on the definitions of the sectors above. Some, for example, distinguish between liquid and solid sorbent DACCS, while others discuss DACCS without making the distinction. Another limitation in the data is the lack of availability of transaction prices due to the limited number of projects selling GGR credits from that pathway; this is especially true for hydrogen BECCS.

In order to overcome these issues, we created three supply scenarios (low, medium, high) to match multiple demand scenarios. This allowed us to examine potential market dynamics in the future, while recognising the uncertain nature of the technologies' pathways. Given that the model draws on assumptions derived from literature on developing technologies, the results should be viewed as exploratory estimates rather than precise forecasts.

The Supply and Demand sections below provide more detail on the factors assessed as being relevant to RQ1, and explain how they fit into the Forecast Model. The Clearing Price section outlines how supply and demand factors affect credit[1] prices within the market. The following discussion centres on the UK-specific model, which is the primary focus of this research.

Supply

Supply of GGR credits comes from projects set up by private companies within the DACCS, power BECCS, hydrogen BECCS, biochar, ERW, and BECCS - EfW sectors. These companies may receive revenues from three sources: sale of products (biochar or energy); carbon credits; and government grants or subsidies.

Generally, projects do not raise enough revenues from sale of products alone, as they are not cost-competitive with products that do not capture carbon (in the case of energy production), or there is not enough demand or a high enough price to make

[1] While there is a distinction between the terms "credits", "offsets", "allowances", and "GGRs", in this report they are used interchangeably.

the projects viable from the sale of the products (in the case of biochar). Carbon credits supplement this revenue by monetizing the captured and stored CO2 emissions. In many cases, however, government support is also necessary to make the projects viable. The UK government has expressed interest in supporting GGR projects via a contract for difference, similar to the structure used in the energy sector. DESNZ currently has two schemes to support GGR projects: GGR business model, with the potential of supporting a diversity of GGR technologies, and the Power BECCS business model, supporting large-scale Power BECCS projects with a minimum abated generating capacity of 100MWe.[2]

This analysis focuses on the price of carbon credits as the sole driver of project revenues, allowing us to model supply-demand dynamics for carbon credits, without needing to consider potential future policy support mechanisms (which are uncertain) or the price of project products like biochar or energy (which is outside the scope of this research).

The price of credits determines whether project developers can profitably generate credits, given their cost of production. The cost of generating credits is a key input into the model, and the price at which supply and demand meet determines whether projects can issue credits or not. The levelized cost of removing a tonne of CO2 from the atmosphere includes the upfront capital expenditures and ongoing operating expenditures, over the project lifetime, divided by the number of tonnes the project will remove over that time. The cost varies primarily by the geography of the project (which dictates labour costs, transportation costs, etc.), and by sector (which dictates the equipment and inputs necessary to set up and run the project).

In addition to the levelized costs, there are other variables that influence the supply of credits that feed into the Forecast Model. These include:

- Number of existing and pending projects issuing credits: The total number projects that are active or pending in the UK and globally, as of June 2025.
- Buyer willingness to pay premium: This premium reflects an assumption around lack of substitution amongst different project types. The premiums are related to perceived quality in the market. That is, a buyer may prefer to pay £100 for a DACCS credit than £75 for a biochar credit, if the DACCS credit is perceived to be of higher quality. Our model generally assumes a premium for closed-system technologies over open-system ones. Closed-system technologies capture and permanently store CO2 in controlled environments, while open-system technologies enhance natural processes, with carbon uptake occurring within broader ecosystems and being less directly

[2] GGRs and Power BECCS business models: amending revenue support regulations relating to directions to a counterparty, publication of information, counterparty's ability to carry out its functions, and eligibility (accessible webpage) - GOV.UK

measurable. The higher willingness to pay for closed-system credits means that, all else equal, buyers increasingly favour these technologies over open-system ones. This premium was calculated based on historical offtake and spot prices for GGRs.

- Change in premium over time: As the general prices of credits change in the market, it is expected that the premiums and discounts associated with technologies will decrease. In other words, when prices in the market are £5/tonne, some buyers may prefer to pay £100/tonne (20x) for biochar credits. However, if general prices rise to £10/tonne, those buyers may be willing to pay £125/tonne for biochar, reducing the premium from 20x to 12.5x relative to the general market price.
- Number of years in the crediting period (or lifetime of the project): This is the period of time over which a project issues credits.
- Number of credits generated per year per project: This, along with the number of projects created, determines the number of credits issued from a sector in a given year.
- Reduction in project setup as price stabilises: The model assumes that at a stable price for credits, a decreasing number of credits will be issued. This is based on the logic that developers set up most profligate projects at a given price first. For example, a developer who can secure a price of £150/tonne for their credits will set up the project that issues the most credits at that price point first. If the price stays the same next year, the developer will create another project, but that project will likely issue fewer credits, because the 'best' project at the £150/tonne price point has already been set up, and so on.
- Length of time to launch a project: This is the gap between project creation and credit generation; it accounts for the time it takes to build a facility, hire staff, conduct project activity, and verify and issue credits.
- Levelized project setup costs: This is the current average cost of setting up a project in a given sector (see above for more on what this includes).
- Minimum theoretical levelized cost of setting up a project: This is the theoretical future cost of setting up a project in a given sector.
- Annual reductions in cost of setting up a project: This is the rate at which levelized costs reduce from their current level to the theoretical minimum.
- Maximum annual scale: The maximum number of credits that can be generated by a technology in one year, which is based on academic literature focussing on the sectors examined in this research.

These model inputs are based on findings of the literature review, as well as AlliedOffsets's own database of GGR activity in the UK and globally.

To account for uncertainty in the projections around technological costs and scale improvements, we created three supply scenarios, with three corresponding sets of variable inputs, reflecting slow technological advancements in GGRs (low scenario), as well as moderate and fast advancements. The table below summarises the key assumptions, split out by supply scenario, also showing the sources for assumption inputs.

Table 1. Key assumption inputs into the modelling, by scenario

Technology	Scenario	Minimum Setup Cost (£/tonne in 2025 GBP)	Starting Willingness to Pay Premium	Learning Rate	Minimum Future Cost (£/tonne in 2025 GBP)	Max UK scale (Mt CO2/yr)	Plant Lifetime in Years
DACCS	Low	£451[1]	390%[7]	3%[2]	£332[1]	50 MtCO2/yr in 2050[3]	20[1 4]
	Medium		390%[7]	5%[2]	£285[1]		
	High		390%[7]	8%[2]	£200[1 3]		
ERW	Low	£165[3]	125%[7]	1%[5]	£158[3]	18.7 MtCO2/yr in 2050[3]	10[7]
	Medium		125%[7]	2%[5]	£140[6]		
	High		125%[7]	4%[5]	£126[6]		
Biochar	Low	£105[8]	35%[7]	2%[9]	£100[10]	20 MtCO2/yr in 2050[3]	10[7]
	Medium		35%[7]	3%[9]	£75[10]		

	High		35%[7]	4%[9]	£47[11]		
BECCS - Power	Low	£226[12 3]	110%[7]	3%[13 5]	£175[3]	90 MtCO2/yr in 2050[3]	20[15]
	Medium		110%[7]	4%[13 5]	£124[3]		
	High		110%[7]	6%[13 5]	£110[3]		
BECCS - Hydrogen	Low	£226[12 3]	110%[7]	3%[13 5]	£175[14]	80 MtCO2/yr in 2050[3]	20[15]
	Medium		110%[7]	5%[13 5]	£120[14 3]		
	High		110%[7]	8%[13 5]	£102[14]		
BECCS - EfW	Low	£162[12 3]	110%[7]	3%[13 5]	£105[3]	12 MtCO2/yr in 2050[3]	20[15]
	Medium		110%[7]	3%[13 5]	£90[3]		
	High		110%[7]	4%[13 5]	£81[3]		

Reference		1. City Science (2025) - central value of least value for SDAC and LDAC 2. Learning rate: Katrin Sievert (2024) 3. Element Energy and the UK Centre for Ecology & Hydrology (2021) 4. Noah McQueen (2020) 5. Faber (2022) - applied a 4.35% learning rate for CCU including mineralization the closest analogue to ERW noting that mineral pre-treatment is a key cost driver in both, we used this our upper bound and made a range of 1-4% 6. Beerling (2020) 7. AlliedOffsets Assumption	8. Disni Gamaralalage (2025) 9. AlliedOffsets Database -Using our proprietary database, we calculated a central learning rate of 3% and added a range 2-4% 10. Royal Society(2018) 11. Concito (2024) 12. DOW OPIS Jones whitepaper on durable removals (2025) 13. Rubin (2007) - As BECCS-specific learning rates are not established, we use a 3–8% composite rate, based on 3–5% CCS benchmarks (Rubin 2007) and 4.35% for capture O&M (Faber 2022), allowing for added learning from biomass integration and logistics. 14. Johannes (2023) 15. Oluchi Emenike (2021)

Demand

On the demand side of the analysis, we evaluated the demand for credits from two distinct sources: voluntary corporate decarbonisation targets and compliance schemes. These sources of demand were selected due to their historic and projected future importance for driving demand for GGR credits. More specifically:

- Science Based Targets initiative (SBTi) / net zero targets: This demand comes from UK-headquartered companies striving to meet stated emission reduction targets. The companies' targets account for both domestic and international emissions.[3] Demand for credits will come from emissions in excess of targets. The low, medium, and high scenarios presented in this analysis differ in the number of companies using offsets, the proportion of excess emissions covered by carbon credits, and the number of companies setting targets into the future.
- CORSIA and UK ETS: ICAO has published offsetting requirement predictions for low, medium, and high emissions scenarios, for which we have identified demand from UK airlines as a simplifying assumption. Additionally, the UK has undergone a consultation regarding integrating GGRs into the UK ETS.[4] This research models the potential demand for GGR credits under three projected ETS allowance and price scenarios.

The sources of demand, and how they influence the model, are described in further detail below.

Voluntary

It is assumed that demand for credits will come from emissions in excess of targets. Excess emissions means that a company who has a target of emitting 10,000 tCO2e in 2030, but emits 12,000 tCO2e will have a demand of 2,000 tCO2e in 2030.

AlliedOffsets has gathered data on nearly 20,000 global companies active in the VCM, further identifying emissions for approximately 2,500 companies. Additionally, we have collected data on 7,500 other companies' sectors, locations, number of employees, and revenues. This allowed us to extrapolate emissions for those companies. In total, we collected or extrapolated emissions data for 1,864 UK companies. Based on historical company emission data, we assume that companies will not be able to meet targets with decarbonisation alone, and that companies will purchase offsets before their target year to remain "on track" with targets. Excess emissions can be predicted by looking at historic emissions amongst companies that

[3] This approach excludes buying activity from Microsoft, which is the current leader in GGR purchases, and has a UK footprint. However, as the company has only contracted 58,900 tCO2e from UK projects (out of 90M tCO2e total purchased), as of October 2025, this omission reflects its limited role in the UK GGR market.

[4] Integrating Greenhouse Gas Removals in the UK Emissions Trading Scheme: Main Response

have set targets, compared to what their emissions should be to be on track to meet their targets. (This is modelled by a linear decarbonisation trajectory in all scenarios.)

The extent to which companies rely on carbon credits to offset excess emissions will be based on historic retirement activity amongst companies that have already set targets. This is a ratio calculated by dividing each company's retirements by its excess emissions. Companies with SBTi net zero (1.5 degree-aligned) near- or long-term targets will follow offsetting guidance published by SBTi. SBTi is in the process of updating its guidance on offset use for companies. The model uses inputs from the draft of SBTi Corporate Net Zero v2 regarding residual emissions, which states that companies may offset residual Scope 1 emissions (10% of baseline Scope 1) with highly durable removals credits. Companies are encouraged by SBTi to begin purchasing removals prior to their net zero year[5]. Aside from the potential for removals to be included in the UK ETS, this is the most stable source of demand for technical removals.

Total demand numbers will depend on how many companies set targets in the future. UK-based companies (and companies globally) have continued setting SBTi and other net-zero targets each year. Future target setting ambition is modelled on historic numbers of companies setting targets each year. Targets set by future companies are assumed to follow SBTi net-zero trajectories with a 50% target reduction by 2030 and 90% target reduction by 2050 relative to the baseline year.

CORSIA and UK ETS

Currently, there are no engineered removals credits that are eligible for use for CORSIA compliance.. The ICAO Council, on recommendation of the Technical Advisory Body, approved carbon offsetting standards that issue engineered removals credits for the first time in November 2025, and to date no engineered removals projects have received the necessary authorisation and corresponding adjustments from host countries to issue CORSIA-eligible credits. Airlines can meet their CORSIA compliance obligation using cheaper credits than those generated by engineered GGRs. In the low scenario for this analysis, we assume that prices for CORSIA credits remain low, below the minimum levelized cost needed by GGRs to make projects viable. The medium and high demand scenarios will assume that CORSIA prices will rise to a rate that makes technical removals competitive, and UK-based technical removal projects will be made available and correspondingly adjusted by the UK government. To account for this uncertainty, we assume that 2.25%[6] of the CORSIA offsetting requirement will be met by engineered removals. Further detail on how CORSIA UK demand is estimated is provided in Appendix A3.

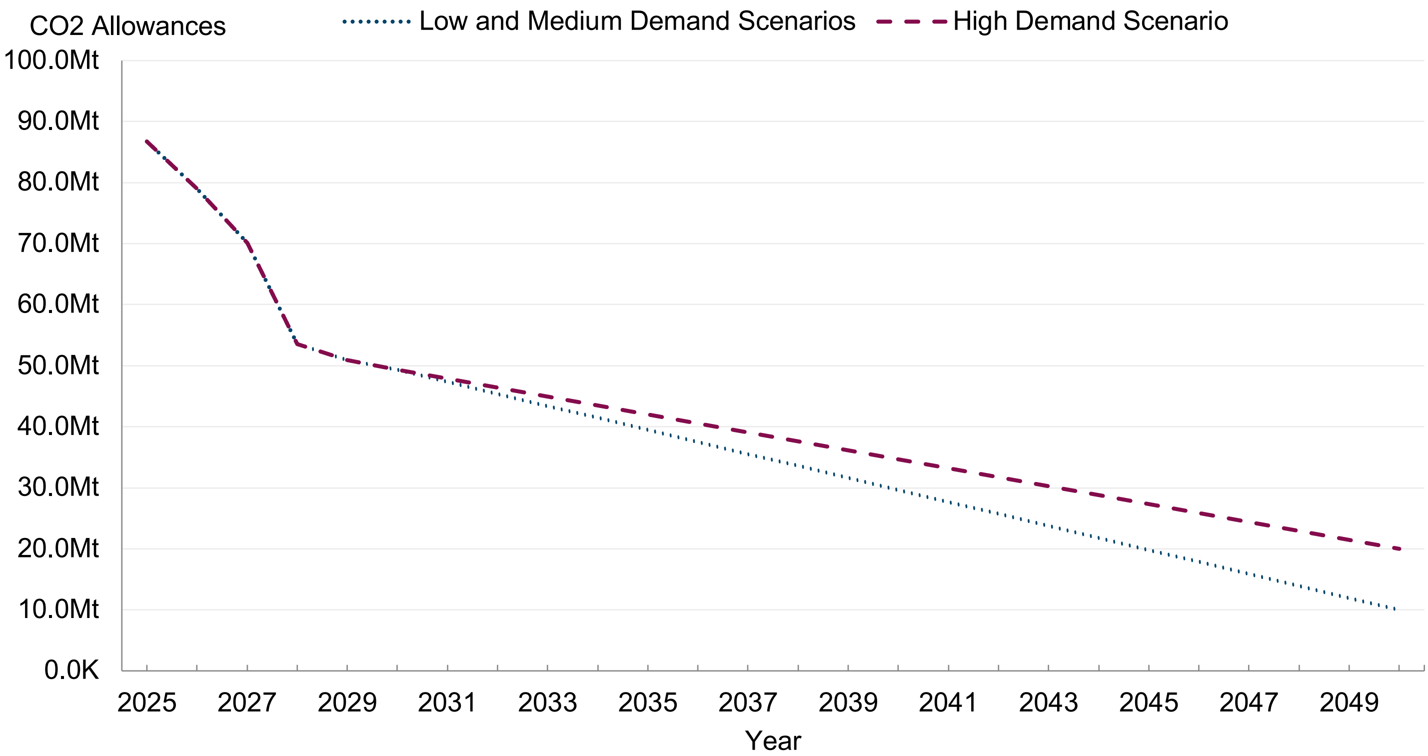
[5] SBTi CORPORATE NET-ZERO STANDARD- Version 2.0 - Initial Consultation Draft with Narrative

[6] Historical proportion of UK airline retirements that are technical removals.

Regarding potential demand from integration of GGRs into the UK ETS, the UK Government has said it will not integrate GGRs into the ETS before 2029. Therefore, UK ETS demand is only included from that year onwards.

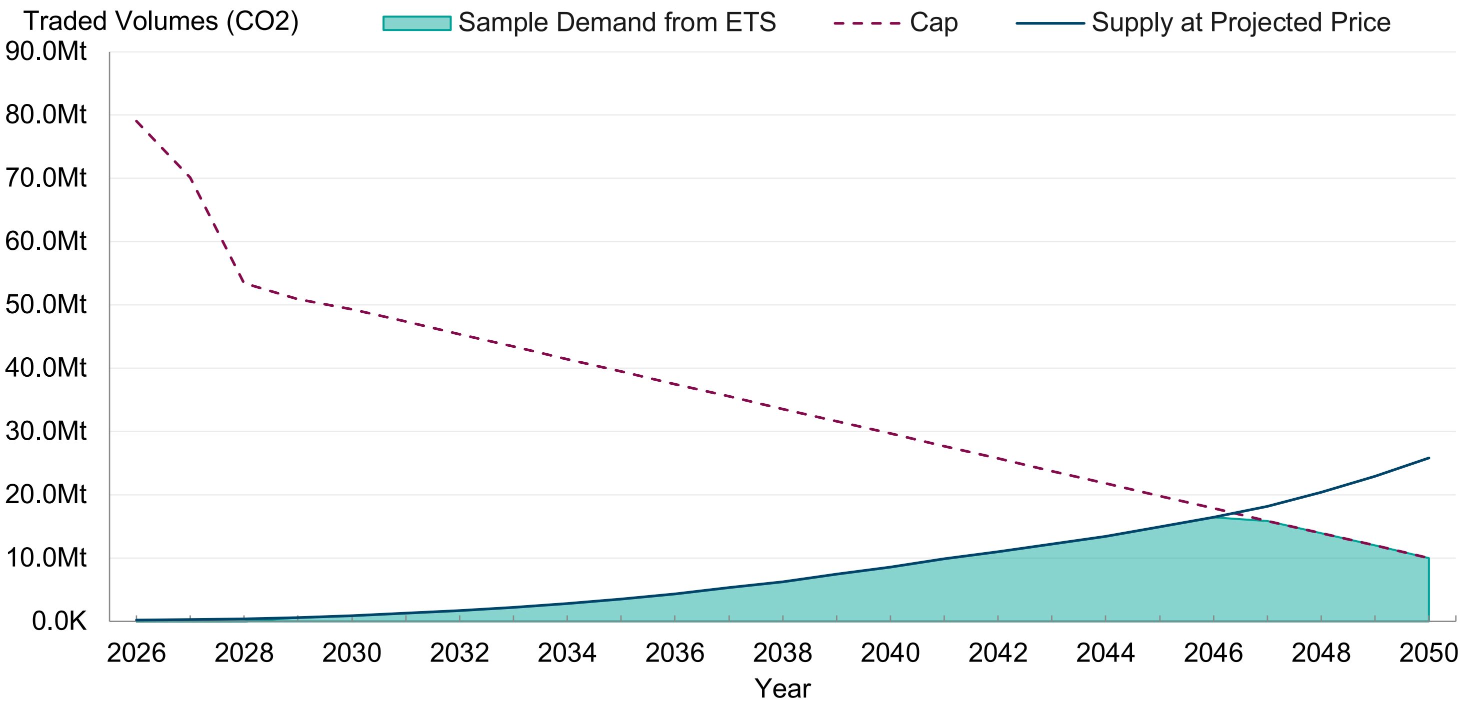
The allowance cap projections until 2030 come from the Greenhouse Gas Emissions Trading Scheme Auctioning (Amendment) Regulations 2023; thereafter, we linearly extrapolate to a cap of 10m in 2050 in the low and medium demand cases, and 20m in 2050 in the high case, doubled to show a high sensitivity; this extrapolation was done based on CCC data. This created the following maximum demand from the UK ETS under the three scenarios.

Figure 2. Projected ETS allowance cap used in the scenarios



The demand projection above presents a problem in that demand for credits from the ETS spikes from 0 today to the maximum allowance under the cap. As companies need time to generate credits, it's highly unlikely that UK developers would be able to supply the maximum number of credits demanded via the UK ETS immediately upon implementation. In order to model the theoretical supply constraint of credits, we modelled the demand that would be filled under UK ETS DESNZ's central price projection for the medium scenario, half the central projection for the low scenario, and double the central projection for the high supply scenario, to show a sufficient range of prices in each of our supply scenarios. The resulting curve allows the model to determine the maximum theoretical supply into the ETS; we take the minimum of the two lines to determine the likely demand from the ETS.

Figure 3. Illustrative projected ETS demand



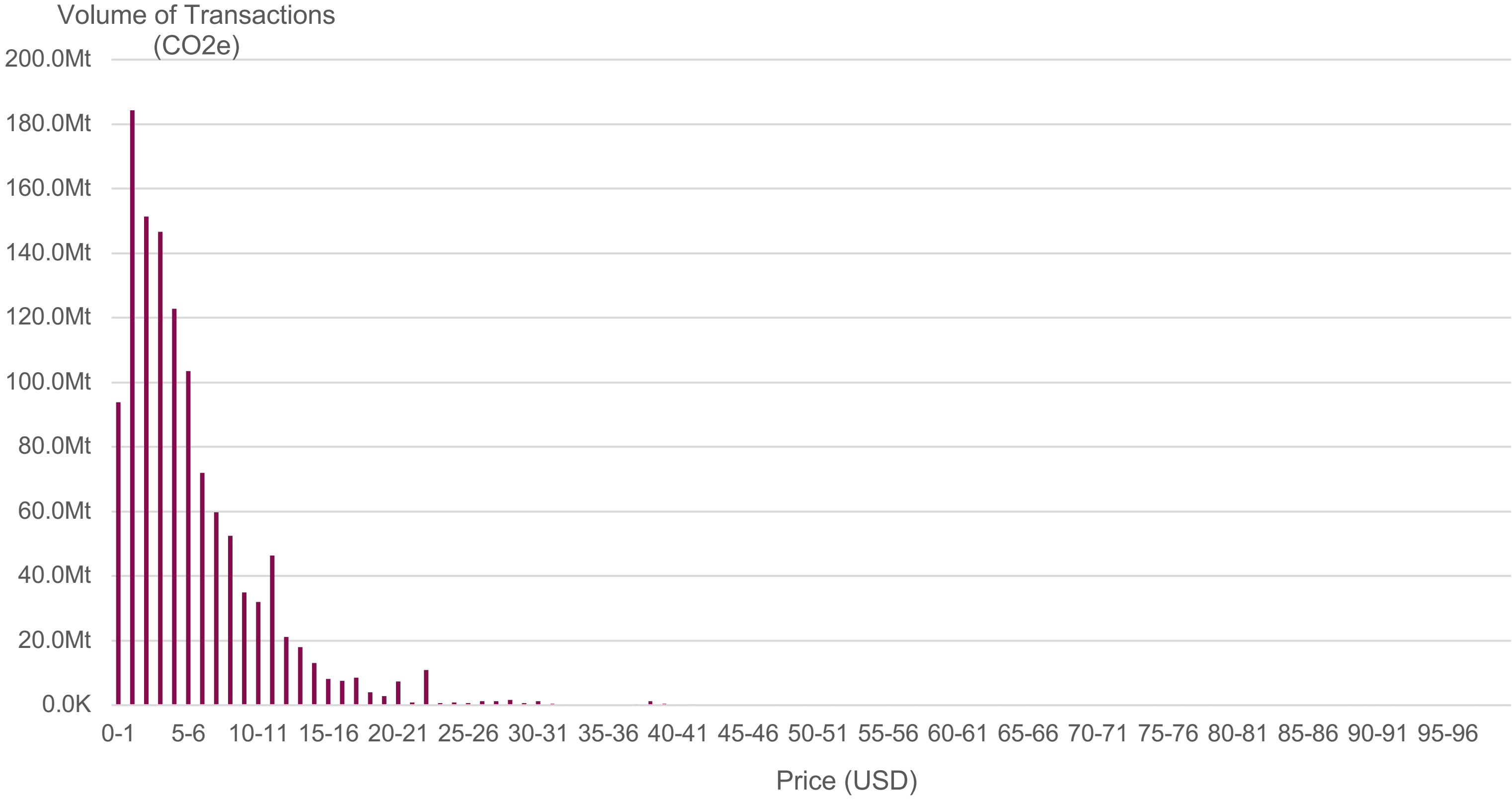
In the chart above, representing how ETS demand works, and not a specific scenario, the dashed line represents the maximum theoretical demand from the ETS allowance, and the blue line represents the demand that would be supplied at forecasted ETS prices. The teal area represents the projected demand, which is the lower of the supply at the projected price, and the maximum allowance demand. In the scenario pictured above we expect GGR credits to make up all of the ETS allowance from 2046 onwards (assuming prices are consistent with the forecast).

Demand Price Sensitivity

Based on historical price and transaction data gathered by AlliedOffsets, a key assumption in the model is that demand is price sensitive. This means as prices rise above buyers' expectations, demand for credits is reduced; when prices are below expectations, demand increases. Price sensitivity differs by demand type: due to legal and financial penalties for failure to comply with compliance schemes, price sensitivity for compliance demand will be much lower than other demand streams.

In order to model price sensitivity, we performed a logarithmic regression analysis on historic retirement volumes at different prices; this analysis is based on AlliedOffsets data. The figure below shows the relationship between prices and retirement or offtake volumes in the VCM since 2020.

Figure 4. Demand volumes by price of credits, 2020 onwards



We used the natural log transform due to the high concentration of retirements at lower prices and a long tail of volumes at higher prices.

*adjusted_demand = base_demand * (1 + price_sensitivity)^(price - base_price)*

Where:

- adjusted_demand: demand for credits, adjusted for the price of credits and price sensitivity
- base_demand: demand for credits calculated by estimating demand from targets and compliance, as described above
- base_price: price a company would expect to pay for a credit
- price_sensitivity: price sensitivity for every £1 increase above the base price
- price: price for credits in a given year

The expected price for credits will change over time. If the market price is £10 one year, companies entering the market the following year will have a base expectation of £10. If the price rises to £15 the following year, companies entering after that will expect to pay £15, and if prices are higher than £15, demand will be lowered.

Price Formation and Sector Allocation

Once the demand and supply of credits are determined following the above, the model overlays supply and demand curves to determine the price needed to reach equilibrium. If the supply is too low, prices must rise to incentivise developers to enter the market and set up new projects. If the prices are too low, the model lowers supply by developers issuing fewer credits from their projects. To obtain the supply-demand equilibrium, the model iterates through prices. Once a price is found that enables supply and demand to reach equilibrium, the model moves on to calculate the price that makes supply and demand meet in the next year, and so on.

When the model settles on a VCM-wide clearing price, it then iterates through each sector to find the sector clearing price by applying a willingness to pay premium. The premium allows the Forecast Model to capture the disparity in prices for different sectors' credits evidenced in the market today. The premiums and discounts are based on AlliedOffsets transaction and offtake data for GGR and broader VCM credits; they are set in the starting model year relative to the projected UK ETS prices (£62/tonne). When the premium-adjusted sector willingness to pay price exceeds the minimum setup cost of generating a credit, the model begins generating credits from that sector. If the cost exceeds the willingness to pay price, implying that developers cannot profitably set up projects, the model generates no credits from that sector.

The figure below illustrates the model's workings. While it is a simplified overview, it highlights key functionality as the model advances from year to year.

Figure 5. Forecast model simplified schema

Year 1 Starting Scenario

Demand from corporate targets equals 100 tCO_2e, at prices of £100/ton.

Current supply of credits from existing projects is 50 tons.

Year 1 Demand-Price Clearing Operations

In order to incentivise new projects to enter the market, the model sets prices to £120/ton.

This generates 50 tCO_2e in additional credits, meeting original demand. However, because companies expect to pay £100/ton, demand is reduced to 75 tons, meaning there is no longer a supply-demand equilibrium.

Therefore, the model lowers the price from £120 to £110/ton. At that price, the supply is 75 tCO_2e, and price-adjusted demand is the same, meaning the market clears.

Year 1 Sector Price Adjustment and Credit Generation

While the market clearing price is £110/ton, some buyers may prefer to pay more for certain credits over others. The model applies a willingness to pay premium or discount in order to determine what buyers will pay for credits within specific sectors.

The premiums determine that buyers are willing to pay £100/ton for biochar and £300/ton for DACCS credits. The levelized cost of generating credits for biochar is £80/ton and DACCS is £350/ton. This means DACCS developers cannot profitably generate credits -- all of the supply to meet demand is generated by biochar projects. The model moves to the next year.

<u>Inter-Year Model Updates:</u>

- New demand is generated from corporates needing to meet targets, reaching 150 tCO_2e
- Price expectation for demand is adjusted to £110/ton, based on last year's price
- Cost of developing projects falls in accordance with the learning rate of each sector
- The willingness to pay premiums by sector are adjusted: premiums and discounts decrease as the market clearing price increases

Year 2 Starting Scenario

Demand from corporate targets equals 150 tCO_2e, at prices of £110/ton.

Current supply of credits from existing projects remains 75 tons.

Year 2 Demand-Price Clearing Operations

In order to incentivise new projects to enter the market, the model sets prices to £150/ton.

This generates 250 tCO_2e in additional credits, meeting original demand. However, because companies expect to pay £110/ton, demand is reduced to 125 tons, meaning there is no longer a supply-demand equilibrium.

Therefore, the model lowers the price from £150 to £125/ton. At that price, the supply is 150 tCO_2e, and price-adjusted demand is the same, meaning the market clears.

Year 2 Sector Price Adjustment and Credit Generation

With the market clearing price at £125/ton, the willingness to pay for biochar rises to £120/ton and to £330/ton for DACCS.

The levelized cost of generating credits for biochar has fallen to £75/ton and for DACCS to £325/ton. This means both biochar and DACCS developers can profitably generate credits to meet buyer demand.

Note that the willingness to pay price for credits from a sector is not affected by the levelized cost of credits. The price determines whether credits can be generated from a sector, but is independent from the cost.

Model updates continue annually until 2050

Defining Scenarios

Demand Scenarios

For this analysis, we defined the following three demand scenarios: low, medium, and high growth.

Low Growth:

- Voluntary demand: This scenario takes into account estimated scope 1 residual emissions for UK-based companies that currently have SBTi net zero (1.5 degree) targets. It assumes that no further companies will set targets. Companies will be willing to purchase removals up to 10% of baseline scope 1 emissions (residual emissions) in their net zero year, with the proportion of residual emissions covered by removals increasing each year.
- Compliance demand: This scenario uses the latest published ICAO low-emissions scenario for international emissions, extrapolating for UK-based airlines. This demand stream assumes GGRs being allowed into CORSIA as offset units, but prices for CORSIA remain significantly lower than GGR prices, resulting in no demand from CORSIA. UK ETS is modelled as the minimum of supply-constrained ETS traded volume using low scenario price projections and the ETS allowance cap, which is extrapolated to 10Mt units in 2050. (Figure 3 above illustrates the relationship between the constrained supply and the allowance cap.)

In the low growth scenario, we assume growth will take place in the market. There is likely to be a scenario under which the market fails to grow. This may be due to lack of interest among private sector firms to offset their emissions, failure to implement compliance demand drivers, or lack of funding available to support GGR projects. Instead of modelling this as the low scenario, we created an alternate set of outputs examining the traded volumes and prices if the UK ETS was the sole driver of GGR activity; this analysis is presented in detail below.

Medium Growth:

- Voluntary demand: This scenario takes into account estimated scope 1 residual emissions for UK-based companies that currently have SBTi net zero (1.5 degree) targets, and assumes that companies will continue setting targets at the rate they have previously, modelled linearly. Companies will be willing to purchase removals up to 10% of baseline scope 1 emissions (residual emissions) in their net zero year, with the proportion of residual emissions covered by removals increasing each year.

- Compliance demand: This scenario uses the latest published ICAO medium-emissions scenario for international emissions, extrapolating for UK-based airlines. This demand stream assumes GGRs being allowed into CORSIA either as offset units or to be included in airline-reported emissions as negative tCO_2e. UK ETS is modelled as the minimum of supply-constrained ETS traded volume using medium scenario price projections and the ETS allowance cap, which is extrapolated to 10Mt units in 2050.

High Growth:

- Voluntary demand: This scenario takes into account estimated scope 1 residual emissions for UK-based companies that currently have SBTi net zero (1.5 degree) targets, and assumes that companies will continue setting targets at the rate they have previously, modelled exponentially. We assume that half of companies will be willing to purchase removals up to 10% of baseline scope 1 emissions (residual emissions) in their net zero year, with the proportion of residual emissions covered by removals increasing each year.
- Compliance demand: This scenario uses the latest published ICAO high-emissions scenario for international emissions, extrapolating for UK-based airlines. This demand stream assumes GGRs being allowed into CORSIA either as offset units or to be included in airline-reported emissions as negative tCO_2e. UK ETS is modelled as the minimum of supply-constrained ETS traded volume using high scenario price projections and the ETS allowance cap, which is extrapolated to 20Mt units in 2050.

The differences in the assumptions across each scenario are depicted in more detail in Table 2 below. In the table:

- ”VCM firms” refers to companies that have purchased credits in the past
- SBTi and Net Zero targets “current” vs. “not yet set” refers to emission reductions coming from companies that have already set one or both of these targets, or those that we are modelling will set targets in the future
- SBTi targets and offsets refer specifically to GGRs, as the standard only allows durable removals, for a maximum of 10% of Scope 1 emissions
- Net Zero targets define an overall offsetting amount and narrow down to a GGR share. The GGR rate, used in the low scenario, is 5% (based on the historical share of GGR retirements relative to avoidance/reduction retirements), while medium and high scenarios use 10% to account for the growing share of removals in the VCM recently
- ”Offsetting proportion” refers to the share of emissions offset by companies
- “Linear” and “exponential” target setting refers to the number of firms committing to lower emissions — whether firms set targets at a constant or accelerated rate over time

- For UK GGR demand from targets and CORSIA, we apply a "domestic" GGR ratio. This ratio, or the proportion of UK engineered GGR credits purchased by UK companies, is 91%. This is derived from historical data on GGR activity within the UK.

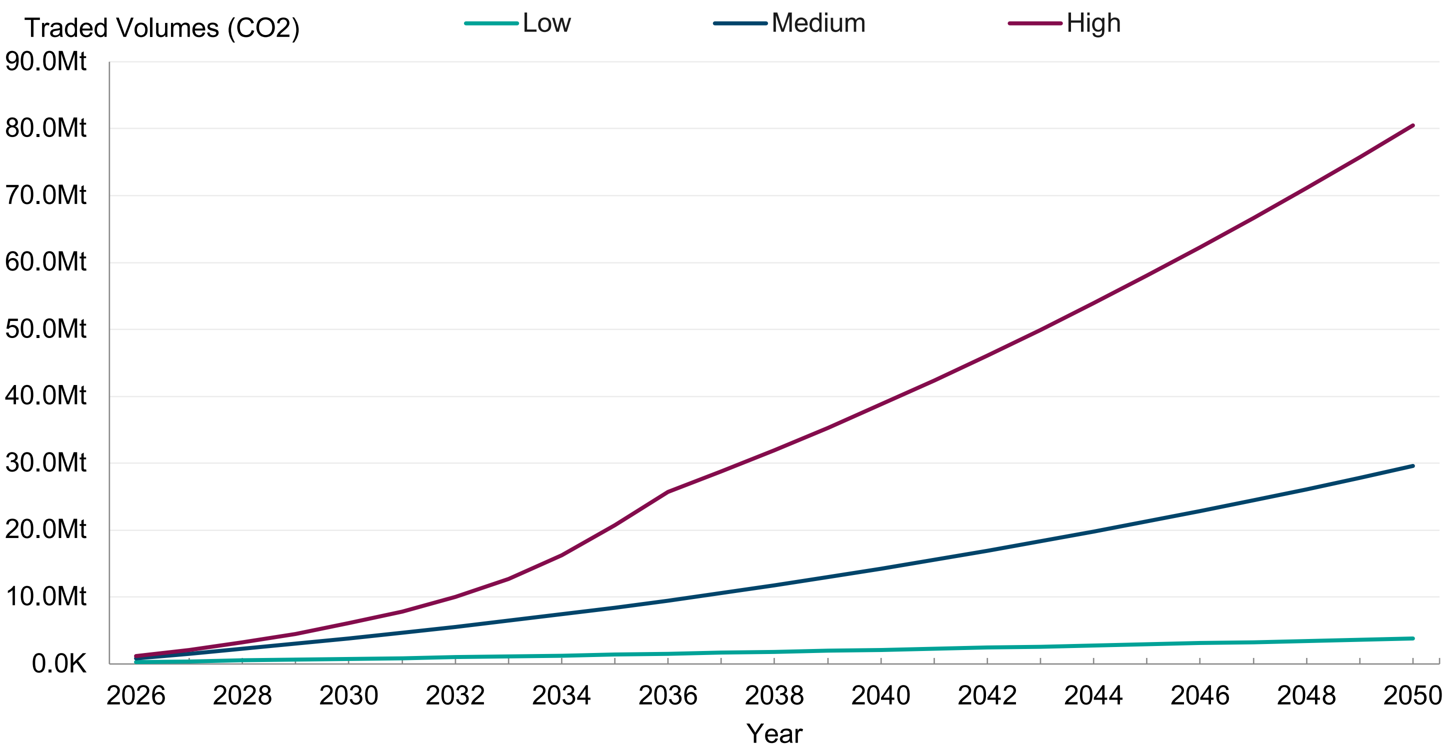
Table 2. Demand assumptions by scenario

Demand source	Low demand growth	Medium demand growth	High demand growth
SBTi targets (current)	10% of scope 1 emissions; only VCM firms	10% of scope 1 emissions; all firms with targets	10% of scope 1 emissions; all firms with targets
SBTi targets (not yet set)	None	Firms set targets at linear rate; 50% of new SBTi firms offset	Firms set targets at exponential rate; 75% of new SBTi firms offset
Net Zero targets (current)	Median offsetting proportion; 5% of retirements for GGR; only VCM firms	62.5th percentile offsetting proportion; 5% of retirements for GGR; all firms with targets	75th percentile offsetting proportion; 5% of retirements for GGR; all firms with targets
Net Zero targets (not yet set)	None	62.5th percentile offsetting proportion; firms set target at linear rate; 50% of new NZ firms offset; 10% of retirements for GGR	75th percentile offsetting proportion; Firms set target at exponential rate; 100% of new NZ firms offset; 10% of retirements for GGR
ETS compliance	UK ETS allowance cap (low/medium), limited by low scenario supply constraints	Allowance cap (low/medium) limited by medium scenario supply constraints	Allowance cap (high) limited by high scenario supply constraints

CORSIA	None	2.25% of CORSIA UK requirement	2.25% of CORSIA UK requirement

The outputs of the demand scenario modelling are shown below. These figures represent theoretical, or "base" demand, meaning the credits demanded before a price adjustment is applied.

Figure 6. Base theoretical demand under three modelled scenarios



The high theoretical demand scenario fits within the UK Government's deployment trajectories within their recent Carbon Budget and Growth Delivery Plan, while the medium and low scenarios present less ambitious projections to examine the market's potential if technology is slower to innovate and demand for credits is more muted. The prices used to generate the base demand correspond to the three modelled prices used for ETS projections (see Table 3 below).

Supply Scenarios

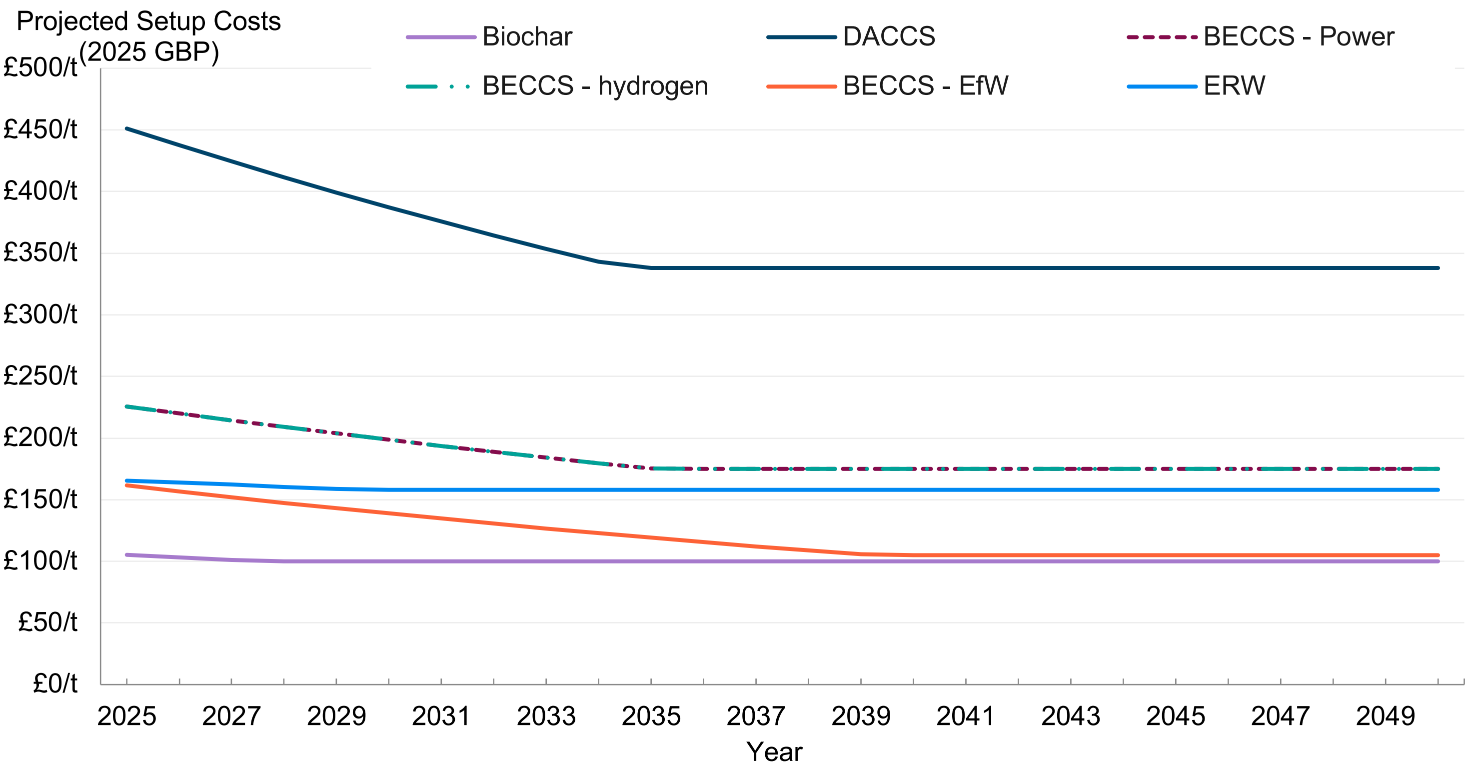
In addition to three demand scenarios, we also modelled three corresponding supply scenarios. The charts below show the levelized setup costs for each technology under different scenarios. These costs are derived from the minimum future levelized cost and the technology-specific learning rate. In combination with sectoral credit price trajectories, they determine the timing of new credit generation across technologies. Costs decline from their current levels toward the scenario-specific theoretical minimum. Where a technology's learning rate causes it to reach that minimum before 2050, costs are assumed to remain constant thereafter.

Across all modelled scenarios, DACCS is the most expensive project type analysed. This reflects both the early stage of technology development and the high energy requirements of removing CO2 directly from ambient air. Furthermore, unlike BECCS, biochar, or ERW, DACCS produces no co-products that can generate additional revenue, meaning its costs are not offset by supplementary revenue streams. By contrast, biochar represents the least expensive sector studied: its production process is relatively mature, and the biochar itself has commercial value as a soil additive, water filter, and in other applications. BECCS and ERW technologies fall between these two extremes.

In addition to differences in levelized setup costs, the scenarios also vary the new project setup rate and the average number of GGRs generated by project per year.

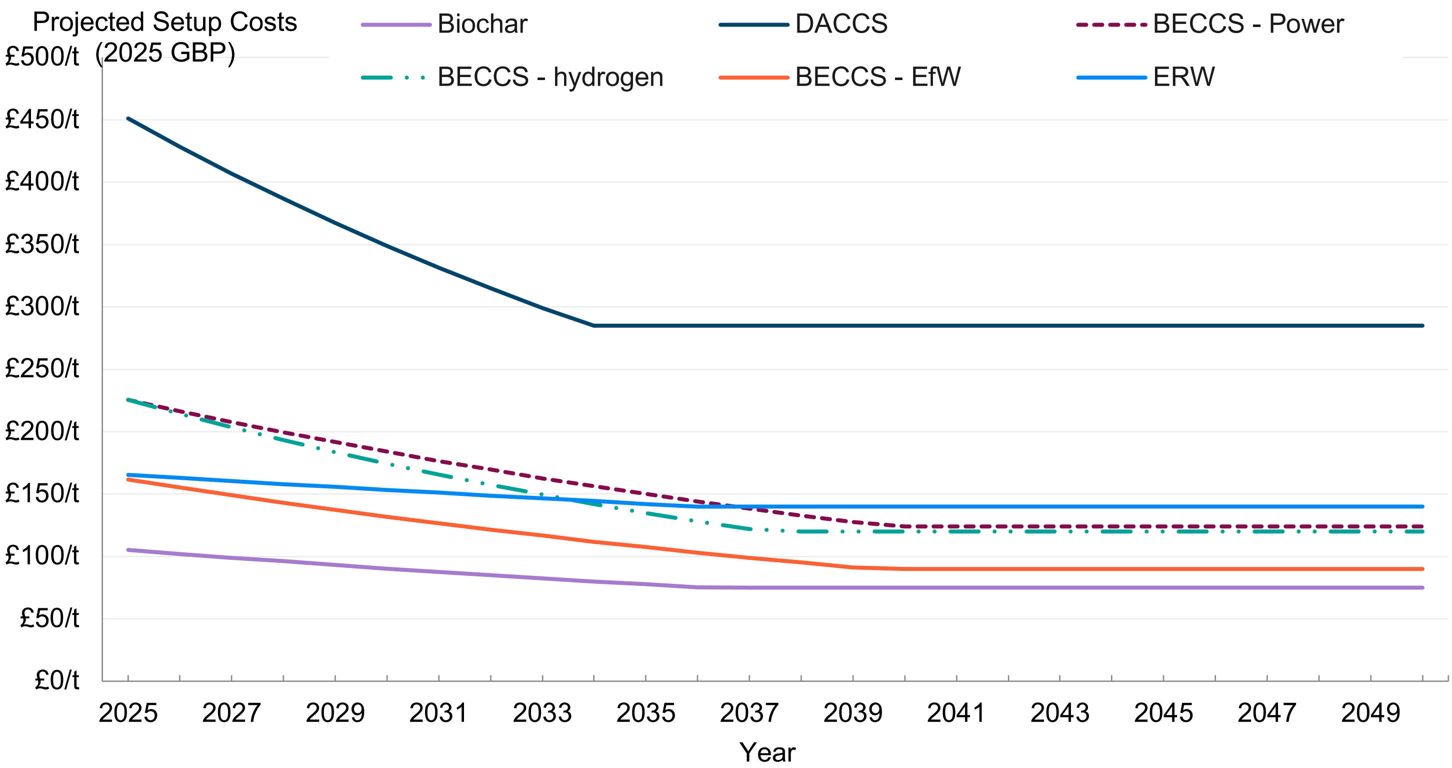
In the low supply scenario, we assume that GGR technology faces challenges in scaling up and in lowering the cost of production. Costs decline only marginally for most technologies, with all sectors reaching the minimum theoretical levelized cost by the late 2030s.

Figure 7. Minimum setup cost over time by technology in the low scenario



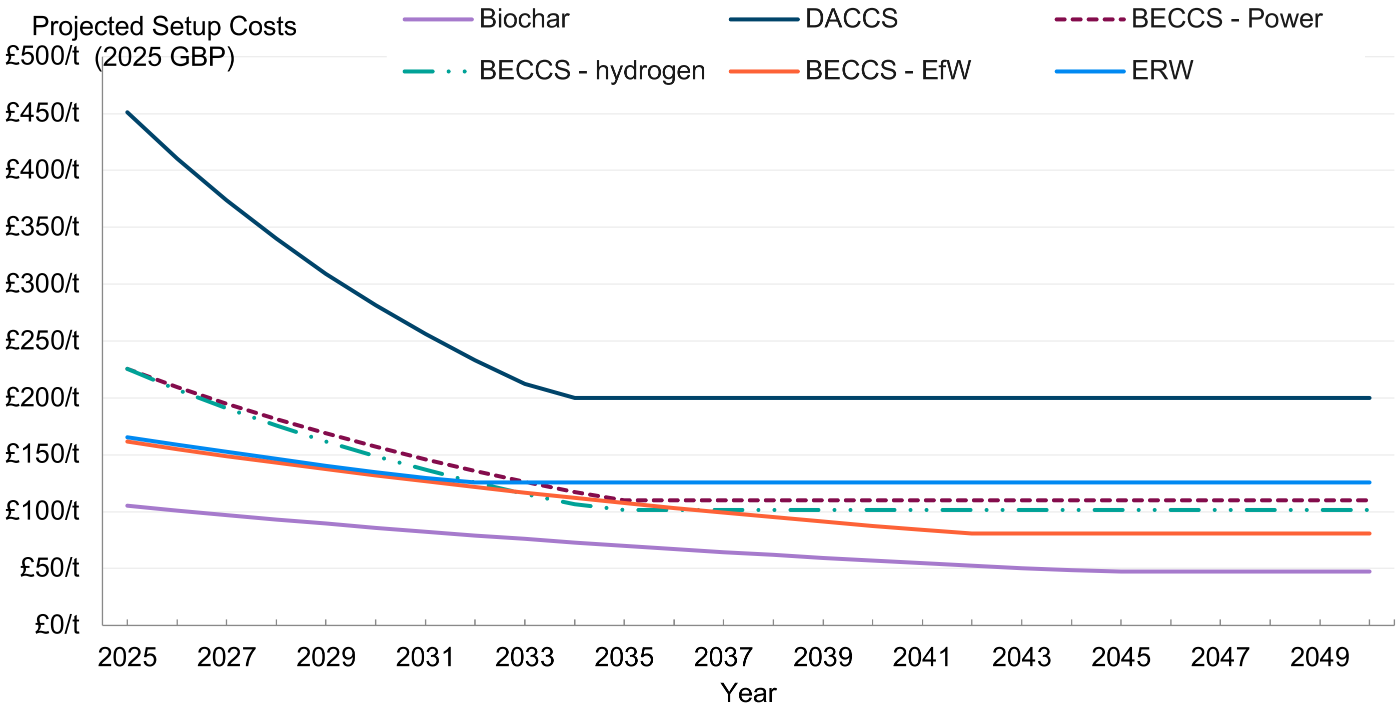
In the medium supply scenario, the levelized costs reach their theoretical minimum for most technologies in the mid-2030s. Biochar and BECCS – EfW both reach a sub-£100 setup cost point before 2040.

Figure 8. Minimum setup cost over time by technology in the medium scenario



In the high supply scenario, the most optimistic future cost projections are used. The cost of removing a CO2 using DACCS falls to £200 by 2034, reflecting a buoyant outlook for the technology's scale up.

Figure 9. Minimum setup cost over time by technology in the high scenario



Once the model generates supply-side cost trajectories, we adjust for market interactions between the voluntary and compliance markets to reflect real-world trading behaviour.

Off-Model Adjustments: Interaction of ETS and VCM

The model generates a voluntary market price per technology in each year, and expected credits traded at that price. However, demand for credits is split between voluntary sources and the UK ETS, and suppliers can sell into both voluntary and ETS markets. In order to estimate how many credits are traded in each market, we apply off-model adjustments based on the relative prices between the VCM and ETS.

While demand for GGRs from UK ETS obligated entities is theoretically as high as the cap in a given year, restricted by supply that could be generated at the ETS price, actual traded volumes may differ depending on the relationship between the VCM prices for different technologies and the ETS price in a given year. If a supplier is able to sell a credit for £200 in the voluntary market, it will likely not sell to a buyer willing to pay only up to an ETS allowance price of, say, £150. Similarly, an ETS-obligated buyer may not be willing to pay a high premium above the allowance price for a GGR in the ETS market.

Constraint: While it is possible that a buyer that has both ETS obligations and decarbonis   ation targets may be willing to pay the premium described above, as the credit may be used towards both obligations, this analysis assumes away this complexity.

We derive the split between GGRs supplied into the UK ETS vs. VCM from the difference between the VCM price for each technology and the supplied ETS price in a given year. This is on the assumption that a developer will choose to sell in the market in which they can obtain the highest price for the credit that they are generating. The below table is based on DESNZ projections[7] for traded carbon values used for modelling purposes.

Table 3. Projected ETS prices, under a medium (central), low (half central), and high (double central) scenario (2024 GBP)

Year	Low	Medium	High
2026	£31/t	£62/t	£124/t
2027	£38/t	£75/t	£150/t
2028	£44/t	£88/t	£176/t
2029	£40/t	£80/t	£160/t
2030	£39/t	£78/t	£156/t
2031	£43/t	£85/t	£170/t
2032	£46/t	£91/t	£182/t
2033	£49/t	£97/t	£194/t
2034	£50/t	£100/t	£200/t
2035	£55/t	£109/t	£218/t
2036	£58/t	£115/t	£230/t

[7] Traded carbon values used for modelling purposes, 2024

2037	£61/t	£122/t	£244/t
2038	£65/t	£130/t	£260/t
2039	£66/t	£132/t	£264/t
2040	£64/t	£128/t	£256/t
2041	£63/t	£125/t	£250/t
2042	£61/t	£122/t	£244/t
2043	£59/t	£118/t	£236/t
2044	£60/t	£119/t	£238/t
2045	£60/t	£120/t	£240/t
2046	£60/t	£119/t	£238/t
2047	£60/t	£119/t	£238/t
2048	£61/t	£121/t	£242/t
2049	£61/t	£122/t	£244/t
2050	£62/t	£124/t	£248/t

In order to model likely real-world behaviour when the VCM price and ETS prices are similar, we have applied the following rules for the split of VCM and ETS traded volumes, using a simplifying assumption for modelling purposes:

- If the VCM and ETS prices are within 25% of each other, suppliers will split volumes 50-50 between the two markets.
- Otherwise, the technology will sell 100% into the more profitable market.

Once we have derived an estimated split of traded volumes between the two markets, we can estimate the value of the combined UK GGR markets, described in further detail in the Results section.

Model Results

This section presents the outputs of the model scenarios analysed, with the figures below showing traded volumes and prices. Note that the forecasted price figures only show prices when trading activity exceeds 45,000 tonnes in a year. This is done to show prices only when there is a meaningful number of credits traded, indicating that the technology is being adopted by buyers. The weighted average GGR price shows the average price paid by buyers, taking into account the volumes of traded credits.

In all scenarios, the BECCS technologies have the same traded price, due to the model inputting the same willingness to pay premium for the BECCS technologies. This was done due to the lack of transaction data and information around the different types of BECCS sub-sectors modelled. In some cases, however, there is traded activity within one sector but not others. This is because the technologies have different setup costs, and the willingness to pay may exceed the minimum setup cost for one BECCS sub-sector, but not the others.

Price and Traded Volumes: UK GGRs

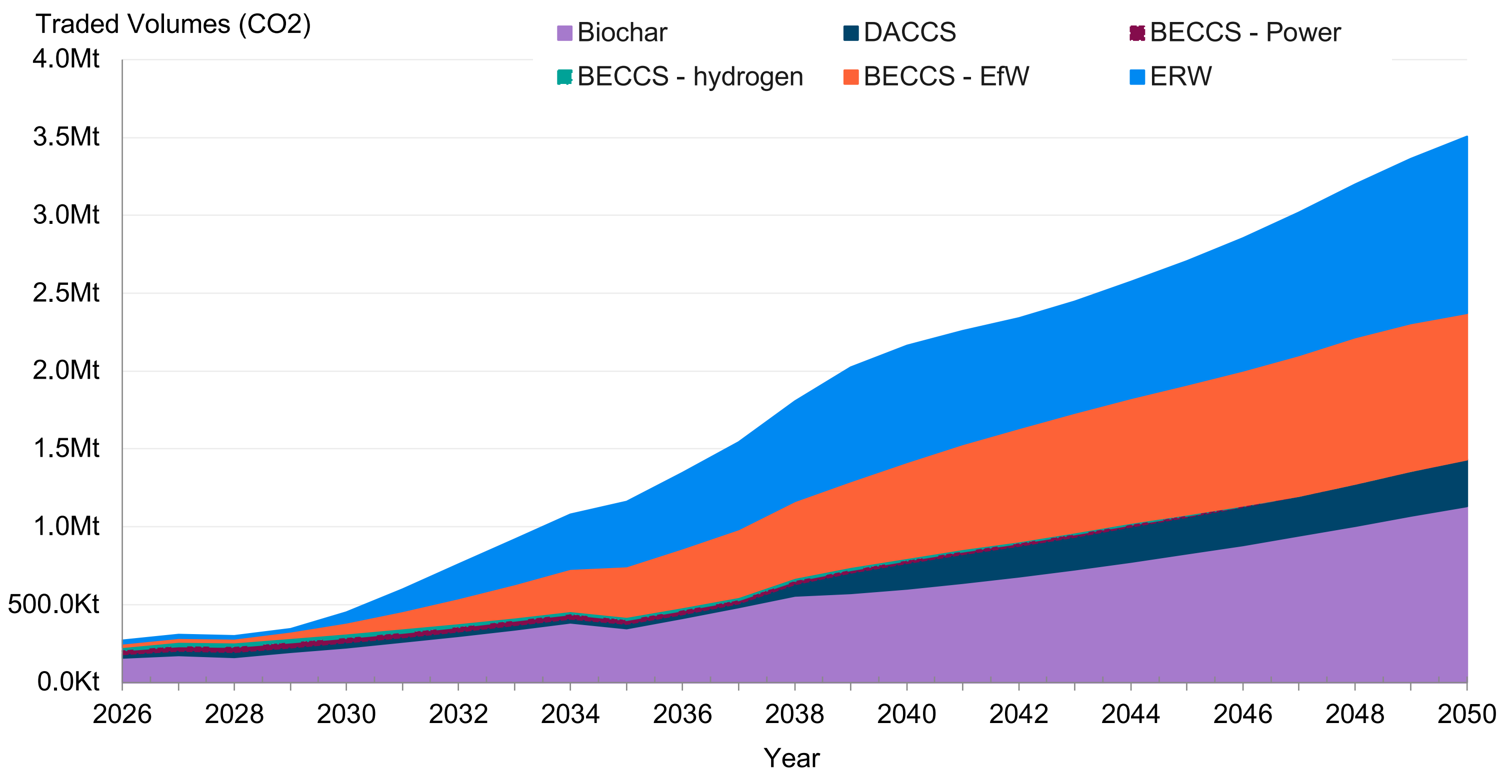
Low Scenario

In a low-growth scenario, the model predicts 43.6Mt GGRs traded between now and 2050 across the VCM and ETS, with annual volumes growing from 0.45Mt in 2030 to 3.5Mt in 2050. Biochar, ERW and BECCS – EfW dominate traded volumes, with DACCS credits only being supplied in large quantities after 2039. Biochar makes up the majority of supply to 2031, after which BECCS – EfW and ERW begin to trade at comparable volumes. Full annual breakdown by technology available in Appendix A4.1.

Biochar's minimum setup costs are lower than other technologies, giving it an early advantage. As prices for GGRs rise, BECCS – EfW becomes more competitive, particularly compared to other BECCS subtypes, because it is cheaper to set up and relies on waste biomass (typically household and commercial waste) rather than dedicated biomass feedstocks. This is reflected in the Forecast Model in the levelized costs of credit generation. DACCS supplies significant volumes at latter stages only, due to its high levelized setup cost, which prevents developers from profitably issuing GGRs until the late 2030s.

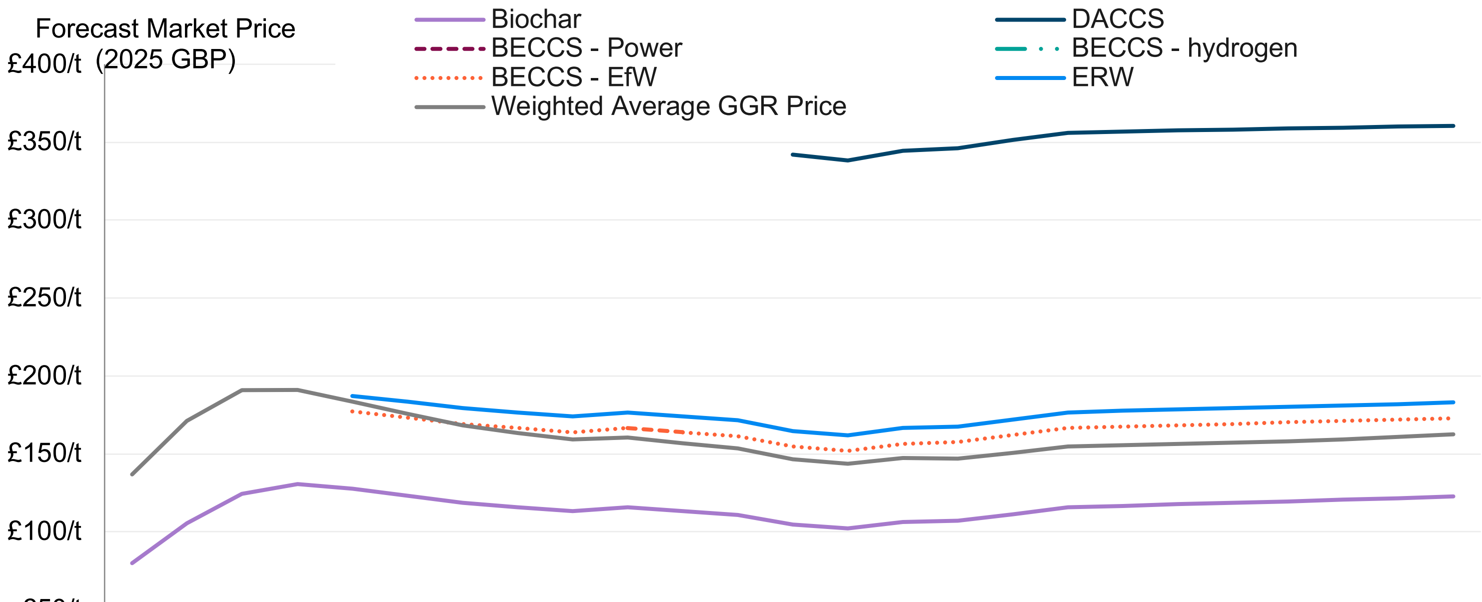
Note that in this scenario, BECCS – Hydrogen and BECCS – Power do not generate a significant number of credits. This is due to their higher levelized setup costs than BECCS – EfW, and a lower willingness to pay premium than DACCS. Combined, these two factors prevent the forecasting model from generating a significant number of credits in our analysis, as the willingness to pay premium prices do not exceed the levelized costs for these technologies.

Figure 10. Sectoral breakdown of credits generated, low scenario



In a low-growth scenario, prices rise between 2025 and 2030, as the lack of supply of credits pushes prices up even in a low-demand environment, and then plateau. The weighted average price across all technologies is £165/tonne by 2050. The full annual breakdown by technology available in Appendix A4.2.

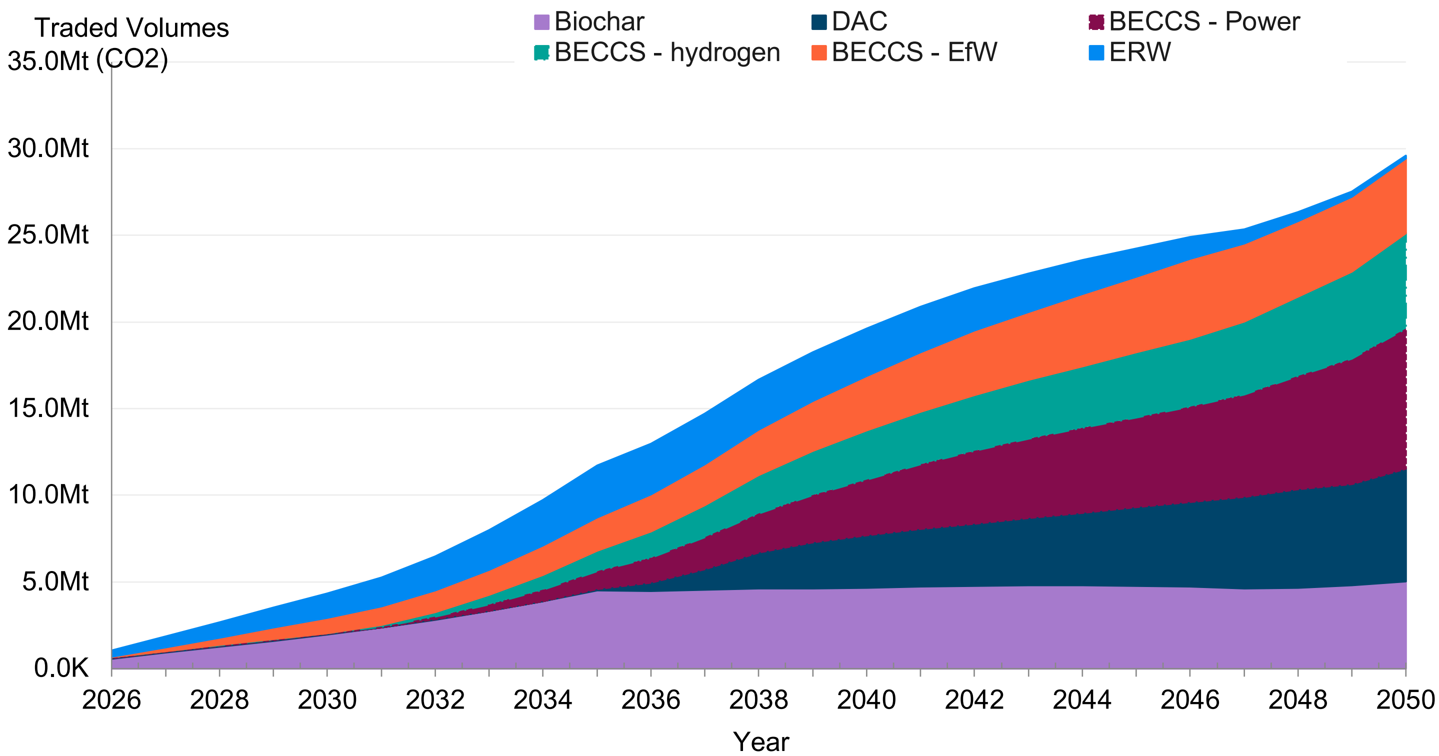
Figure 11. Forecast traded prices by technology, low scenario



Medium Scenario

In a medium-growth scenario, the model predicts 384 Mt GGRs traded between now and 2050 across the VCM and ETS, with annual volumes growing from 4M in 2030 to 30Mt in 2050. Volumes are relatively evenly split between technologies, with the exception of DACCS credits which are only supplied in significant volumes from 2035 onwards, due to a higher minimum setup cost and longer lead times. ERW supply declines toward the end of the period as prices from other GGR sectors become competitive with ERW. The model assumes a higher buyer willingness to pay for closed-system than open-system GGR methods as they are more verifiable. Full annual breakdown by technology available in Appendix A4.3.

Figure 12. Sectoral breakdown of credits generated, medium scenario

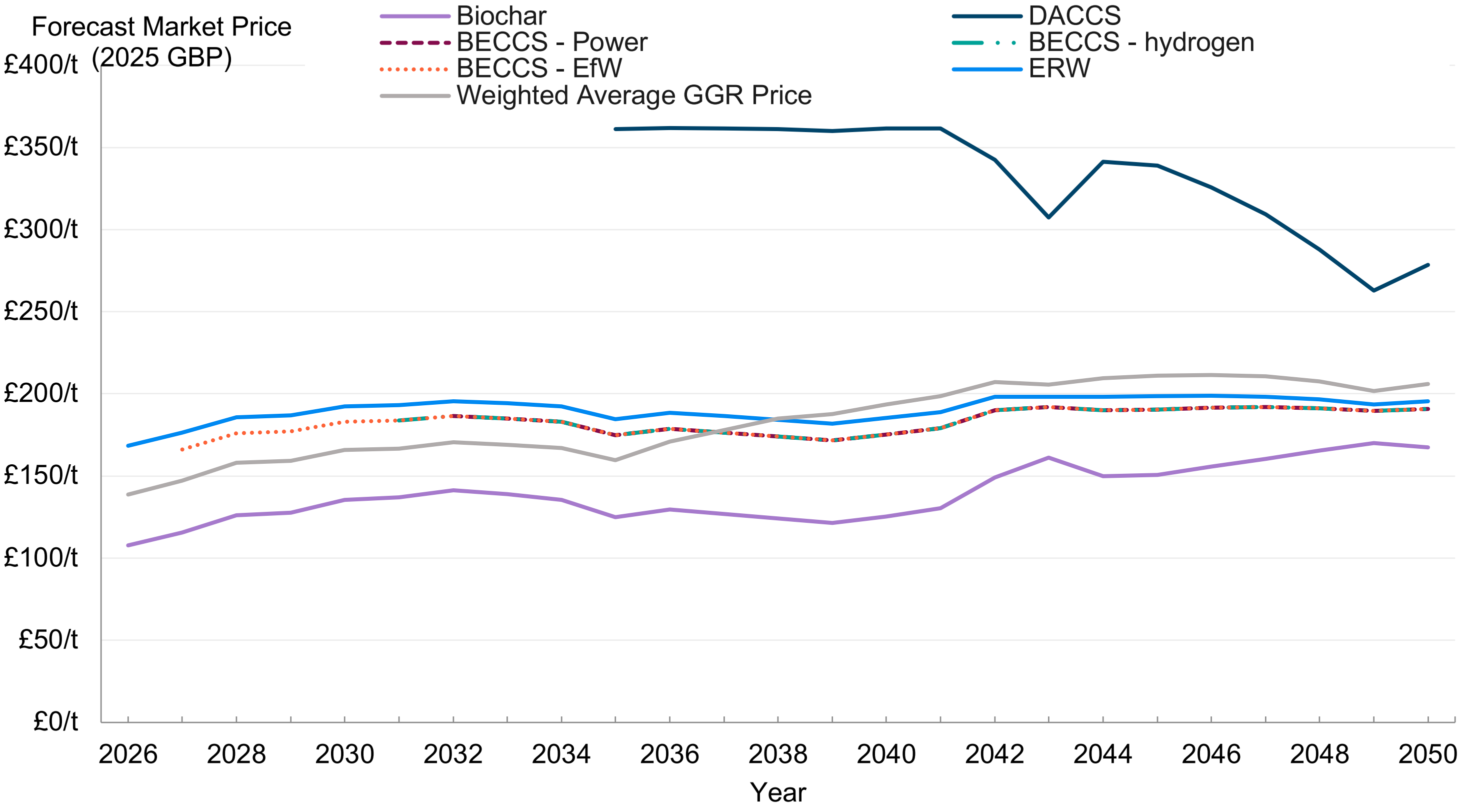


In a medium-growth scenario, the model predicts a high premium for DACCS credits until around 2045, when prices for all technologies begin to converge. The weighted average price across all technologies in 2050 is £208.[8] Full annual breakdown by technology available in Appendix A4.4.

[8] The decline of DACCS prices is a result of our assumption regarding the change in price premiums over time described in the methodology section above.

In the late 2030s, biochar output begins to stall as the supply of new potential projects is exhausted. This happens because the model assumes that when prices for a sector stay consistent, a decreasing number of new projects can be created at the same price point. In other words, developers who can profitably generate credits when prices are £150/tonne will set up initial projects in year 1. If prices don't change next year, those developers will be set up fewer projects in year 2, and so on. Because prices in this scenario stay fairly consistent, we expect biochar developers to create fewer new projects over time.

Figure 13. Forecast traded prices by technology, medium scenario

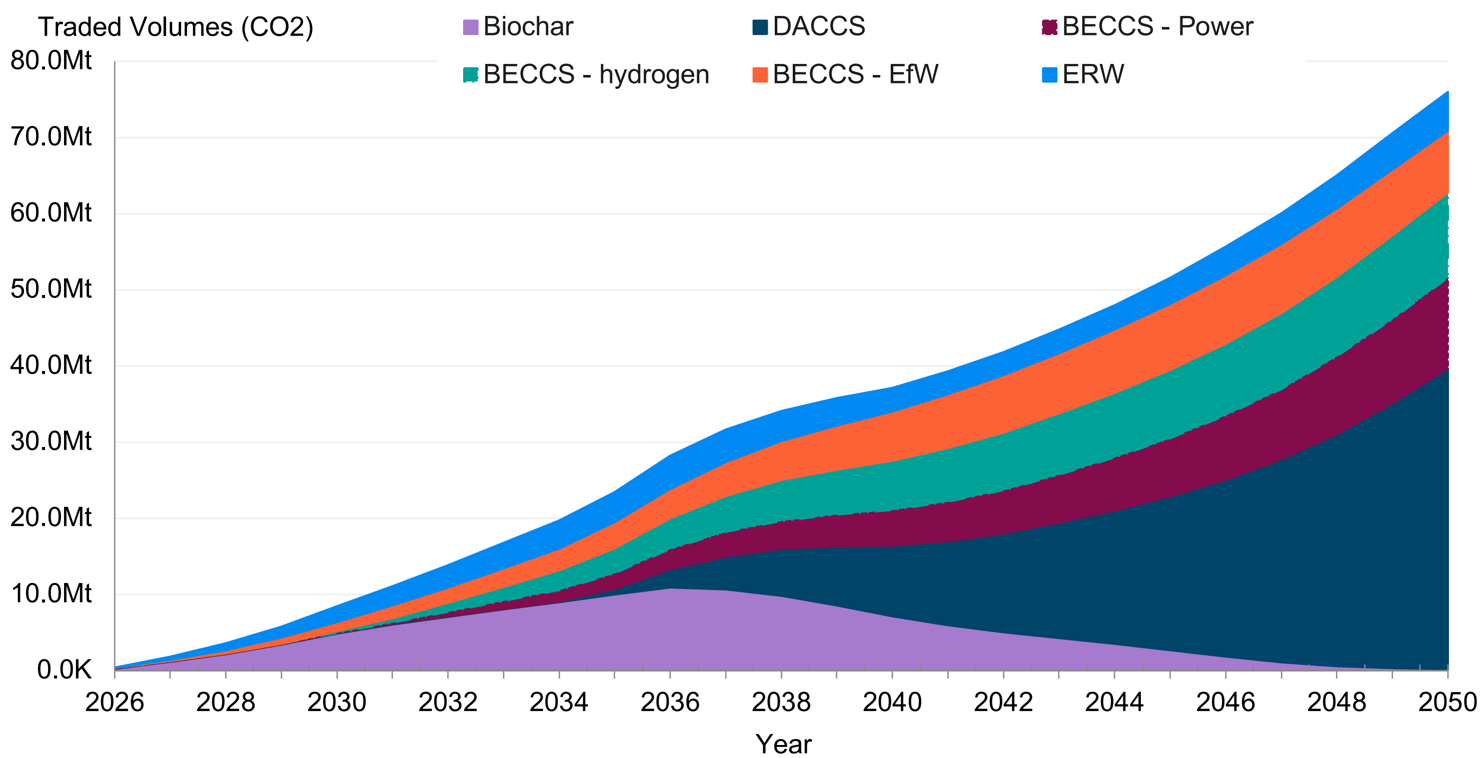


High Scenario

In a high-growth scenario, the model predicts 824Mt GGRs traded between now and 2050 across the VCM and ETS, with volumes growing from 8.4Mt in 2030 to 76 Mt in 2050. The model predicts that DACCS credits will comprise larger shares of the market as time goes on, with volumes accelerating from 2035 onwards. Full annual breakdown by technology available in Appendix A4.5.

In this scenario, levelized cost reductions and steeper efficiency gains lead to large-scale credit supply entering the market, matching the growing demand for credits from both voluntary and compliance sources. In the early years, the deployment sequence mirrors previous scenarios, with biochar dominating initial volumes, followed by BECCS and ERW. Once the price buyers are willing to pay for DACCS credits exceeds the cost of generation, supply expands rapidly. As market prices rise, buyers are expected to shift away from biochar credits. This reflects the modelled assumption that buyers exhibit a higher willingness-to-pay premium for other GGR technologies. Therefore, as overall credit prices increase, buyers are more likely to opt for higher-cost options such as BECCS over biochar. For example, if biochar credits are available at £190/tonne and BECCS - EfW at £200/tonne, buyers are assumed to select the latter due to the more robust MRV processes and durability associated with closed-system technologies.

Figure 14. Sectoral breakdown of credits generated, high scenario

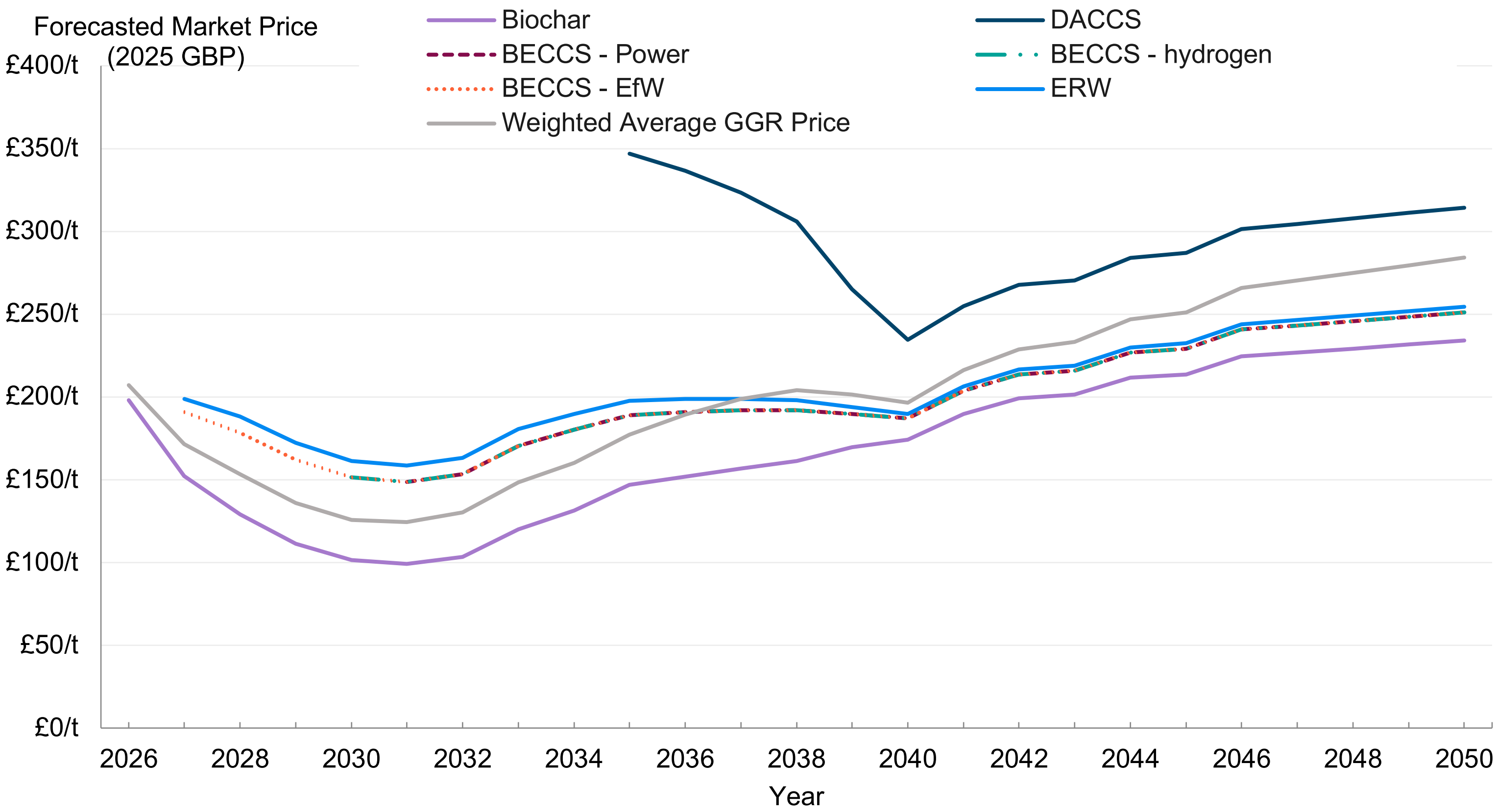


In a high-growth scenario, the model predicts prices to fluctuate until 2040, with growing demand for credits counterbalanced by steady declines in the cost of generating credits that leads to prices falling in the first five years of the model. After 2040, however, increasing compliance and voluntary demand leads to steady price growth, reaching a weighted average of £284/tonne in 2050.

Once they begin trading at scale in 2035, we forecast DACCS credits to reduce in price, as the levelized cost of production fall until 2040. At that point, with buyer demand increasing steadily, the prices begin to rise, as the higher prices across the market lead prices for all technologies to grow.

Full annual breakdown by technology available in Appendix A4.6.

Figure 15. Forecast traded prices by technology, high scenario



Volumes Traded in ETS vs. VCM: UK GGRs

The table below summarises differences in key assumptions made for each of the scenarios:

Table 4. Summary of UK ETS assumptions in the three modelled scenarios

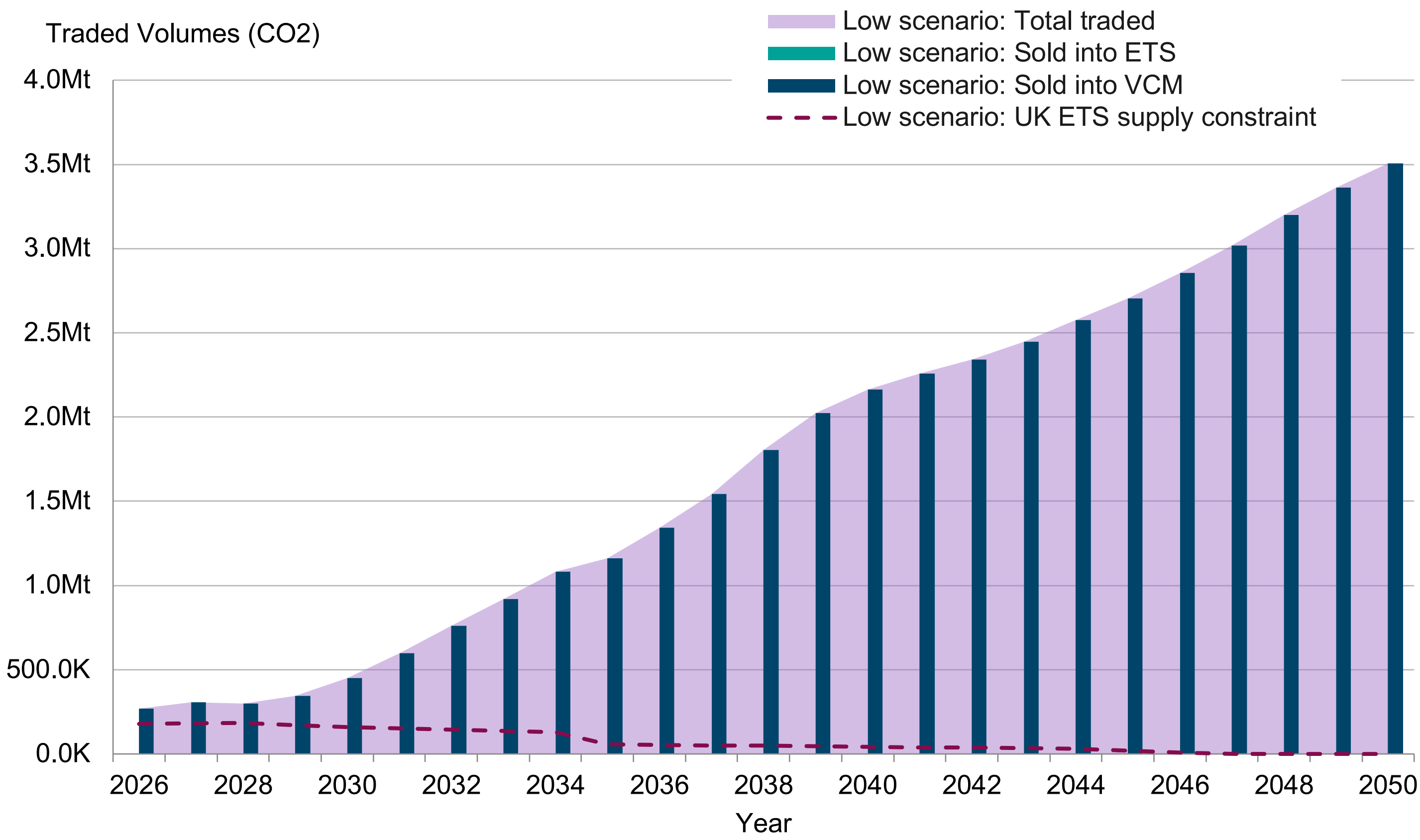
Scenario	ETS Prices	ETS Cap
Low	Prices are modelled at half central scenario values (reaching £62/tonne in 2050)	ETS allowances modelled to 10m units in 2050
Medium	Prices are modelled at central values (reaching £124/tonne in 2050)	ETS allowances modelled to 10m units in 2050
High	Prices are modelled at double central values (reaching £248/tonne in 2050)	ETS allowances modelled to 20m units in 2050

Low Scenario

Prices for all technologies are significantly higher than the ETS price in the low scenario (£62/tonne in 2050), so no GGRs are supplied into the UK ETS.

The line showing UK ETS maximum traded supply constraint shows the number of credits that would be generated at projected ETS prices in the low scenario.

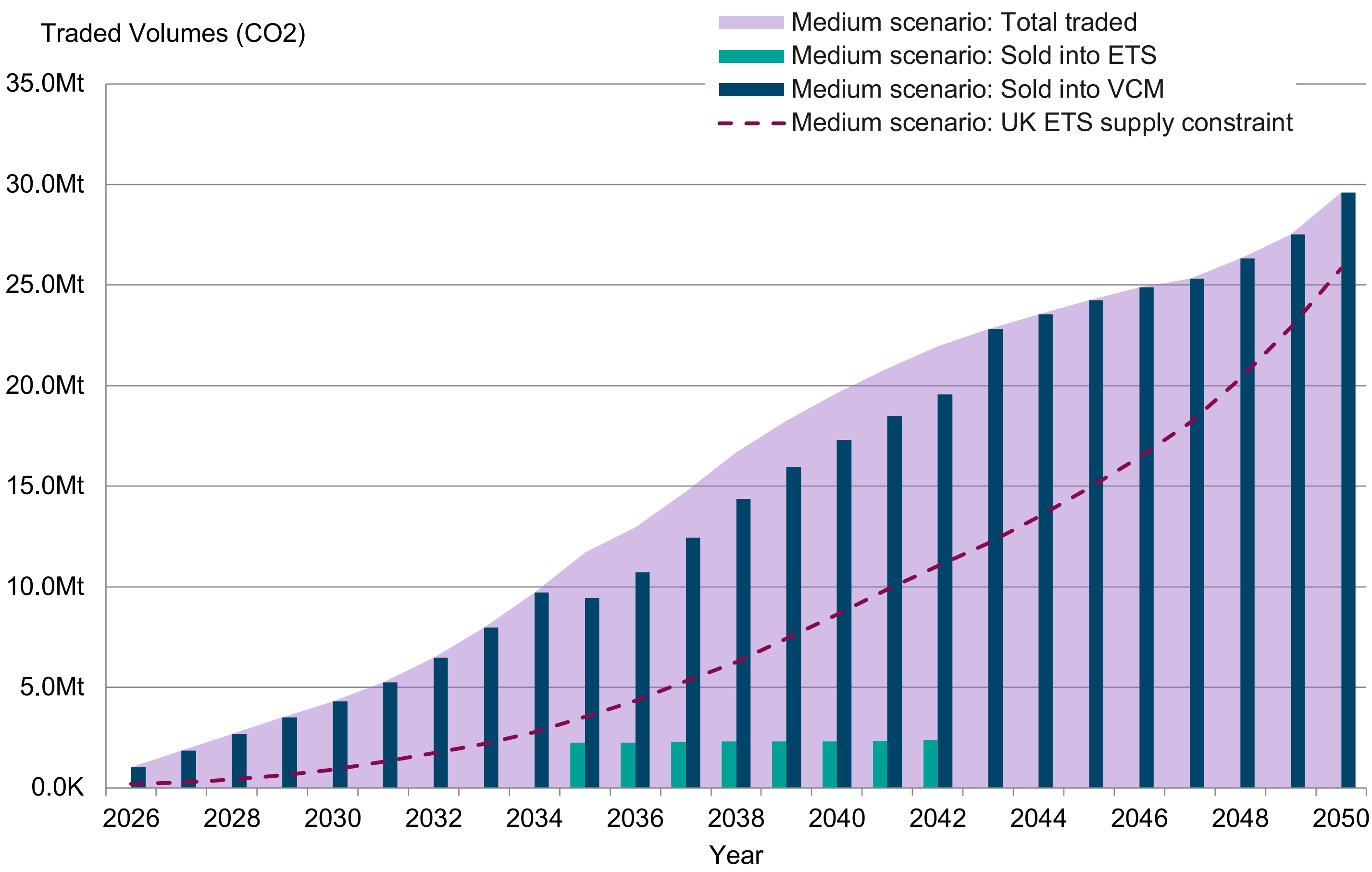
Figure 16. Voluntary vs. ETS in low supply and demand scenario



Medium Scenario

In the medium scenario, the ETS price is only competitive with the VCM price for biochar credits, between 2035 and 2042. Because the ETS price is never greater than 25% of the VCM price for biochar, we assume that biochar suppliers would sell into both markets equally. In total, only 18.5Mt biochar GGRs are sold into the ETS in this scenario; once prices in the VCM exceed ETS prices by more than 25%, we assume all supply will be sold into the VCM.

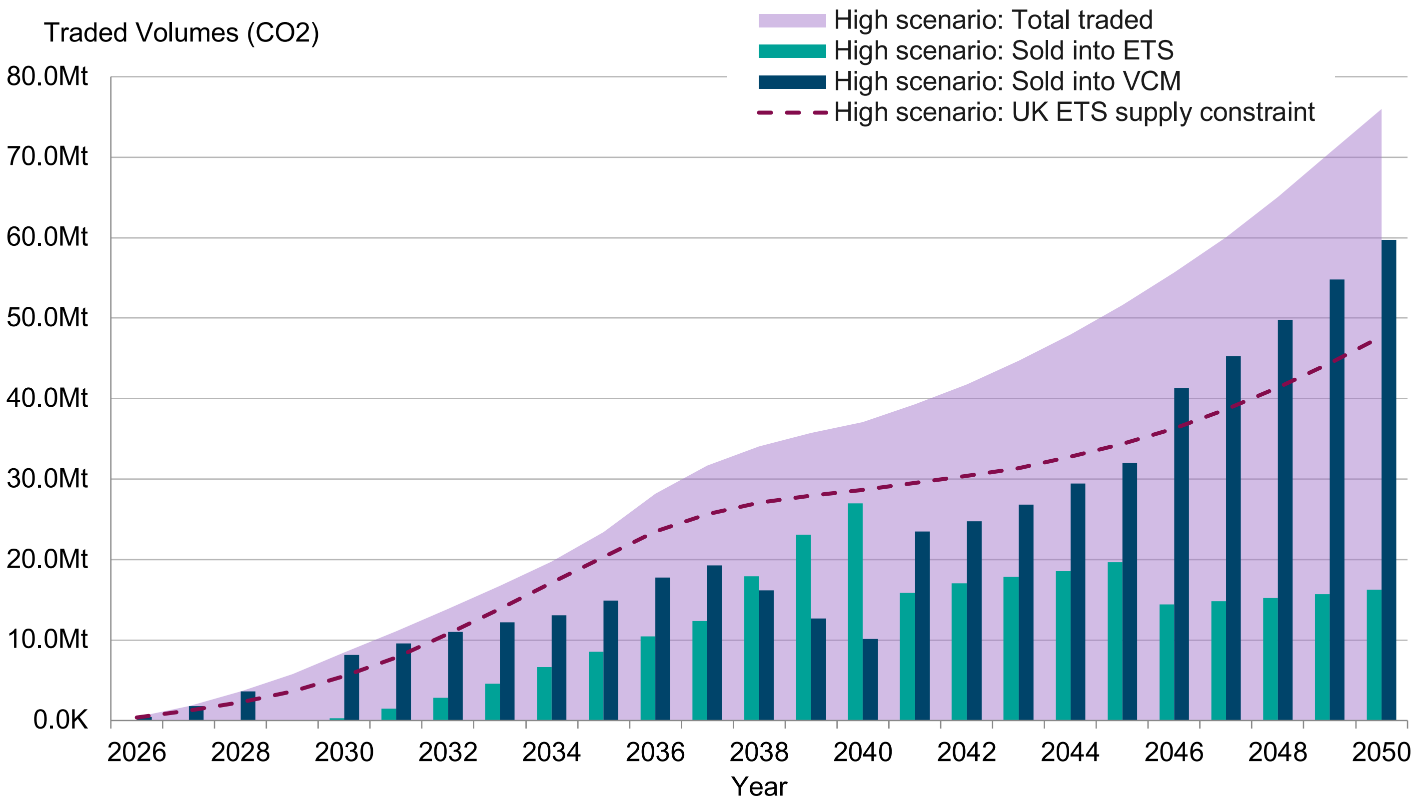
Figure 17. Voluntary vs. ETS in medium supply and demand scenario



High Scenario

In the high scenario, the ETS price is competitive with the VCM price for most technologies from 2029 onwards, meaning they sell at least a portion of their credits into the ETS. The one exception to this is DACCS, whose suppliers only sell into the ETS between 2038 and 2045; this is due to higher willingness to pay prices in the VCM. From 2029 onwards, 34% of credits generated are sold into the ETS in the high scenario.

Figure 18. Voluntary vs. ETS in high supply and demand scenario



Total Spent on Each Technology: UK GGRs

The following section calculates value of total sales of each technology per scenario. For VCM-traded credits, this is the (volume traded in the VCM) x (VCM price). For ETS-traded credits this is the (volume traded in the ETS) x (ETS price).

Low Scenario

In the low scenario, total predicted trading volume is coming purely from the VCM. The value of all GGRs traded between 2026 and 2050 in this scenario is £7.2B (£ billions). Technologies with the largest market share are ERW, BECCS – EfW and Biochar.

Table 5. Total spent and share per technology, low scenario (2026-50)

Technology	Total spent	Spent on ETS[9]	Share (%) of Total Spent
Biochar	£1.6B	£0	22%

[9] This is the amount that market participants in the UK ETS have spent on GGR allowances within the scheme.

DACCS	£1.1B	£0	15%
BECCS - Power	£77.2M	£0	1%
BECCS - Hydrogen	£66.2M	£0	1%
BECCS - EfW	£2.0B	£0	28%
ERW	£2.3B	£0	33%
Total	£7.2B	£0	100%

Medium Scenario

In the medium scenario, the majority of value of GGRs comes from VCM trading, with only £2.3B of biochar ETS credits traded in the period of study. The value of all GGRs traded in this scenario is £75B. DACCS has the largest market share at 24%, with BECCS and biochar technologies accounting for ~15% of the market each, and ERW at 10%.

Table 6. Total spent and share per technology, medium scenario (2026-50)

Technology	Total spent	Spent on ETS	Share (%) of Total Spent
Biochar	£13.3B	£2.3B	18%
DACCS	£18.3B	£0	24%
BECCS - Power	£13.1B	£0	17%
BECCS - Hydrogen	£10.1B	£0	13%
BECCS - EfW	£12.0B	£0	16%
ERW	£8.4B	£0	11%
Total	£75.1B	£2.3B	100%

High Scenario

In the high scenario, 57% of the value of GGRs comes from VCM trading, with £688B of the total £205B spent on ETS GGRs. DACCS has the largest market share at 37%, with BECCS - hydrogen next at 15%, and all other technologies between 8-14%.

Table 7. Total spent and share per technology, high scenario (2026-50)

Technology	Total spent	Spent on ETS	Share (%) of Total Spent
Biochar	£27.1B	£24.0B	13%
DACCS	£76.7B	£5.0B	37%
BECCS - Power	£25.4B	£14.6B	12%
BECCS - Hydrogen	£30.3B	£17.8B	15%
BECCS - EfW	£28.8B	£17.0B	14%
ERW	£17.5B	£9.7B	8%
Total	£205.8B	£88.0B	100%

The high scenario is the only one where projected ETS prices reach high enough levels to support significant demand into the VCM. This underscores the importance of a strong voluntary market, which we anticipate will be the key driver of GGR activity in the UK. The following section presents the outputs for a hypothetical scenario in which UK ETS is the sole source of demand for GGRs.

Role of the ETS in a “VCM Failure” Scenario: UK GGRs

Up to this point, the analysis has assumed an interplay between the VCM and the UK ETS. In each scenario described above, the ETS comprises very little of the total GGR market. This is because the predicted voluntary demand is high enough, relative to supply constraints, to keep VCM prices higher than the ETS price in most years. However, the predicted demand is by no means guaranteed. Companies may renege on their targets or opt for lower cost credits in place of technical GGRs.

Unlike the voluntary market, the UK ETS can provide a dependable source of demand for GGRs, given the compulsory nature of the market. In this section, we will explore the potential of the ETS to stimulate the GGR market in the UK in the absence of voluntary demand. Using the “maximum ETS traded (low/medium/high supply constrained)” volumes depicted in the Volumes traded in ETS vs. VCM section above, we have three “VCM failure” scenarios:

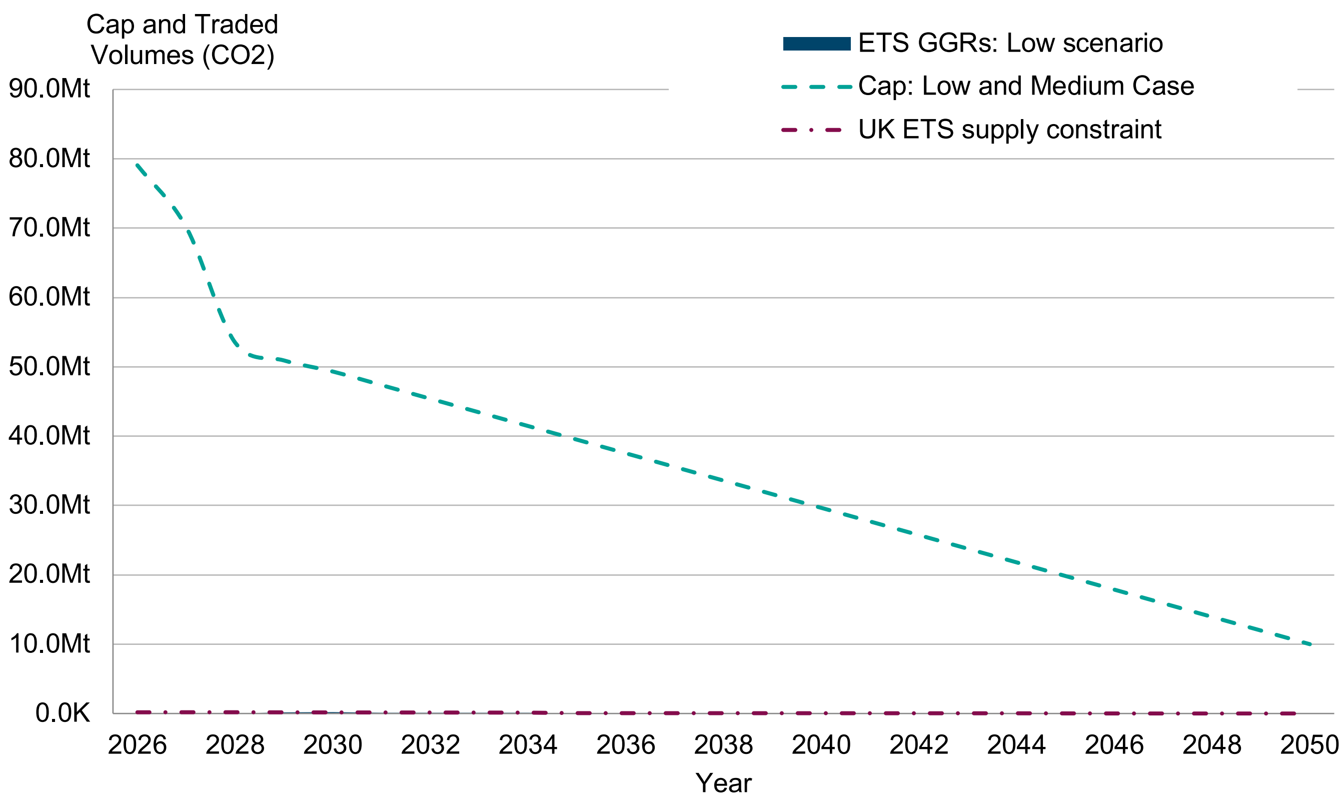
- Low supply assumptions, low ETS price;
- Medium supply assumptions, central ETS price; and
- High supply assumptions, high ETS price.

In other words, the above scenarios assume 0 demand for GGRs from the VCM, with the UK ETS making up all of traded credits. All supply-side assumptions remain the same as described above.

Low ETS-Only Scenario

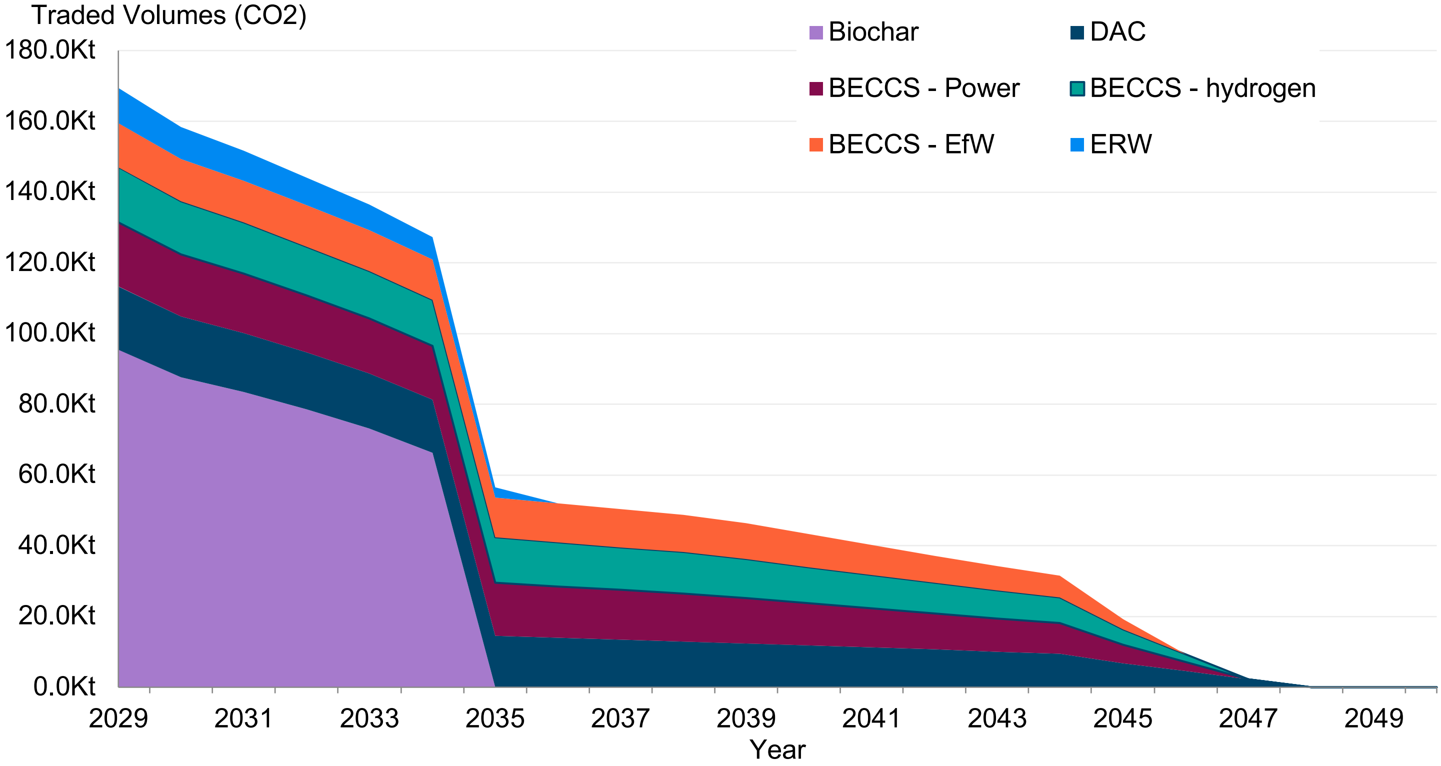
In the low scenario, ETS prices do not reach the minimum setup cost for any technology. The maximum ETS price is £66 in 2039, and the lowest minimum setup cost in any year is £75/tCO2e for biochar. Therefore, the model assumes no new credits will be supplied, and the only credits sold into the ETS will be from projects in existence today.

Figure 19. ETS-only traded volumes, low scenario



Note in the figure above, the traded volumes are too small to register in the context of the projected ETS cap. In this scenario, biochar GGRs are sold into the ETS in the largest proportions until they are depleted in 2035. Residual credits from projects in other sectors are also sold into the ETS, in smaller volumes, after 2035, until the projects finish their crediting periods.

Figure 20. Sectoral breakdown, low scenario



In this scenario, the ETS results in only £68m being traded. This is because the low ETS price modelled does not stimulate new project creation in any year between 2029 and 2050. Assuming that suppliers have set projects up at costs greater than the ETS price, we can conclude that if they were to sell into the ETS only, suppliers would experience net losses. If suppliers were to sell into the ETS under these conditions, it would be only in cases where ETS prices were greater than costs to operate on already built capital. We know that a significant proportion of projects in existence today have purchases secured through offtake agreements, so it is possible that none of these credits would be sold into the ETS. Regardless, ETS prices in the low scenario would not be sufficient to stimulate growth of the GGR market in the United Kingdom.

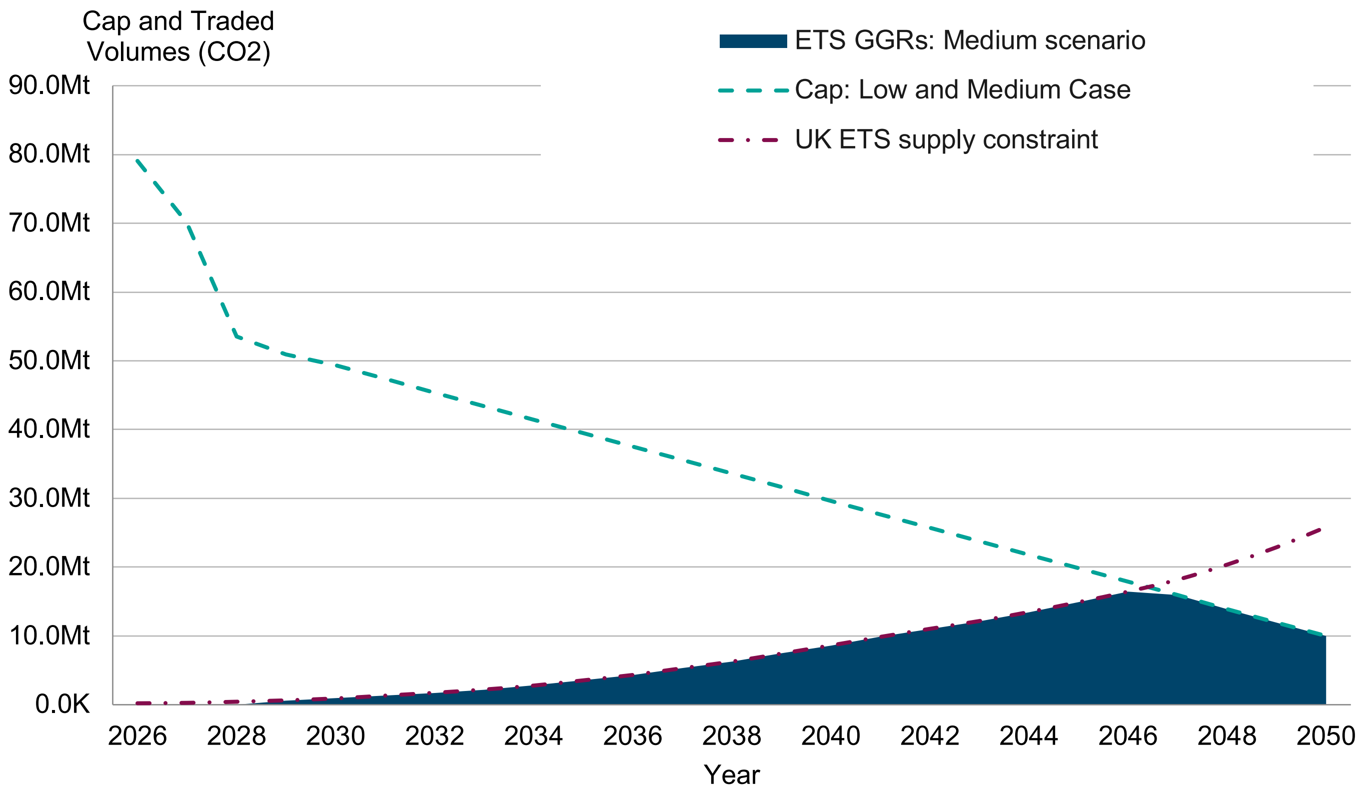
Table 8. ETS spending by technology, low scenario

Technology	Total Spent	Share (%) of total spent
Biochar	£21.2M	31%
DACCS	£12.5M	18%
BECCS - Power	£12.2M	18%
BECCS - Hydrogen	£10.5M	15%
BECCS - EfW	£8.9M	13%
ERW	£2.3M	3%
Total	£67.6M	100%

Medium Scenario

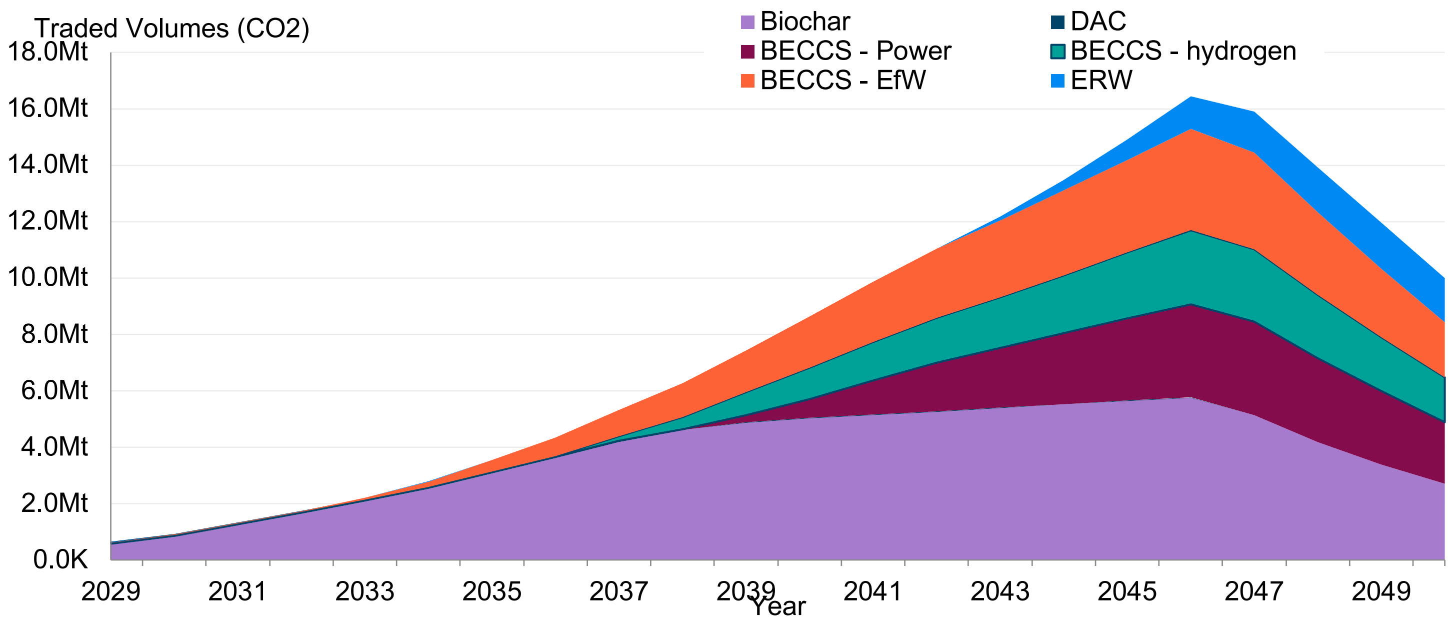
In the medium scenario, ETS prices exceed the minimum setup costs for biochar from 2032 onwards, for BECCS – EfW from 2035 onwards, and for BECCS (power) and BECCS (hydrogen) sporadically from 2037 onwards. The ETS price is well below the minimum setup cost for DACCS projects. Overall, the supply-constrained volumes exceed the emissions cap in 2047 only. In this scenario, the ETS price is assumed to peak at £132/tCO_2 in 2039.

Figure 21. ETS-only traded volumes, medium scenario



In this scenario, biochar credits dominate the market through 2050, with BECCS, in particular BECCS - EfW, technologies increasing their market share from 2035. Prices at these levels fail to stimulate DACCS supply, due to the large difference between setup costs and the ETS price. ERW credits may be sold toward the end of the study period as demand increases and GGRs from other technologies run out. The decline in credits after 2046 is due to the allowance cap being reached: the model projects GGRs to make up 100% of the (declining) cap from then until 2050.

Figure 22. Sectoral breakdown, medium scenario



In a medium ETS-only scenario, we predict the ETS to bring £21B into the GGR market. Biochar suppliers will likely sell into the ETS the most, considering their relatively low levelized setup costs.

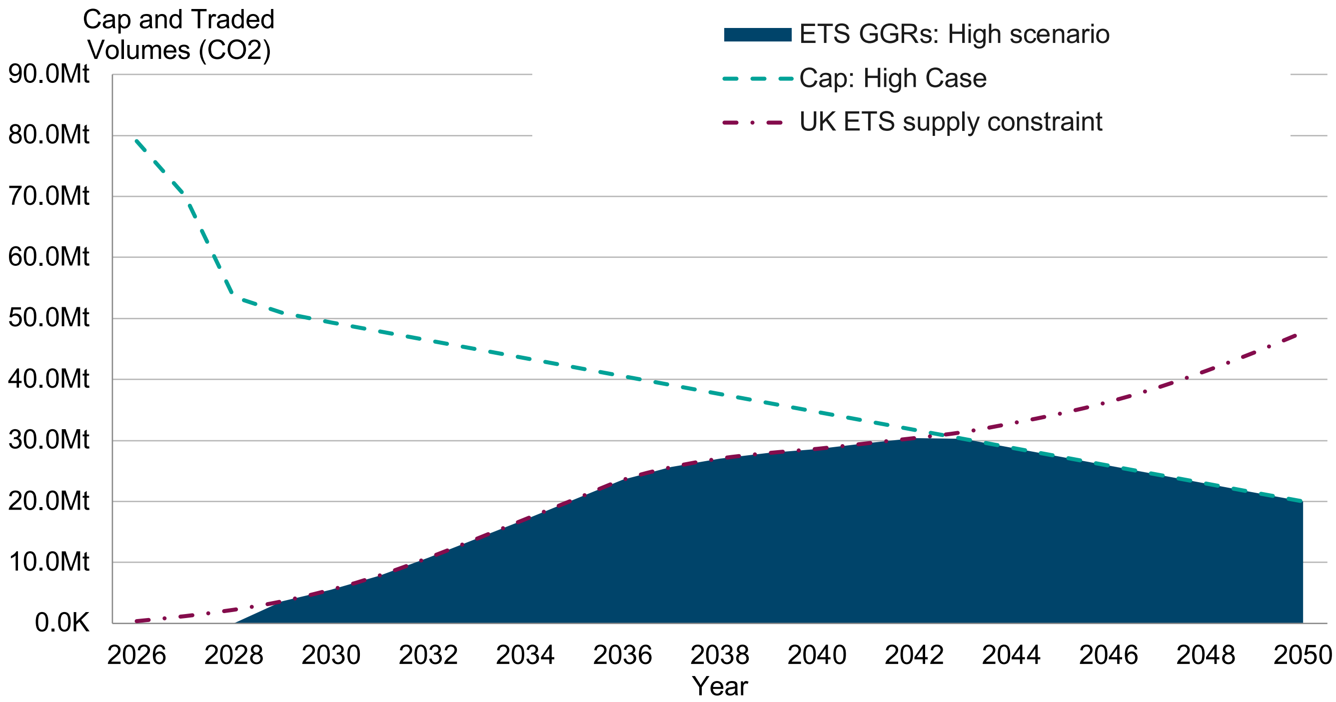
Table 9. ETS spending by technology, medium scenario

Technology	Total Spent	Share (%) of total spent
Biochar	£9.8B	47%
DACCS	£28.8M	0%
BECCS - Power	£3.1B	15%
BECCS - Hydrogen	£2.8B	13%
BECCS - EfW	£4.2B	20%
ERW	£1.1B	5%
Total	£21.0B	100%

High Scenario

In the high ETS only scenario, ETS prices exceed the minimum setup costs for all technologies between 2026 and 2032, and the ETS price remains above the costs for all technologies until 2050, meaning ETS demand alone is enough to stimulate project creation in all sectors. Overall, the supply-constrained volumes exceed the emissions cap in 2043. This means there will be excess supply of credits to the market. In this scenario, the ETS price is assumed to peak at £264/tCO2 in 2039.

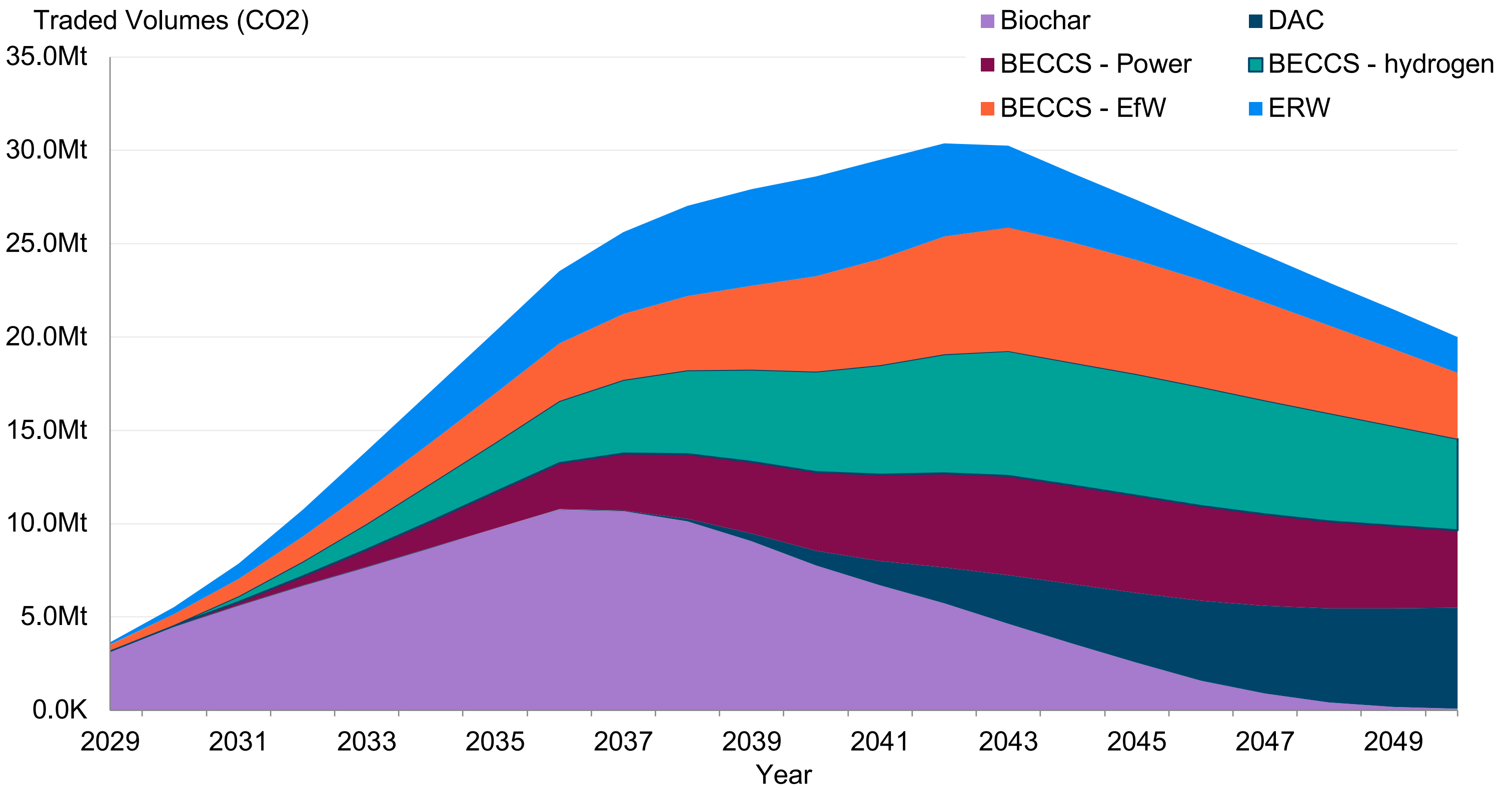
Figure 23. ETS-only traded volumes, high scenario



In this scenario, biochar credits dominate the market through 2040, with BECCS and ERW technologies growing their market share from a small base from 2030 onwards. DACCS credits command a larger market share between 2045-2050 as prices rise and they become more profitable to sell.

At high enough prices, we see demand for biochar decreasing, while demand for other technologies increases. This is due to buyer preference for closed-system credits mentioned above: at high enough ETS prices, all else equal, we anticipate buyers would prefer to spend money on credits that are more highly regarded. In other words, if ETS compliant entities can pay the same price for a biochar credit vs. a DACCS credit, the model assumes they will prefer to purchase the DACCS credit.

Figure 24. Sectoral breakdown, high scenario



In a high ETS-only scenario, we predict the ETS to bring £112B into the GGR market. The high ETS-only scenario creates the most diversified GGR market of the scenarios modelled. Biochar and BECCS still command the largest market share, with ERW and DACCS falling closely behind.

Table 10. ETS spending by technology, high scenario

Technology	Total spent	Share (%) of total spent
Biochar	£27.2B	24%
DACCS	£9.4B	8%
BECCS - Power	£17.1B	15%
BECCS - Hydrogen	£21.7B	19%
BECCS - EfW	£20.2B	18%
ERW	£16.2B	14%

Total	£111.7B	100%

Model Risks

The AlliedOffsets Forecast Model is a complex and detailed product, which can be tweaked by inputting a range of assumption inputs. There are five key risks the modelling work carries:

- Incorrect variable inputs: This relates to risks arising from overly optimistic or pessimistic inputs being fed into the model. To minimise this risk, we created multiple scenarios to show a range of potential outcomes, and reviewed dozens of sources to identify the inputs for the model. However, it's possible that these do not represent the full range of potential outcomes in the future.
- Lack of real-world track record: The model is highly detailed, with more than 40 assumptions underpinning each sector's supply curves. While we have tested the model extensively to ensure results are consistent with real world outcomes, we are limited by the lack of historical track record to test the model against (especially given the nascent nature of the GGR sectors studied).
- Unanticipated scenarios: Given the uncertain nature of the GGR market, it is possible that there will be technological breakthroughs we are not accounting for, or policy headwinds or tailwinds that impact the market. As we limited the scope of this analysis to prices and costs of GGR credits, without incorporating any potential policy changes (outside UK ETS integration) or exogenous technological shocks in sectors' levelized costs, the model does not consider these potential changes and their outcomes.
- Data quality: The model relies on a diverse range of external datasets and literature sources, each with differing methodologies, definitions, and update frequencies. Inconsistencies or outdated information in these inputs could affect the comparability of results across technologies and regions.
- Model structure: As with any modelling exercise, simplifying assumptions are necessary to make the analysis tractable. Structural assumptions, like technologies' premiums and discounts, how costs change, or how demand responds to price, may not fully capture the complexity of real-world market behaviour.

Discussion

This report addresses two central research questions: What are the factors influencing global demand and supply of engineered removals to 2050, and what are the projected prices and traded volumes of removals in the voluntary carbon market?

The answer to the first section, discussed in the first part of this report, is familiar to those who follow the GGR (and broader VCM) markets. On the demand side, growing compliance market demand for credits is helping to buttress fledgling voluntary demand.

Compliance demand, while limited, is important because it can send a price signal to project developers and buyers and is more stable than demand from voluntary commitments to lower emissions and use GGRs. Voluntary demand remains the largest potential source of demand for GGRs, and we forecast this will remain the case into the future. Standards like SBTi play an important role in helping to define the scope of GGR use by companies, as well as the project types that companies can use to meet their emission reduction targets. Additionally, voluntary buyers are more likely be price-sensitive to certain GGRs over others, while compliance buyers are more likely to fill their obligation with the cheapest allowable credits. This preference, or the premium they are willing to pay for certain GGRs, is variable and can be influenced by external factors, making this source of demand even more difficult to project.

On the supply side of the market, key factors include the levelized costs of setting up projects (by technology), today and in the future; the learning rate, which defines the speed with which project developers can reduce their setup costs to their theoretical minimum; and the volume of GGRs generated. The extent to which costs can be brought down for various technologies is a matter of extensive academic discussion. The costs are influenced by a number of factors, like labour, MRV, raw material inputs, and energy; they vary country to country.

The literature review component of this research synthesised the various studies into a set of inputs that are fed into three UK-centric supply scenarios for the market. We modelled demand by calculating emissions and reduction targets of companies currently in the VCM, projecting them forward to account for residual emissions that may need to be offset, and modelling out new companies setting targets. We supplemented this with compliance demand to generate projections for total GGR demand until 2050. With the assumptions in place, supported by academic research and based on historical data trends, we executed the model to generate traded volume and price projections.

The model's outputs highlight several key findings. Firstly, historical demand for credits, as modelled in the low scenario, is not sufficient to stimulate growth of the

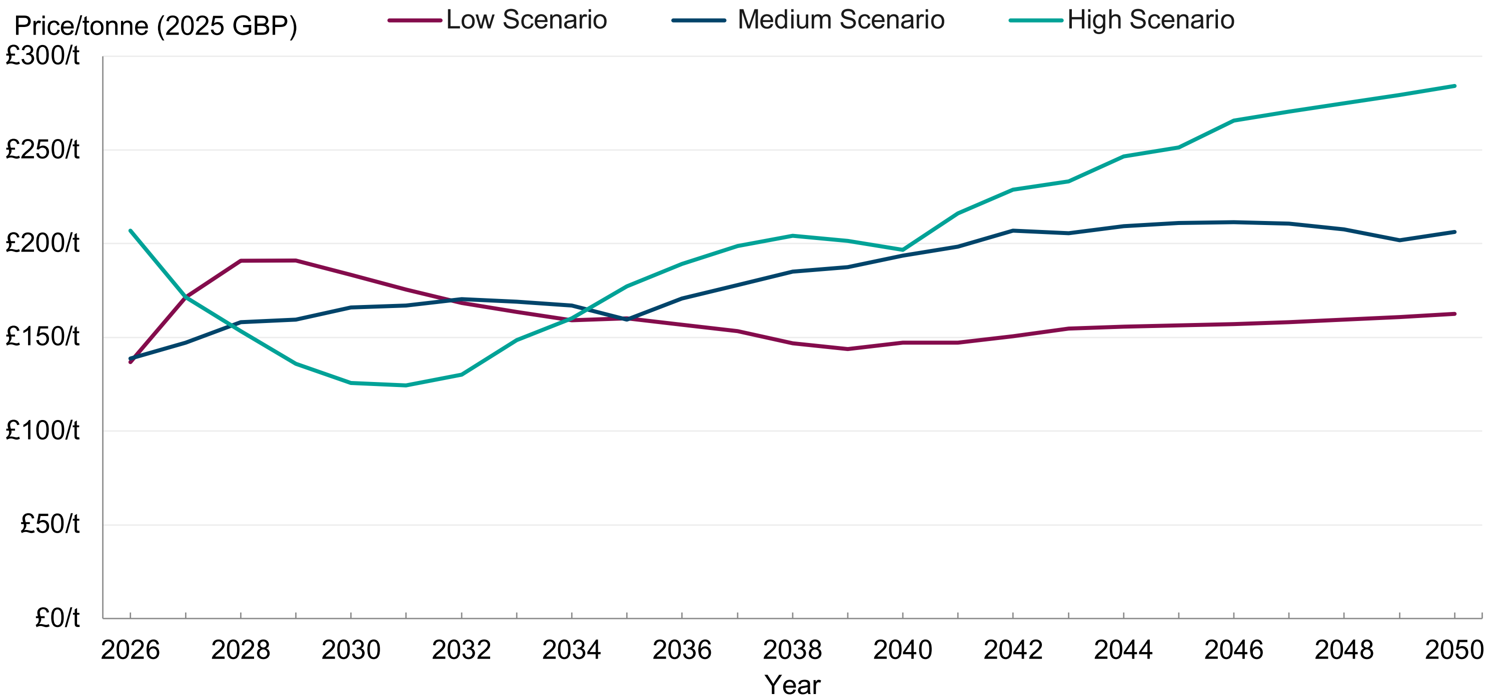
UK GGR market. In this scenario, GGR prices remain relatively low, and actually decrease from 2028 to 2040, as a lack of demand provides downward pressure. UK ETS integration is not enough to boost the market, as the projected allowance prices remain too low to stimulate project creation.

Secondly, the high scenario, which falls in line with the UK Government's Carbon Budget and Growth Delivery Plan, stimulates significant GGR demand, leading to prices that exceed £250/tonne by 2050. This highlights that were the government's goals to be met, all of the technologies examined in this report would scale considerably. This indicates a need for coordination between the UK Government and the private sector in order to ensure demand can be elevated to high scenario levels. It also suggests a need to invest in capacity building across all GGR pathways, not a single technology.

Thirdly the impact of the ETS relative to the VCM is modest, due to relatively high VCM prices. However, as noted in the "VCM failure" section, these VCM prices are contingent on voluntary demand growing as expected. Were voluntary demand to remain low (or collapse altogether), we predict that the ETS could play a significant role in stimulating activity in the UK GGR market, but only at central and high ETS prices.

Figure 25 below shows average prices for UK GGRs across the three scenarios, weighted by volumes of credits transacted from each sector. A noteworthy observation is that prices are higher in the low growth scenario compared to the high scenario until 2034. This is explained by the surge in demand in the early years being met with a larger proportion of less expensive biochar GGRs. (For example, biochar makes up 58% of GGRs transacted in 2030 in the high scenario vs. 50% in low scenario). As demand continues to ramp up, projects from other sectors are brought online, contributing to a higher weighted average price across the market.

Figure 25. Average GGR prices across the three scenarios



For CORSIA to generate demand for UK GGRs, developers need to get their methodologies approved by ICAO, the UK government needs to correspondingly adjust the credits via an Article 6 adjustment, so that the emissions removed do not count against the UK's Nationally Determined Contribution (NDC) under the Paris Agreement, and buyers need to be willing to pay relatively high prices for engineered removals. All these conditions make it unlikely that CORSIA will be a dependable demand stream for UK GGRs, and as such CORSIA's contribution to compliance demand is very limited in our modelling. It is important to note that, although we have made a simplifying modelling assumption here that UK-based GGR credits will only be purchased by UK airlines under CORSIA, this may not hold in reality. If significant numbers of other airlines purchase credits from UK-based GGRs, demand could be substantially higher than indicated here.

This modelling exercise concludes that the UK Government can stimulate growth in the UK GGR market by allowing GGRs into the ETS, thereby creating conditions to send a strong, predictable carbon market signal, that both buyers and sellers will be incentivised to purchase and create GGRs, respectively.

References

The following references were used as part of this report:

AlliedOffsets Database. (2025). *Proprietary dataset on GGR projects, transactions, and emissions trajectories.*

AlliedOffsets Forecast Model. (2025). *Internal Python-based model for carbon market projections.*

Beerling, D. J. (2020). *Potential for large-scale CO2 removal via enhanced rock weathering with croplands.*

Beerling, D. J. (2020). *Transforming U.S. agriculture with crushed rock for CO2 sequestration and increased production.*

City Science. (2025). *Assessing the Feasibility for Large-scale DACCS Deployment in the UK.*

Concito. (2024). *The Balancing Act: Risks and Benefits of Integrating Permanent Carbon Removals into the EU ETS.*

Department for Energy Security and Net Zero (DESNZ). (2025). *Carbon Budget and Growth Delivery Plan.*

Department for Energy Security and Net Zero (DESNZ). (2023). *Greenhouse Gas Emissions Trading Scheme Auctioning (Amendment) Regulations 2023.*

Department for Energy Security and Net Zero (DESNZ). (2025). *GGRs and Power BECCS Business Models.*

Disni Gamaralalage. (2025). *Biowaste to biochar: a techno-economic and life cycle assessment of biochar production from food-waste digestate and its agricultural field application.*

Element Energy & UK Centre for Ecology and Hydrology (UKCEH). (2021) *Greenhouse gas removal methods and their potential UK deployment.*

Emenike, O. (2021). *Techno-economic and environmental assessment of BECCS in fuel generation for FT-fuel, bioSNG and OMEx.*

Faber, J. (2022). *Adapting Technology Learning Curves for Prospective Techno-Economic and Life Cycle Assessments of Emerging Carbon Capture and Utilization Pathways.*

International Civil Aviation Organization (ICAO). (2024). *CORSIA Emissions and Offsetting Requirements Projections, https://www.icao.int/sites/default/files/environmental-protection/CORSIA/Documents/CORSIA%20Periodic%20Review/CAEP_Inputs-to-2025-CORSIA-periodic-review-C234.pdf.*

Janusz Kotowicz. (2025). *Advancements and Challenges in Direct Air Capture Technologies: Energy Intensity, Novel Methods, Economics, and Location Strategies.*

Johannes, N. (2023). *Carbon-negative hydrogen production (HyBECCS): An exemplary techno-economic and environmental assessment.*

John Young. (2022). *The cost of direct air capture and storage: the impact of technological learning, regional diversity, and policy.*

Katrin Sievert. (2024). *Considering technology characteristics to project future costs of direct air capture.*

Kenneth Möllersten. (2023). *The role of carbon dioxide removal in contributing to the long-term goal of the Paris Agreement.*

Mohammad Madankan. (2023). *Enhanced Rock Weathering Potential and Supply Constraints in the UK.*

Noah McQueen. (2020). *Natural Gas vs. Electricity for Solvent-Based Direct Air Capture.*

OPIS Dow Jones. (2025). *White paper on Durable Removals.*

Patel. (2024). *Evaluating the agronomic and economic viability of biochar in sustainable crop production.*

Reiner, D. (2023). *Final Report on Expert Elicitation for NETPs.*

Royal Society & Royal Academy of Engineering. (2018). *Greenhouse Gas Removal Technologies Report.*

Rubin, E. (2007). *Use of experience curves to estimate the future cost of power plants with CO2 capture.*

Science Based Targets initiative (SBTi). (2024). *Corporate Net-Zero Standard v2 (Draft).*

Torben Schreiter. (2024). *Will Direct Air Capture Ever Be Affordable? The Rise of DAC 3.0.*

Williams, E. (2022). *Global Direct Air Capture Cost and Deployment Scenarios. Environmental Research Letters.*

World Economic Forum (WEF). (2025). *State of the Carbon Removals Market.*

Appendix

A1. Summary of literature review

Author and Year of publication	GGR type	Region	GGR configuration	Cost Estimates (all prices per tonne)	Removal Potential	Financial and Operational Assumptions	Learning rates
Katrin Sievert (2024)	DACCS	Global	Liquid Solvent (900°C)	Initial: $670 ($521–$894) 1 Gt Scale: $341 ($226–$544)	-		
Katrin Sievert (2024)	DACCS	Global	Solid Sorbent (100°C)	Initial: $1,282 ($1,180–$1,392) 1 Gt Scale: $374 ($281–$579)		Discount Rate: 7% Plant Lifetime: 25 years Capacity factor: 90%	Type 1 (Simple Design): 22% ± 5 Type 2 (Design Intensive): 13% ± 4 Type 3 (Complex & Customised): 5% ± 4
Katrin Sievert (2024)	DACCS	Global	CaO Ambient Weathering (870°C)	Initial: $2,481 ($2,153–$2,874) 1 Gt Scale: $371 ($230–$835)			

John Young (2022)	DACCS	Global	KOH BPMED	1 Gt Scale: $450–$1,350 (High electricity requirement)			
John Young (2022)	DACCS	Global	Solid Sorbent	1 Gt Scale: $140–$730		Discount Rate : variable location based Plant Lifetime : 25 years Capacity factor : 90%	CAPEX : 10 - 15 % OPEX : 0 - 5 %
John Young (2022)	DACCS	Global	MgO Ambient Weathering	1 Gt Scale: $90–$540 (Economically agnostic to location & electricity source)			

Janusz Kotowicz (2025)	DACCS	Global	Liquid Solvent	Performs best in warm, humid regions; 75% capture above 17°C & 90% humidity. Energy choice (grid, gas, hybrid) affects net removal.			
Janusz Kotowicz (2025)	DACCS	Global	Solid Sorbent	High temperatures improve performance; costs 40% higher in cold, humid regions. Lack of accurate adsorption models in varying conditions.			

Janusz Kotowicz (2025)	DACCS	Global	General DAC	Geothermal offers lowest costs (~$182/tonne). ~25% of Earth may be unsuitable due to legal, energy, or climate constraints.			
Noah McQueen (2020)	DACCS	Global	Liquid Solvent + Geothermal	$250–$440			
Noah McQueen (2020)	DACCS	Global	Liquid Solvent + Nuclear	$370–$620			
Noah McQueen (2020)	DACCS	Global	Liquid Solvent + Wind	$360–$570		WACC : 8.5 % Plant Lifetime : 20 years Capacity factor : 90%	
Noah McQueen (2020)	DACCS	Global	Liquid Solvent + Solar PV	$430–$690			
Noah McQueen (2020)	DACCS	Global	Liquid Solvent + Hybrid	$300–$490			

[David Reiner (2023)](#)	DACCS	Global	Solid Sorbent (Climeworks)	Current Cost: €581 2030: €494 ($514) 2040: €395 ($411) 2050: €280 ($291)			2030: -15% 2040: -22% 2050: -27% (-52% from 2020)
[David Reiner (2023)](#)	BECCS	Global	Power (DRAX)	Current Cost: €172 2030: €205 ($213) 2040: €183 ($190) 2050: €153 ($159)		Feedstock : Miscanthus Land : 100 km2	2030: +19% 2040: -11% 2050: -16% (-11% from 2020)
[Eric Williams (2022)](#)	DACCS	Global	General	Lowest-cost scenario: $137 Middle-cost scenario: $223 Highest-cost scenario: $412	Removal Scenarios in 2065 ($GtCO_2$): High-cost scenario: 0.03 Gt Middle-cost scenario: 8.3 Gt Low-cost scenario: 16.4 Gt	Discount rate: 5% Capacity factor: solar Hybrid solar PV & thermal tech (3.5 GJ heat to 1 GJ electricity) powers DACCS. Pipelines, storage, and grid electricity costs included in model.	Post-2035: Capital cost declines 0.3%/yr; Energy use declines 0.5%/yr
[Concito (2024)](#)	Biochar	Europe	General	50 - 200 €	125 Mt		

Concito (2024)	CCS on Biogas	Europe	General	50 - 150 €	50 Mt		
Concito (2024)	BECCS	Europe	General	150 - 200 € at 1 Gt	100 Mt		
Concito (2024)	DACCS	Europe	General	203 to 750 € at 1 GT scale	None		

Torben Schreiter (2024)	DACCS	Global	General	100$ - 250$ at GT scale			DAC 1.0 (Late 2000s): 8% learning rate (similar to coal power), projected gigatonne-scale cost of ~$250/tonne. DAC 2.0 (2018): 13% learning rate (similar to wind), potential cost ~$100/tonne at scale. DAC 3.0 (2021): 14% learning rate (similar to gas power), also targeting ~$100/tonne at scale.

Element Energy and the UK Centre for Ecology & Hydrology(2021)	DACCS	UK	General Dac	2030: £150-£700 (c: 300) 2050: £70 - £250 (central: 130)	0 – 1.3 Mt/yr in 2030 0 – 10 Mt/yr in 2040 0 – 30 Mt/yr in 2050	Study Focus: Based on a 1 Mt/yr capacity plant, Transport & Storage Fees: £17/tonne in 2030, reducing to £10/tonne in 2050. Net Removal Efficiency: 2030: 0.7 – 0.95 (c:0.9) tCO2 net removed per tCO2 gross removed. 2050: 0.85 – 1 (c:0.93) tCO2 net removed per tCO2 gross removed.	
Element Energy and the UK Centre for Ecology & Hydrology (2021)	BECCS	UK	Power	2030: £70-£150 (central: £120) 2050: £30-£170 (central: £100)	0 – 8 Mt/yr in 2030 4 – 22 Mt/yr in 2040 4 – 29 Mt/yr in 2050		BECCS power

Element Energy and the UK Centre for Ecology & Hydrology (2021)	BECCS	UK	EFW	2030 costs: £60-140 (c: 70) 2050 costs: £50-110 (c: 60)	0.5 - 1.2 Mt/yr in 2030 2 - 5 Mtyr in 2040 2.5 - 7.5 Mt/yr in 2050	Revenue Sources: Primarily gate fees for waste disposal, with additional income from power export and heat utilization. Study Focus: Retrofit of carbon capture to existing EfW plants rather than alternative waste disposal methods. Reference Plant: 350 kt waste/year capacity, 94% CO_2 capture rate. Emissions Accounting: Fossil CO_2 assumed to be fully captured.	

Element Energy and the UK Centre for Ecology & Hydrology (2021)	BECCS	UK	Industry	2030 costs: £50-270 (c: 100) 2050 costs: £40-300 (c: 90)	0 – 1 Mt/yr in 2030 0.5 – 4 Mt/yr in 2040 3 – 6.5 Mt/yr in 2050	CO2 T&S Costs: £17/tonne in 2030, decreasing to £10/tonne in 2050. Co-Capture: Fossil/process CO2 treated as a cost-sharing benefit. Emission Adjustments: Includes ~5% supply chain emissions, ~1% electricity use emissions, and plant construction emissions.	
Element Energy and the UK Centre for Ecology & Hydrology (2021)	BECCS	UK	Hydrogen and other	2030 Costs: £50-120 (c: 60) 2050 Costs: £30-100 (c: 50)	0 – 2 Mt/yr in 2030 5 – 18 Mt/yr in 2040 11 – 35 Mt/yr in 2050	Hydrogen Production: 2.3-3.5 MWh (HHV) per tonne of CO2 removed. Biomass Demand: 3-3.1 MWh (LHV) per tonne of CO2 removed.	

Element Energy and the UK Centre for Ecology & Hydrology (2021)	BCH	UK	General	£14 - £130 (c: 72.5)	0 – 1.1 $MtCO_2$/yr in 2030 0 – 2.8 $MtCO_2$/yr in 2040 0 –15 $MtCO_2$/yr in 2050	CO_2 Removal per Hectare: 4.2 - 27.5 tCO_2/ha (central estimate: 15.9 tCO_2/ha). Max Technical Potential: 20.0 $MtCO_2$/yr (range: 5.3 - 34.7 $MtCO_2$/yr). Land Application: Spread on cropland & temporary grassland. Decomposition: Assumed negligible	
Element Energy and the UK Centre for Ecology & Hydrology (2021)	ERW	UK	General	2050 : £144 - £866 (c: 289)	0 – 1.2 Mt/yr in 2030 0 – 3 Mt/yr in 2040 0 –18 Mt/yr in 2050	Land: 20 t/ha on arable land & 50% of permanent grassland (max 7.8Mha). CO_2 Removal Potential: 18.7 $MtCO_2$/yr (range: 6.2 - 37.4 $MtCO_2$/yr). Carbon Capture Efficiency: 0.1 - 0.3 tCO_2 per t rock. Constraints: Avoids organic soils to prevent decomposition of soil carbon.	

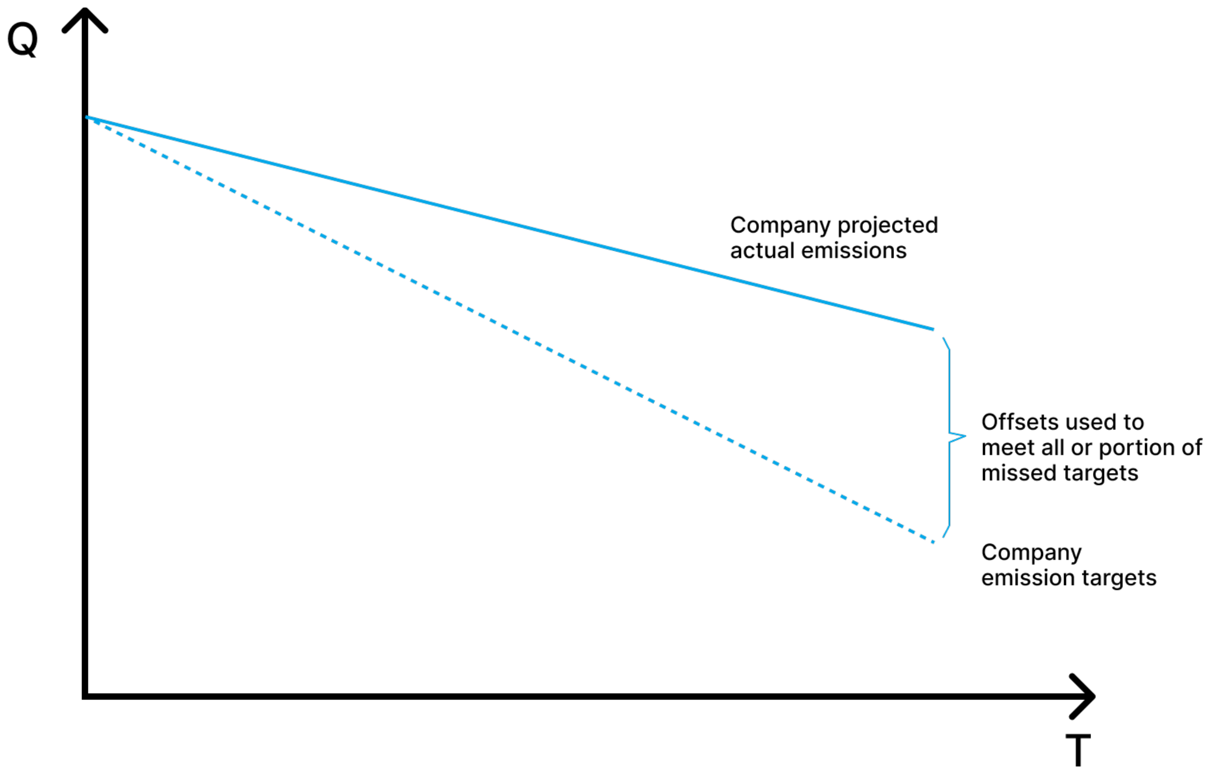
Kenneth Möllersten (2023)	BECCS	Market Transaction	General	$57 - $145	0.5 - 11.0 Gt/yr in 2050 (IPCC AR6)	
Kenneth Möllersten (2023)	Biochar	Market Transaction	General	$53 - $163	0.3 - 6.6 Gt/yr in 2050 (IPCC AR6)	
Kenneth Möllersten (2023)	DAC	Market Transaction	General	$133 - $585	5.0 - 40.0 Gt/yr in 2050 (IPCC AR6)	
Kenneth Möllersten (2023)	ERW	Market Transaction	General	$51 - $196	2.0 - 4.0 Gt/yr in 2050 (IPCC AR6)	

Mohammad Madankan (2023)	ERW	UK	General		6 - 30 Mt/yr in 2050	Current Rock Production: ~14.8 Mt/yr, Waste Fine Production: ~3.7 Mt/yr, Permitted Reserves: ~490 Mt, Cropland Requirement: ~2–4% of UK croplands for 10–20 Mt/yr	
CIty Science (2025)	DACCS	UK	Solid DAC	2030 - £558 2040 - £420 2050 - £328	9 Mt/yr in 2050	Capacity factor: 85% - 90% Discount rate : 3.5% Lifetime: 15 - 25 years CAPEX process contingency: 5% - 20% FOAK Electricity requirement: 0.7 MWhe/tonne captured FOAK Thermal requirement: 3.31 MWhth/tonne captured	CAPEX learning rate: 8% - 16% Sorbent cost learning rate: 5% - 10% Energy demand learning rate (electricity & thermal): 2.5% - 7.5%

CIty Science (2025)	DACCS	UK	Liquid DAC	2030 - £326 2040 - £279 2050 - £242	14 Mt/yr in 2050	Capacity factor: 90% Lifetime: 20 - 30 years CAPEX process contingency: 20% - 35% FOAK Electricity requirement: 0.46 MWhe/tonne captured FOAK Thermal requirement: 1.8 MWhth/tonne captured	CAPEX learning rate: 5% - 11% Energy demand learning rate (electricity & thermal): 1.5% - 4.5%
Beerlling (2020)	ERW	Global	General	2050 costs : $80 $180			
Disni Gamaralalage (2025)	BCH	UK	General	£100			
Yuzhou Tang (2025)	BCH	UK	General	2030: £75			

A2. Excess emissions calculations

In order to calculate demand for credits from decarbonisation targets, we collected data on Scope 1, 2, and 3 emissions of relevant companies, and calculated those companies' emissions trajectories. In cases where companies are off-track to meet their targets, we assumed a certain percentage of their emission target miss would be offset. The graph below illustrates how voluntary demand is calculated.



A3. UK CORSIA demand calculation

We derived future UK airline CORSIA offsetting requirements from ICAO published demand figures, ICAO published emissions between state-pairs, and a dataset of international flights.

We projected emissions for flights between each state-pair by using ICAO projected demand and historic state-pair emissions, carrying forward the percentage contribution of each state-pair from historic years. We then needed to estimate what proportion of emissions between each state-pair would be attributed to UK airlines. We used a historic dataset on international flights that included airline call signs, origin country and destination country. We then aggregated the total flights between each origin and destination country by the airline's ICAO administering state. Finally, we applied the percentage of all international flights by UK airlines to each origin/destination state-pair to derive CORSIA demand from UK airlines.

With the above, we were able to derive future offsetting requirements from the ICAO demand projections and reported 2019 baseline data. UK airline emissions are the sum of all offsetting requirements for which the UK is the attributed host state.

A4. Price and traded volumes by scenario per year: tables

Note in the price tables below, prices only show when traded volumes exceed 45,000 credits in a year. Where there are fewer credits traded than this suggests the supply of GGRs is being issued by existing projects, not new ones.

A4.1. Low scenario volumes traded across VCM and ETS

Year	Biochar	DACCS	BECCS - Power	BECCS - Hydrogen	BECCS - EfW	ERW	Total
2026	159.3Kt	22.4Kt	24.8Kt	21.2Kt	22.3Kt	20.6Kt	270.7Kt
2027	175.3Kt	27.8Kt	30.8Kt	26.3Kt	24.7Kt	21.9Kt	306.8Kt
2028	164.7Kt	32.2Kt	32.1Kt	27.5Kt	23.8Kt	20.4Kt	300.5Kt
2029	194.5Kt	31.8Kt	32.0Kt	27.4Kt	41.1Kt	18.8Kt	345.6Kt
2030	225.9Kt	31.4Kt	31.0Kt	26.6Kt	72.0Kt	64.9Kt	451.8Kt
2031	259.6Kt	30.9Kt	29.8Kt	25.5Kt	111.7Kt	139.4Kt	597.1Kt
2032	297.8Kt	30.3Kt	28.6Kt	24.5Kt	160.1Kt	218.3Kt	759.6Kt
2033	338.6Kt	29.6Kt	27.5Kt	23.6Kt	213.2Kt	286.4Kt	918.9Kt
2034	383.0Kt	28.6Kt	26.4Kt	22.6Kt	267.9Kt	351.7Kt	1.1Mt
2035	347.7Kt	27.6Kt	25.8Kt	22.1Kt	322.6Kt	414.8Kt	1.2Mt
2036	412.3Kt	26.5Kt	24.3Kt	20.8Kt	378.0Kt	482.3Kt	1.3Mt
2037	481.7Kt	25.5Kt	22.8Kt	19.5Kt	434.6Kt	558.3Kt	1.5Mt

2038	556.2Kt	75.4Kt	21.0Kt	18.0Kt	492.7Kt	640.8Kt	1.8Mt
2039	575.0Kt	129.1Kt	19.5Kt	16.7Kt	552.4Kt	730.3Kt	2.0Mt
2040	603.3Kt	163.3Kt	18.6Kt	16.0Kt	613.8Kt	748.6Kt	2.2Mt
2041	639.4Kt	183.6Kt	17.4Kt	15.0Kt	677.0Kt	726.9Kt	2.3Mt
2042	678.9Kt	198.1Kt	16.5Kt	14.1Kt	726.7Kt	705.1Kt	2.3Mt
2043	724.3Kt	211.6Kt	15.5Kt	13.3Kt	766.6Kt	715.3Kt	2.4Mt
2044	773.8Kt	225.3Kt	14.2Kt	12.2Kt	801.6Kt	747.8Kt	2.6Mt
2045	826.9Kt	234.9Kt	8.7Kt	7.4Kt	833.2Kt	794.5Kt	2.7Mt
2046	883.3Kt	245.8Kt	4.3Kt	3.7Kt	866.4Kt	851.4Kt	2.9Mt
2047	942.9Kt	257.0Kt	0.0Kt	0.0Kt	903.2Kt	914.6Kt	3.0Mt
2048	1.0Mt	268.4Kt	0.0Kt	0.0Kt	941.3Kt	982.8Kt	3.2Mt
2049	1.1Mt	284.2Kt	0.0Kt	0.0Kt	950.8Kt	1.1Mt	3.4Mt
2050	1.1Mt	300.0Kt	0.0Kt	0.0Kt	939.1Kt	1.1Mt	3.5Mt
Total	13.9Mt	3.1Mt	471.4Kt	403.8Kt	12.1Mt	13.3Mt	43.3Mt

A4.2. Low scenario market traded prices (2025 nominal GBP) by technology

Year	Biochar	DACCS	BECCS - Power	BECCS - Hydrogen	BECCS - EfW	ERW	Weighted Average Price
2026	£80/t						£137/t
2027	£105/t						£171/t
2028	£124/t						£191/t
2029	£131/t						£191/t
2030	£128/t				£177/t	£187/t	£183/t
2031	£123/t				£173/t	£183/t	£176/t
2032	£118/t				£169/t	£179/t	£168/t
2033	£116/t				£167/t	£177/t	£164/t
2034	£113/t				£164/t	£174/t	£159/t
2035	£116/t				£167/t	£177/t	£160/t
2036	£113/t				£164/t	£174/t	£157/t
2037	£111/t				£161/t	£171/t	£153/t
2038	£104/t	£342/t			£155/t	£165/t	£147/t
2039	£102/t	£338/t			£152/t	£162/t	£144/t
2040	£106/t	£345/t			£157/t	£167/t	£147/t
2041	£107/t	£346/t			£158/t	£168/t	£147/t
2042	£111/t	£351/t			£162/t	£172/t	£151/t

2043	£116/t	£356/t			£166/t	£177/t	£155/t
2044	£117/t	£357/t			£167/t	£178/t	£156/t
2045	£118/t	£357/t			£168/t	£178/t	£156/t
2046	£119/t	£358/t			£169/t	£179/t	£157/t
2047	£120/t	£359/t			£170/t	£180/t	£158/t
2048	£121/t	£359/t			£171/t	£181/t	£159/t
2049	£122/t	£360/t			£172/t	£182/t	£161/t
2050	£123/t	£360/t			£173/t	£183/t	£163/t

A4.3. Medium scenario volumes traded across VCM and ETS

Year	Biochar	DACCS	BECCS - Power	BECCS - Hydrogen	BECCS - EfW	ERW	Total
2026	569.8Kt	25.0Kt	36.6Kt	32.0Kt	24.3Kt	357.2Kt	1.0Mt
2027	925.6Kt	29.1Kt	37.2Kt	32.8Kt	215.3Kt	626.5Kt	1.9Mt
2028	1.3Mt	33.4Kt	38.0Kt	33.8Kt	430.5Kt	877.6Kt	2.7Mt
2029	1.6Mt	33.5Kt	37.6Kt	33.8Kt	648.5Kt	1.1Mt	3.5Mt
2030	2.0Mt	32.8Kt	37.9Kt	33.3Kt	852.3Kt	1.4Mt	4.3Mt
2031	2.4Mt	31.7Kt	36.5Kt	102.5Kt	1.1Mt	1.7Mt	5.3Mt
2032	2.8Mt	30.7Kt	140.3Kt	277.5Kt	1.3Mt	2.0Mt	6.5Mt
2033	3.3Mt	29.6Kt	350.7Kt	539.9Kt	1.5Mt	2.3Mt	8.0Mt

2034	3.9Mt	28.6Kt	650.3Kt	853.9Kt	1.7Mt	2.6Mt	9.7Mt
2035	4.5Mt	93.6Kt	1.0Mt	1.2Mt	1.9Mt	3.0Mt	11.7Mt
2036	4.5Mt	486.4Kt	1.4Mt	1.5Mt	2.2Mt	2.9Mt	13.0Mt
2037	4.6Mt	1.2Mt	1.8Mt	1.8Mt	2.4Mt	2.9Mt	14.7Mt
2038	4.6Mt	2.1Mt	2.3Mt	2.2Mt	2.6Mt	2.9Mt	16.7Mt
2039	4.6Mt	2.6Mt	2.7Mt	2.6Mt	2.9Mt	2.8Mt	18.3Mt
2040	4.7Mt	3.0Mt	3.2Mt	2.8Mt	3.2Mt	2.7Mt	19.6Mt
2041	4.7Mt	3.3Mt	3.7Mt	3.0Mt	3.5Mt	2.6Mt	20.9Mt
2042	4.8Mt	3.6Mt	4.2Mt	3.2Mt	3.7Mt	2.4Mt	21.9Mt
2043	4.8Mt	3.9Mt	4.6Mt	3.4Mt	3.9Mt	2.2Mt	22.8Mt
2044	4.8Mt	4.2Mt	4.9Mt	3.6Mt	4.2Mt	1.9Mt	23.6Mt
2045	4.8Mt	4.5Mt	5.2Mt	3.7Mt	4.4Mt	1.6Mt	24.2Mt
2046	4.7Mt	4.9Mt	5.5Mt	3.9Mt	4.6Mt	1.2Mt	24.9Mt
2047	4.6Mt	5.3Mt	5.9Mt	4.2Mt	4.5Mt	798.8Kt	25.3Mt
2048	4.7Mt	5.7Mt	6.5Mt	4.6Mt	4.4Mt	506.4Kt	26.3Mt
2049	4.8Mt	5.8Mt	7.3Mt	5.0Mt	4.3Mt	307.9Kt	27.5Mt
2050	5.0Mt	6.5Mt	8.1Mt	5.5Mt	4.3Mt	168.8Kt	29.6Mt
Total	93.9Mt	57.4Mt	69.8Mt	54.3Mt	64.5Mt	44.0Mt	383.9Mt

A4.4. Medium scenario market traded prices (2025 nominal GBP) by technology

Year	Biochar	DACCS	BECCS - Power	BECCS - hydrogen	BECCS - EfW	ERW	Weighted Average Price
2026	£108/t					£168/t	£139/t
2027	£115/t				£166/t	£176/t	£147/t
2028	£126/t				£176/t	£186/t	£158/t
2029	£128/t				£177/t	£187/t	£159/t
2030	£136/t				£183/t	£192/t	£166/t
2031	£137/t			£184/t	£184/t	£193/t	£167/t
2032	£141/t		£186/t	£186/t	£186/t	£195/t	£170/t
2033	£139/t		£185/t	£185/t	£185/t	£194/t	£169/t
2034	£136/t		£183/t	£183/t	£183/t	£192/t	£167/t
2035	£125/t	£361/t	£175/t	£175/t	£175/t	£185/t	£160/t
2036	£130/t	£362/t	£179/t	£179/t	£179/t	£189/t	£171/t
2037	£127/t	£362/t	£177/t	£177/t	£177/t	£186/t	£178/t
2038	£124/t	£361/t	£174/t	£174/t	£174/t	£184/t	£185/t
2039	£121/t	£360/t	£172/t	£172/t	£172/t	£182/t	£188/t
2040	£126/t	£361/t	£175/t	£175/t	£175/t	£185/t	£194/t
2041	£130/t	£362/t	£179/t	£179/t	£179/t	£189/t	£198/t
2042	£149/t	£343/t	£190/t	£190/t	£190/t	£198/t	£207/t

2043	£161/t	£307/t	£192/t	£192/t	£192/t	£198/t	£206/t
2044	£150/t	£341/t	£190/t	£190/t	£190/t	£198/t	£209/t
2045	£151/t	£339/t	£191/t	£191/t	£191/t	£198/t	£211/t
2046	£156/t	£326/t	£192/t	£192/t	£192/t	£199/t	£211/t
2047	£161/t	£309/t	£192/t	£192/t	£192/t	£198/t	£211/t
2048	£165/t	£288/t	£191/t	£191/t	£191/t	£197/t	£208/t
2049	£170/t	£263/t	£190/t	£190/t	£190/t	£194/t	£202/t
2050	£167/t	£278/t	£191	£191/t	£191/t	£195/t	£206/t

A4.5. High scenario volumes traded across VCM and ETS

Year	Biochar	DACCS	BECCS - Power	BECCS - Hydrogen	BECCS - EfW	ERW	Total
2026	244.9Kt	24.2Kt	44.1Kt	38.3Kt	24.3Kt	35.3Kt	411.0Kt
2027	1.1Mt	33.2Kt	41.4Kt	37.1Kt	177.0Kt	404.4Kt	1.8Mt
2028	2.2Mt	34.9Kt	39.8Kt	35.8Kt	440.2Kt	902.1Kt	3.6Mt
2029	3.4Mt	33.8Kt	37.5Kt	34.6Kt	790.2Kt	1.5Mt	5.8Mt
2030	4.9Mt	32.8Kt	37.3Kt	200.7Kt	1.2Mt	2.1Mt	8.4Mt
2031	6.0Mt	31.7Kt	208.8Kt	612.4Kt	1.6Mt	2.5Mt	11.1Mt
2032	7.1Mt	30.7Kt	582.3Kt	1.2Mt	2.0Mt	2.9Mt	13.8Mt
2033	8.0Mt	29.6Kt	1.0Mt	1.8Mt	2.5Mt	3.3Mt	16.7Mt

2034	9.0Mt	28.6Kt	1.6Mt	2.5Mt	2.9Mt	3.7Mt	19.7Mt
2035	10.0Mt	674.4Kt	2.1Mt	3.3Mt	3.4Mt	4.0Mt	23.4Mt
2036	10.9Mt	2.4Mt	2.7Mt	4.0Mt	3.9Mt	4.3Mt	28.2Mt
2037	10.6Mt	4.3Mt	3.3Mt	4.7Mt	4.5Mt	4.2Mt	31.6Mt
2038	9.8Mt	6.1Mt	3.7Mt	5.3Mt	5.1Mt	4.0Mt	34.1Mt
2039	8.6Mt	7.7Mt	4.2Mt	5.9Mt	5.8Mt	3.6Mt	35.8Mt
2040	7.1Mt	9.3Mt	4.7Mt	6.5Mt	6.5Mt	3.1Mt	37.1Mt
2041	6.0Mt	11.0Mt	5.2Mt	7.1Mt	7.1Mt	3.0Mt	39.3Mt
2042	5.0Mt	12.9Mt	5.7Mt	7.6Mt	7.5Mt	3.0Mt	41.8Mt
2043	4.3Mt	15.1Mt	6.3Mt	8.0Mt	7.9Mt	3.1Mt	44.7Mt
2044	3.5Mt	17.5Mt	7.0Mt	8.5Mt	8.3Mt	3.2Mt	48.0Mt
2045	2.7Mt	20.2Mt	7.7Mt	9.0Mt	8.6Mt	3.5Mt	51.6Mt
2046	1.8Mt	23.2Mt	8.4Mt	9.5Mt	9.0Mt	3.8Mt	55.7Mt
2047	1.1Mt	26.6Mt	9.3Mt	10.0Mt	9.1Mt	4.1Mt	60.1Mt
2048	585.6Kt	30.4Mt	10.2Mt	10.5Mt	9.0Mt	4.4Mt	65.0Mt
2049	301.6Kt	34.7Mt	11.1Mt	11.0Mt	8.7Mt	4.7Mt	70.5Mt
2050	155.3Kt	39.5Mt	11.9Mt	11.2Mt	8.2Mt	5.1Mt	76.0Mt
Total	124.5Mt	261.8Mt	107.0Mt	128.6Mt	124.3Mt	78.3Mt	824.4Mt

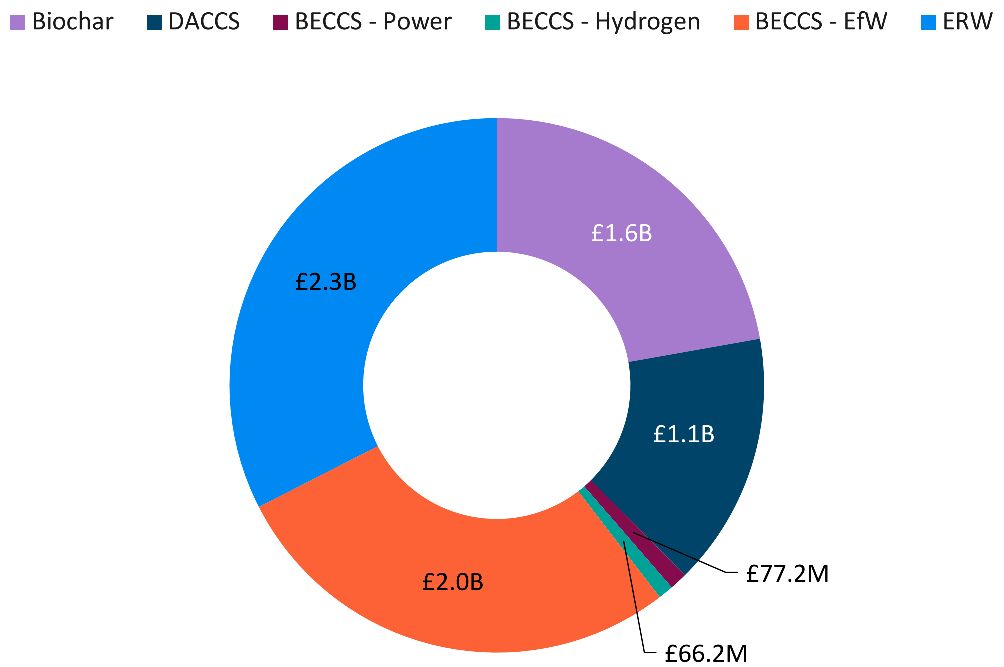
A4.6. High scenario market traded prices (2025 nominal GBP) by technology

Year	Biochar	DACCS	BECCS - Power	BECCS - Hydrogen	BECCS - EfW	ERW	Weighted Average Price
2026	£198/t						£207/t
2027	£152/t				£191/t	£199/t	£171/t
2028	£129/t				£178/t	£188/t	£153/t
2029	£111/t				£162/t	£172/t	£136/t
2030	£102/t			£151/t	£151/t	£161/t	£126/t
2031	£99/t		£149/t	£149/t	£149/t	£159/t	£124/t
2032	£103/t		£153/t	£153/t	£153/t	£163/t	£130/t
2033	£120/t		£171/t	£171/t	£171/t	£181/t	£149/t
2034	£132/t		£180/t	£180/t	£180/t	£190/t	£160/t
2035	£147/t	£347/t	£189/t	£189/t	£189/t	£198/t	£177/t
2036	£152/t	£337/t	£191/t	£191/t	£191/t	£199/t	£189/t
2037	£157/t	£323/t	£192/t	£192/t	£192/t	£199/t	£199/t
2038	£161/t	£306/t	£192/t	£192/t	£192/t	£198/t	£204/t
2039	£170/t	£265/t	£190/t	£190/t	£190/t	£194/t	£202/t
2040	£174/t	£235/t	£187/t	£187/t	£187/t	£190/t	£197/t
2041	£190/t	£255/t	£204/t	£204/t	£204/t	£206/t	£216/t
2042	£199/t	£268/t	£214/t	£214/t	£214/t	£217/t	£229/t

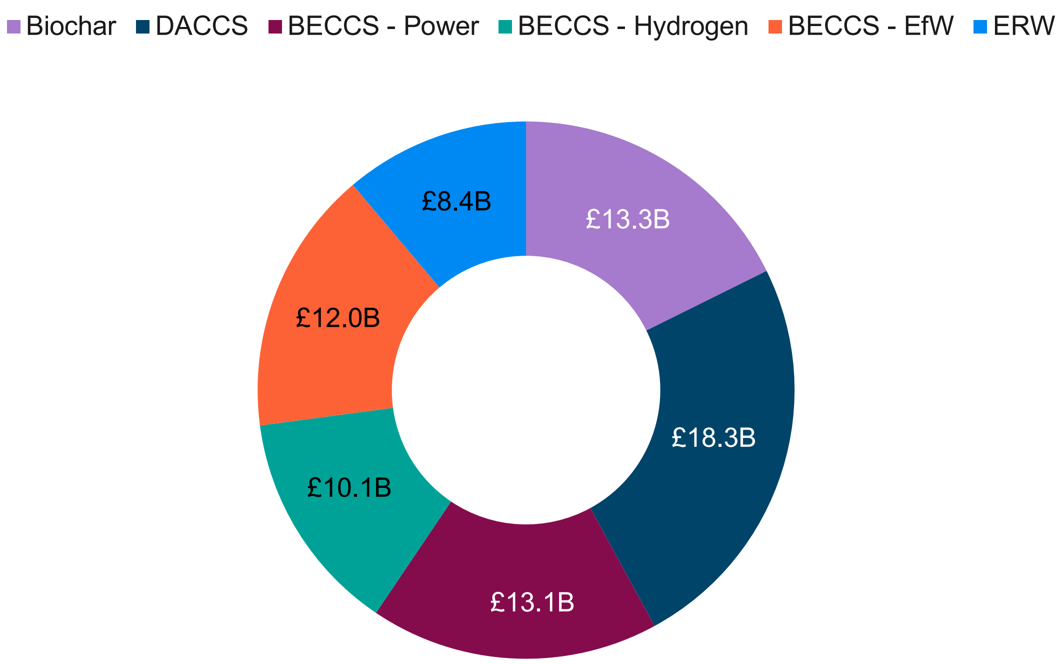
2043	£201/t	£270/t	£216/t	£216/t	£216/t	£219/t	£233/t
2044	£211/t	£284/t	£227/t	£227/t	£227/t	£230/t	£247/t
2045	£214/t	£287/t	£229/t	£229/t	£229/t	£232/t	£251/t
2046	£224/t	£301/t	£241/t	£241/t	£241/t	£244/t	£266/t
2047	£227/t	£305/t	£243/t	£243/t	£243/t	£247/t	£270/t
2048	£229/t	£308/t	£246/t	£246/t	£246/t	£249/t	£275/t
2049	£232/t	£311/t	£248/t	£248/t	£248/t	£252/t	£279/t
2050	£234/t	£314/t	£251/t	£251/t	£251/t	£254/t	£284/t

A5. Distribution of spend per technology (VCM and ETS)

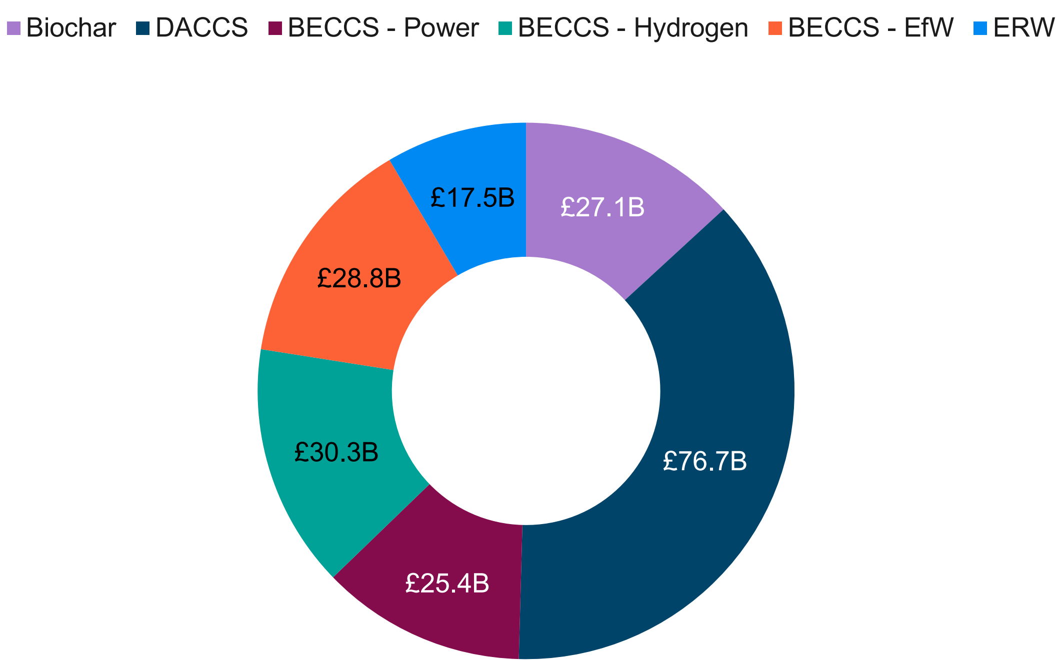
A5.1. Low scenario



A.5.2. Medium scenario

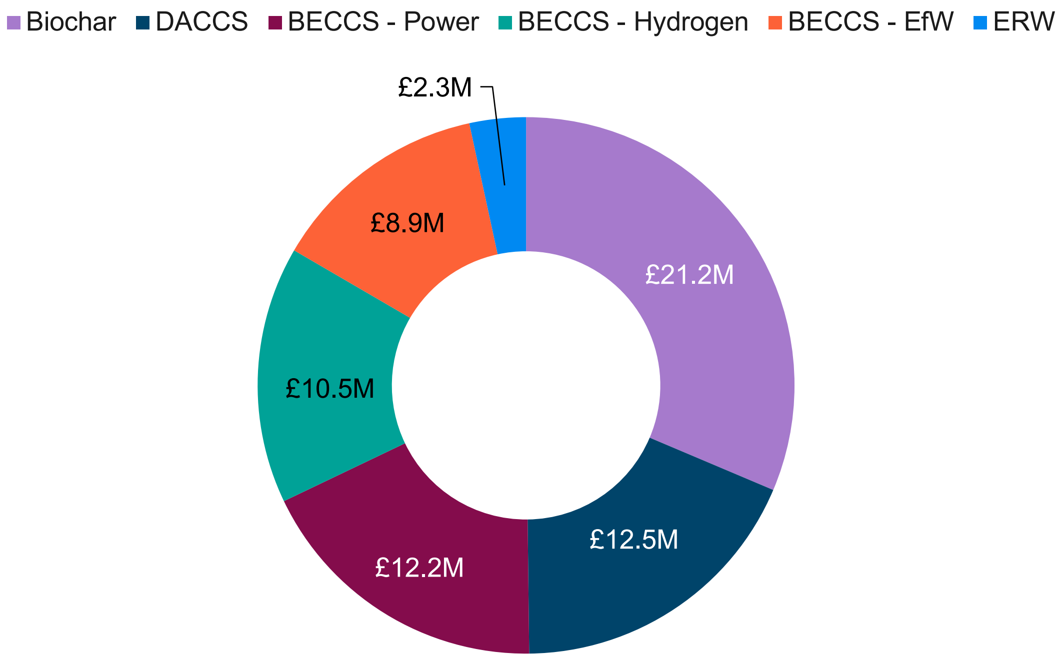


A.5.3. High Scenario

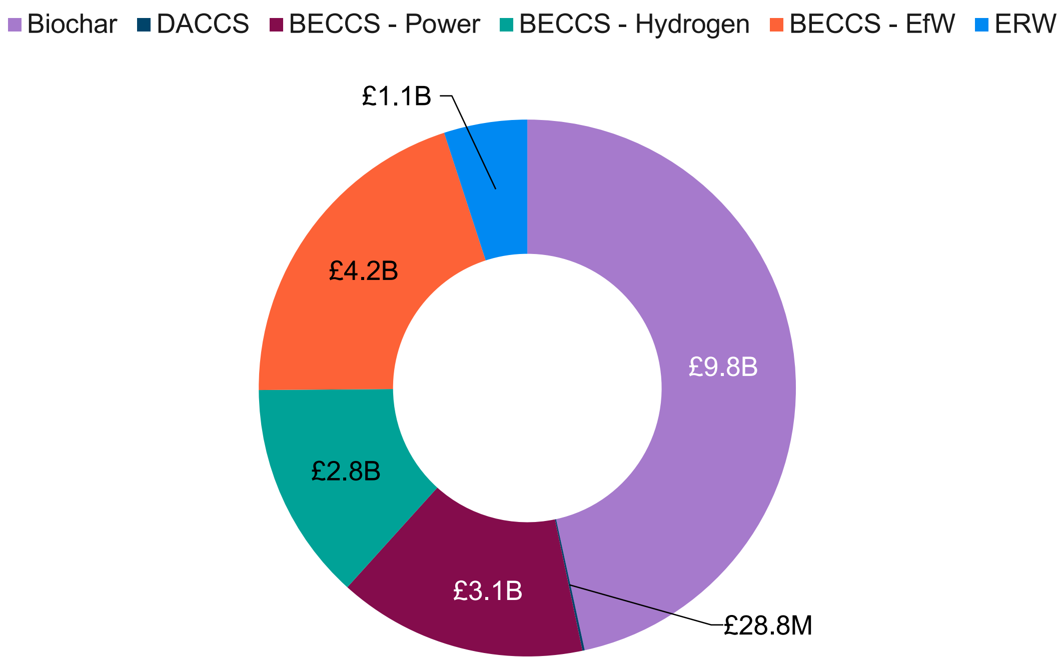


A6. Distribution of spend per technology (VCM failure)

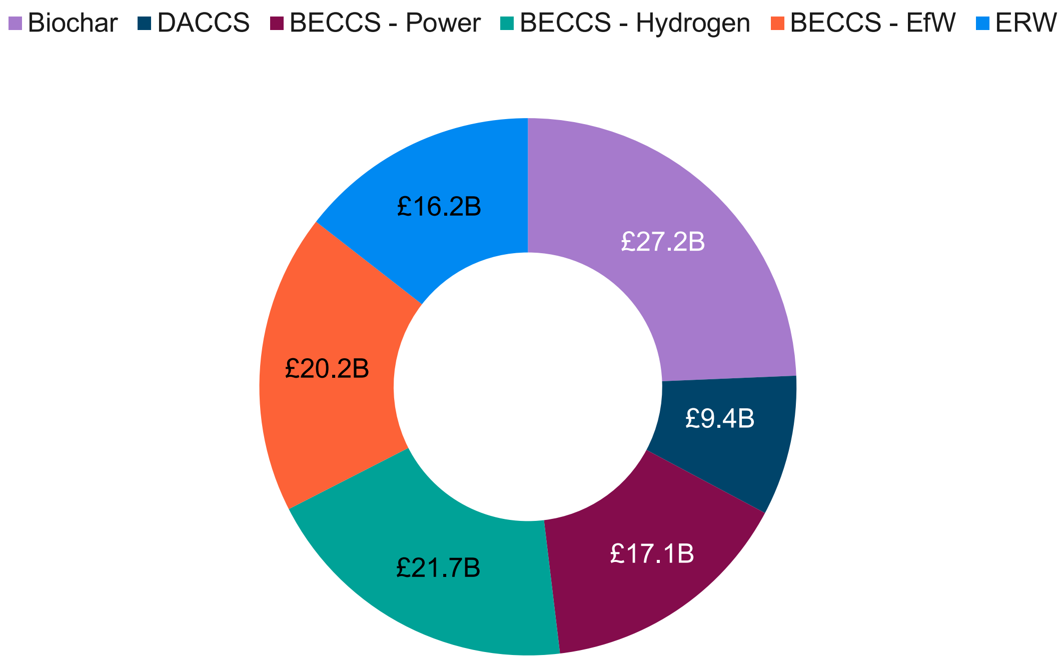
A6.1. Low scenario



A6.2. Medium scenario



A6.3. High scenario



If you need a version of this document in a more accessible format, please email alt.formats@energysecurity.gov.uk. Please tell us what format you need. It will help us if you say what assistive technology you use.