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Agriculture, Environment
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Integrating Greenhouse Gas Removals in the UK Emissions Trading Scheme: Woodland Evidence Annex

July 2025

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Executive Summary

The UK ETS Authority could only consider including woodland GGRs in the UK ETS if doing so maintained the very high environmental integrity of the scheme. In the context of woodland, this means carbon removals would have to be UK based, highly permanent and associated with high environmental quality woodland. Additionally, the Authority would need to be convinced including woodland represents good value for money.

This paper summarises the analysis undertaken to explore these questions. The analysis has been completed by Defra, Forest Research, Forestry Commission, and DESNZ. The analysis has been reviewed by the Devolved Governments and the Trees and Woodland Scientific Advisory Group (independent academic advisers).¹

Permanence

The permanence section presents new evidence on how permanent carbon storage in new UK woodland is likely to be. This uses satellite data to identify woodland losses to different causes, including fire, storms, pest & disease, and development. The evidence suggests that current rates of woodland loss are low (approximately 0.039% of all woodland is lost each year).

Modelling of future rates of loss also suggests rates are likely to remain relatively low, even in the high natural disturbance scenario and the high development scenario. Based on current buffer pool contribution rates of 20%, if there's no change in management, woodland carbon units are projected to represent continuously stored carbon for 2,300 years in the central scenario, and 500 years in the worst-case scenario (high natural disturbance impacts). We consider this to be highly permanent carbon storage.

Costs, Benefits and Market Impact

This section summarises a cost benefit analysis produced by Defra and uses it to explore whether the ETS is an appropriate market for woodland removals.

The analysis concludes that including woodland carbon removals (from here 'woodland removals') in the ETS, when combined with appropriate grants for co-benefits, achieves woodland creation targets and is projected to result in carbon benefits of £36 billion, co-benefits of £12 billion (biodiversity, air quality, timber, flood regulation, and health),² and an overall social net present value of £34 billion over a 50-year appraisal period³. Options involving ETS integration have higher net present value and benefit cost ratios than options with no ETS integration, indicating that the ETS provides better value for money.

The analysis also finds that including woodland in the UK ETS is unlikely to lead to adverse market impacts such as oversupply of woodland removals. This is driven by the relatively high cost of woodland creation in the UK, that is estimated to require support equivalent to carbon prices of, on average, around £173/t with the cost of support varying across the four nations alongside woodland creation targets. This suggests that UK ETS carbon prices, currently projected to fall in the range £44-154/t from now to 2050, will not over-reward woodland creation. There are also supply constraints that limit woodland creation rates in the medium

¹ [Trees and Woodlands Scientific Advisory Group](#): Membership, Minutes and Publications.

² [Enabling a Natural Capital Approach \(ENCA\) - GOV.UK](#)

³ This is a standard appraisal period for woodland schemes, given the long-term nature of benefits delivery.

term, including land, labour, and sapling availability, which will limit supply of woodland removals to the ETS. Further safeguards for ETS market stability are provided by the approach to maintaining the cap as GGRs are integrated, and the potential for a specific Woodland Cap to provide an upper limit on the number of allowances awarded to woodland. Overall, the inclusion of woodland removals is not projected to destabilise the ETS market through oversupply.

Finally, the analysis suggests that wider negative impacts – for example on food production, the local environment and communities – are unlikely.

Forestry in the UK

Trees and woodlands are a critical part of all four nations' plans to achieve net zero by 2050. Woodland creation can support the transition to net zero and the nature recovery elements of the clean energy superpower mission. This pathway includes specific contributions from various sectors, including land use and forestry. The CCC's Carbon Budget 7 advice outlines a balanced pathway to meet net zero and highlights the critical role of nature-based solutions, including woodland creation, in providing sufficient carbon sequestration. The CCC recommend more than doubling tree planting rates to 37,000 hectares per year by 2030 which would see woodland land cover in the UK increase from 13% today to 19% by 2050.⁴ The below table summarises the tree planting targets for each of the four nations of the UK as well as the combined target. These targets are referred to throughout this document.

Table 1: Cumulative Woodland Creation Targets by 2050 for each of the four nations.⁵

Nation	Total afforestation target by 2050 (ha)	Cumulative CO ₂ e sequestration by 2050 (MtCO ₂ e) ⁶	Total % increase in woodland land cover 2025-2050
England	250,000	9	2
Scotland	450,000	17	7
Wales	180,000	7	9
Northern Ireland	47,000	5	12
Total combined target	927,000	34	4

Woodland creation targets vary per UK nation due to the scale and availability of land. This is a key consideration in ensuring the commercial viability of woodland creation as well as exploring wider impacts across the four nations of the UK. This is discussed in more detail in the [Costs, benefits and market impact](#) section.

⁴ [CCC Advice on the Seventh Carbon Budget \(2025\)](#).

⁵ For the UK and England this accounts for the increase in annual woodland creation from 2035 onwards.

UK wide: [Seeing the wood for the trees: the contribution of the forestry and timber sectors to biodiversity and net zero goals, 2022-2023](#).

England: [Natural England and Forestry Commission: Our position on woodland creation](#).

Scotland: [Modelling scenarios for woodland expansion in Scotland - Forest Research](#).

Wales: [Woodland Creation in Wales](#).

Northern Ireland: [Northern Ireland Forestry Strategy \(2006\) | Department of Agriculture, Environment and Rural Affairs](#).

⁶ These figures are quantified using the Woodland Carbon Code carbon calculator, based on afforestation from 2025-2050. They are an underestimate of the carbon stored as they're based on units issued so factor in a 20% reduction for model accuracy and a further 20% reduction for contributions to the WCC buffer. They assume average carbon sequestration based on typical species choices and management approaches across the four nations.

The Woodland Carbon Code

The Woodland Carbon Code (WCC) is a scheme for afforestation carbon projects. Projects conform with the UK Forestry Standard as part of their WCC agreement.⁷

The WCC accounts for changes in the amount of carbon stored in woodland on an area basis, not an individual tree basis. Changes in the amount of carbon stored in woodland per hectare in the long term are therefore the key outcome of a WCC project, not the number of trees standing. A woodland may suffer from a disturbance event, but under UK legislation (Forestry Act (1967) and Environmental Impact Assessment Forestry Regulations (1997)), a woodland remains a woodland even if tree cover is temporarily absent. The amount of carbon stored in the woodland will, eventually, return to the previous level in most cases.⁸

Carbon captured by WCC woodland creation projects is verified by an independent third party. This confirms the carbon is sequestered through a field survey and verifies the creation of Woodland Carbon Units (WCUs, from hereafter referred to as units). Projects can have units verified throughout their lifetime, which is typically 100 years, and the woodland remains in situ as a permanent feature after this. Verification uses standard forest measurement techniques, and the data are converted to carbon stocks - a measured quantity of carbon stored in woodlands - using several standard and species-specific methods.

Alongside compliance with the UK Forestry Standard and permanence rules under the Forestry Act, there are mechanisms within the WCC that safeguard the permanence of issued units. Principally, the WCC runs a buffer pool system: when units are verified, 20% are immediately moved to the UK-wide pooled buffer and the remaining 80% allocated to the woodland owner/project developer for use.

If a woodland suffers any losses that impact the stored carbon corresponding to units already issued, the WCC Buffer rules are activated. An immediate loss report is issued, and the WCC Buffer puts on hold all units necessary to cover the loss. Once the number of units lost has been verified, all necessary buffer units are cancelled to cover the loss. The units that the affected project contributed to the buffer pool are cancelled first. If the project's losses were greater than its contributions to the buffer, then units from the UK-wide buffer pool are cancelled, acting as a socialised insurance fund. To date, since the scheme launched in 2011, the buffer has never been called upon.

The landowner will be required to replant the woodland after a loss. As units are created by that replanting, they will help to replenish the buffer. If the loss was avoidable, for example due to poor management, all buffer pool units must be returned through replanting. However, if the loss was unavoidable, for example due to wildfires, then only the units taken from the UK-wide pool need to be replenished (i.e. above what the project originally donated to the buffer). The woodland owner is not issued any further units until buffer pool is replenished.

⁷ This is an agreement between a landowner and the Woodland Carbon Code registry which commits the landowner to a management regime and certifies and monitors a woodland project for verified carbon sequestration. All contracts involve a permanent change of land use to woodland cover.

⁸ Forest Research completed analysis exploring the rates of woodland loss and regeneration/restocking which were also used in the analysis below.

Impacts of Management Change

Current WCC agreements typically enter a 100-year management regime. There is a risk that after that 100-year agreement, UK woodland could enter a clear-fell management system i.e. the landowner removes all trees from a specific area to support timber harvest and encourage planned regrowth.⁹ In this instance the permanence of some units issued would be significantly undermined. To align with the proposed permanence framework for the UK ETS, woodland will likely need to commit to a consistent management regime for at least 200 years, and this will mitigate the risk of reversals and loss of issued units.

To ensure prolonged management commitments new policy options could be used. For example, non-intervention woodlands entering the UK ETS could be required to adopt long-term commitments such as conservation covenants.¹⁰ If non-intervention woodlands are maintained indefinitely, the long-term integrity of carbon stocks, and corresponding units, will be maintained.

⁹ For woodlands managed under a clear-fell regime, trees are cut down when they reach the age where they grow the fastest, based on standard forestry growth and yield models (Edwards and Christie, 1981). The frequency of this is then guided by the WCC clear-fell cap. Clear-felled woodland can be thinned to generate a rolling income and to increase productivity before the site is clear-felled.

¹⁰ A conservation covenant is an agreement to conserve the natural or heritage features of some land. They are voluntary, private and legally binding. A conservation covenant must include actions the landowner or responsible body will or won't take. For example, they might include commitments to maintain woodland under certain management conditions.

Permanence

Woodland creation in the UK is a permanent land-use change. This means once new woodland is created, landowners are not legally permitted to remove trees without a felling license, as set out in the Felling License requirements in each of the four nations' respective legislation.¹¹ Woodland management practices and licenses, including felling licences, are then regulated by the Forestry Commission, Scottish Forestry, Natural Resources Wales and the Northern Ireland Forest Service in, respectively England, Scotland, Wales and Northern Ireland.

If a landowner wishes to harvest timber from their woodland, they are required to have a felling licence issued by the relevant regulator.¹² Felling licences are also granted for thinning (cutting back some trees as a part of healthy woodland management) and clear-fell (removing most or all trees in a given area). For most instances of removing trees a condition is applied to replant, unless removal is for the purpose of open habitat restoration. Future open-habitat restoration would be highly unlikely for any new UK woodland, given the high environmental thresholds that now apply to woodland creation projects.¹³

Only highly permanent removals should be included in the UK ETS. The Authority agrees with the CCC and other stakeholders that permanence is a priority. New analysis was commissioned by Defra in 2024 to assess the permanence of UK woodlands. The analysis was carried out by Forest Research (the research agency of the Forestry Commission) and the Forestry Commission and has been independently reviewed by the Trees and Woodland Scientific Advisory Group (independent academic advisers).¹⁴ The work has also been reviewed across the Devolved Governments. This section sets out the methodology and results from this analysis.

Methodology

This analysis examines permanent loss of woodland due to development or following natural disturbance events and the resulting permanence of woodland carbon stocks. The analysis does not consider the short to medium term perturbations to carbon stocks in remaining woodland arising from natural disturbance events, or the effects of climate change on the frequency, or intensity, of those disturbance events. However, a number of scenarios are explored based on the current annual variability of natural disturbance.

¹¹ For Wales this is the [Environment \(Wales\) Act 2016](#), for Scotland this is the [Forestry and Land Management \(Scotland\) Act 2018](#), Northern Ireland is the [Forestry Act \(Northern Ireland\) 2010](#) and England is [Forestry Act 1967](#).

¹² This applies to anyone aiming to sell more than 2 cubic meters per calendar quarter (or 5 cubic meters if for 'self-supply').

¹³ [When to convert woods and forests to open habitat: operations note 68](#).

¹⁴ [Trees and Woodlands Scientific Advisory Group](#): Membership, Minutes and Publications.

The growth and permanence of all woodland in Great Britain was modelled.¹⁵ The net growth of new woodland, and the subsequent accumulation of stored carbon in woodland, is subject to the following:

1. **Woodland growth and carbon accumulation**– woodland growth depends on factors including species choice, tree breeding, and the woodland management practices for example thinning compared to non-intervention approaches.
2. **Permanent woodland losses** – this can only occur in two legal ways¹⁶:
 - a. Natural disturbance (i.e. loss to storms, disease, pests or wildfire) followed by no replanting or natural regeneration; or
 - b. Development (new land cleared for infrastructure or housing).

These factors can be used in a model to calculate the total growth of woodland carbon stocks as a balance of losses and gains, based on an analysis of woodland affected by natural disturbance events and the proportion of affected woodland area that is not replanted.

The current rate of permanent loss of all GB woodland was estimated through an assessment of woodland by Forest Research across England, Wales and Scotland (GB). Data for Northern Ireland was not available. It should be noted that all current GB woodland will be less resilient to climate change than new WCC woodland given the additional resilience requirements of all UK woodland planted today. As a result, the loss modelled through this analysis is likely an overestimate. This analysis identified the areas of woodland affected by natural disturbance and development, before assessing the proportion of that area that had not been restocked 10-15 years later.

These GB-wide estimates provided a current, annual, rate of loss. It should be noted that this analysis did not consider current rates of permanent woodland loss from drought and flooding, nor do extensive modelling of projected rates of loss in future climate scenarios. Defra has committed to further research on this subject.

To establish the long-term storage of carbon held in WCC woodlands, Defra used the current rate of permanent losses with woodland growth forecasts from the WCC carbon lookup tables¹⁷. Together this provided a conservative, central model of long-term permanence based on losses from all woodlands. Sensitivity scenarios, with higher rates of permanent woodland loss, were modelled to explore the potential effects of climate change and high rates of loss to development.

¹⁵ Data was only available for Great Britain, as data was taken from the National Forest Inventory's satellite data sets which only cover Great Britain. For example, areas of windblow were identified using 2014 Disaster Monitor Constellation (DMC) satellite images using the National Forest Inventory (NFI) woodland map methodology. For further details on the methodology please [see Supporting documents page](#).

¹⁶ In 2023 0.13% of felling was undertaken without approval from the [Forestry Commission](#) (2023), page 21. Any felling without approval must be restocked, so there is no permanent loss of forestry through this route. Plus, the entity which felled without approval can face an unlimited fine.

¹⁷ Carbon lookup tables are carbon estimates of sequestration to and release from forest stands, based on Forest Research's CARBINE model. For full discussion of the original research to develop the WCC's lookup tables, see [Randle & Jenkins \(2011\)](#), published by Forest Research (previously known as the Research Agency of the Forestry Commission).

To assess the social value of the carbon stored in woodland, standard appraisal methodologies were used. For all scenarios, the social value of the carbon that remained after 1,000 years was calculated and compared to the value of the carbon if no reversals had taken place.

Woodland Growth and Carbon Accumulation

Woodland growth in WCC projects was forecast by Defra. To estimate the total accumulation of carbon a simplified, representational mix of woodland types and management regimes across GB was used (Table 2). This was based on the makeup of projects within the WCC as of the 30 June 2024. The estimated growth rates of these woodland types were taken from the WCC Carbon Calculation Spreadsheet.¹⁸

Growth Rates Factored in Different Management Regimes

For management practices most woodland was assumed to be thinned, with the exception of non-intervention woodland.¹⁹ The total carbon accumulated by these projects was calculated over 200 years.²⁰

With the forecast of carbon accumulation, the total number of units issued and therefore the quantity of contributions to the buffer pool could be calculated. A WCC project must contribute 20% of the units issued into the buffer pool to cover future reversal events. While the WCC management regime is modelled to continue for 200 years, in the model no additional units were awarded after the first 100 years even though carbon is still being stored in the woodland. This is a conservative scenario where carbon allowances from WCC projects enter the UK ETS and meet the minimum requirements for storage duration (as laid out in the permanence framework).

¹⁸ [WCC Carbon Calculation Spreadsheet](#) version 2.4.2 (April 2024).

¹⁹ In non-intervention woodland that there is no thinning, although there may be some removal of biomass to keep rides and footpaths open, or to maintain integral open space.

²⁰ The models estimate the carbon storage in five-year intervals. Since these intervals do not provide values for every single year, this is done through linear interpolation to fill in the gaps.

Table 2: Breakdown of the GB WCC projects by management type as used in the forecast. The populations of these trees are shown as a percentage of the total area of WCC projects (35,077 ha).

Woodland/management type	% of total area in WCC
Clear-fell conifer (thinned) ⁹	46
Non-intervention broadleaf	38
Continuous cover conifer (thinned)	6
Continuous cover broadleaf (thinned)	6
Non-intervention conifer (Scots pine)	4
Total	100

Separately to the central scenario, the carbon stored in woodlands at year 200 was modelled, considering if all new UK woodland planted from 2025 were to enter a clear-fell management system⁹ from year 101 onwards (after the 100-year WCC agreement ends).

Estimating Current Losses

Forest Research was commissioned to quantify current rates of permanent woodland loss²¹ across GB from wildfire, windstorm, pest and disease and development. Forest Research established areas of woodland affected by natural disturbance between 2005²² and 2014,²³ and between 2014 and 2024.²⁴ Areas affected by natural disturbance were assessed against satellite imagery²⁵ to identify those areas that had not been restocked²⁶ or regenerated over the intervening ten years. Satellite imagery was analysed using a binary woodland/non-woodland characterisation achieved through an AI-trained algorithm.

The analysis assumes that reversal events occur at the same rate for all woodland types. It also does not consider the potential interdependency between risks, for example pest/disease outbreaks and enhanced wildfire risk which may lead to an underestimation of permanent woodland losses in the results. Conversely, the analysis of permanent woodland loss due to development and natural reversal was calculated using established woodland, rather than newly planted woodland (such as that in the WCC). Newly planted woodlands are less vulnerable to losses thanks to a better understanding of how resilience can be incorporated

²¹ Permanent woodland loss is defined in the National Forest Inventory as areas of land that were previously woodland but where tree cover has been absent for a period of ten years.

²² 2005 imagery used aerial photography.

²³ 2014 satellite imagery used was collected from [Landsat 8 satellites](#).

²⁴ 2024 satellite imagery was collected from [ESA Sentinel-2](#) (2024).

²⁵ Both sources of satellite imagery provided frequent, wide-area images with a resolution of 10 to 60 meters making them useful for monitoring land cover, vegetation, forests, and other features in high detail.

²⁶ Restocking is an essential part of the calculation. If woodlands are disturbed, e.g. trees lost to fire, then most of the time in the UK they are replanted ('restocked'). When followed by restocking, disturbances such as fires have no long-run impact on carbon storage. Forest Research estimated restocking rates based on satellite data, which are used in the analysis presented here.

into the design of the woodland, meaning the results calculated here could be overestimates of rates of reversal.

Four potential events that could lead to permanent woodland loss were explored using the approach above and are described in more detail below. Both an average, current rate of loss and a high rate of loss was identified for use in the model (further detail in the next section).

Loss from Windstorm

Windstorms can lead to tree mortality through windthrow and windsnap:²⁷ if not replanted or regenerated this will result in permanent woodland loss. Current rates of loss from windstorms were identified by comparing 2014 satellite imagery²⁸ with aerial photography from 2005. This established the area of woodland affected by windstorms. Of the affected area, 10.2% was not restocked, as a result there was an average, annual permanent loss of 0.007%²⁹ across all GB woodland over the baseline period.

The analysis has not explicitly modelled impacts of future climate change on the severity of future windstorm (but see extreme natural disturbance scenario for implicit model). For the purposes of this analysis it is assumed that any increase in the future frequency and intensity of windstorms that may result from climate change will be balanced by improved forest management.³⁰ & ³¹ However, no modelling of impacts of future climates (e.g. changes to storm system energetics, or rainfall) has been conducted, and future research is needed to address this evidence gap.

The maximum observed rate of loss was identified in 2021 due to Storm Arwen and subsequent storms. This affected 12,741 ha,³² which, assuming the same restocking percentage, is 6.8 times higher than the average loss over the baseline period.

Loss from Pest and Disease Outbreaks

Pests and disease outbreaks can directly result in tree mortality, or the requirement to fell if a Statutory Plant Health Notice (SPHN) is issued. To determine current rates of loss, areas where a SPHN was issued between 2010-2014 were assessed using satellite imagery for evidence of restocking in 2024. This provided an average annual reversal estimate for pests

²⁷In a storm: windthrow is where trees are blown over (i.e. uprooted) and windsnap is when a tree's trunk is broken.

²⁸ Satellite imagery was taken in 2014, but due to the nature of windstorm debris, areas affected by windstorm could have occurred anytime over the previous 9 years (2014 to 2006), i.e. after the previous 2005 images. Thus, to average the effects, yet remain conservative, the areas affected by windblow were annualised by dividing by two rather than nine.

²⁹ 0.067% of all GB woodland was affected by windstorm of this 10.2% is permanently lost which equates to 0.007% of all GB woodland. The 0.007% is for all GB woodland whilst the 10.2% is the proportion of windstorm damaged woodland that is permanently lost. They reference the same area of woodland (208 ha), but the proportion given is different due to the total woodland being considered.

³⁰ This could use decision-support systems such as [ForestGales](#) and adoption of continuous cover systems of management that are generally more resilient to wind damage, as set out in the UK Forestry Standard Practice Guide on [adapting forest and woodland management to the changing climate](#).

³¹ Forest Research (Forthcoming publication) 'Establishing Rates of GB Forest Lost to Natural Disturbance'.

³² [Forest Research \(2022\)](#) Research Highlights 2022-2023. the worst year on record was 2021, due to Arwen and subsequent storms. This resulted in losses of 12,741 ha, compared to 2022 ha in the main Central scenario. These figures assume the same rates of restocking in both scenarios.

and disease outbreaks of 0.003% at national (GB) scale (4.2% of affected woodland not restocked).³³

The maximum observed rate of loss was based on the highest number of SPHNs issued in each country over the period 2010/11 to 2023/24.³⁴ This would result in permanent losses of 0.01%, which is approximately 4.2 times higher than in the average current rates of loss over the baseline period.

Loss from Wildfire

Satellite imagery from the baseline year (2014) revealed only a very small area of woodland affected by wildfire (3 ha). This is largely because most woodland fires in Britain are currently surface fires which have lower levels of tree mortality compared to fires affecting the canopy. Given the minimal area observed as affected by wildfire, it is unsurprising that none of this area was observed as not restocked. Therefore, to calculate a more representative estimate for the current rate of loss, Defra used data provided by the Fire and Rescue Services (FRS) in England, Scotland and Wales for 2009-2015 (Forestry Commission, 2016, unpublished), to represent the area subject to wildfire damage. The proportion of the area subject to wildfire damage that was not restocked was assumed to be the aggregate permanent loss for windstorm, and pest and disease (8.4%). The resulting estimate is that currently 0.006% of all GB woodland is lost each year to wildfire.

The maximum observed annual rate of loss of all woodlands was 0.028%, calculated from the largest area subject to wildfire in any year during the baseline period for England, Scotland and Wales. This is 4.8 times higher than the average current annual rate of loss.

These are likely an overestimate of wildfire-related losses at the present time due to the difference between the area reported in the wildfire data and that observed through the satellite imagery. In addition, recent improvements in woodland design and management may reduce wildfire risk and improve woodland resilience to fires.³⁵ The analysis here assumes higher rates of loss due to future climate change, as set out by Arnell *et al.* (2021)³⁶, and is consistent with surface fires occurring more frequently and becoming more damaging canopy fires as the climate changes.

Loss to Development

Woodland can be felled for the development of housing and infrastructure; however, there has been no reported losses of woodland due to development from any validated WCC projects to date. As a result, any estimated rate of loss to development will likely be an overestimate.

³³ The analysis was restricted to pest and disease where SPHNs are issued requiring that a stand is felled. It does not consider the impacts of endemic pests and diseases affecting individual trees, where it is assumed that natural regeneration/restocking replaces those trees that are lost.

³⁴ This calculation (Forestry Statistics [2018](#) and [2024](#)). The assumptions for restocking were the same as those in the central scenario. Average areas affected by pests and diseases is 7,900 ha compared with 1,832 ha in the central scenario.

³⁵ There are opportunities to improve woodland design and management to reduce wildfire risk, as outlined in the UK Forestry Standard Practice Guide on [Building Wildfire Resilience into Forest Management Planning](#) (Forestry Commission, 2014). These measures will help to limit reversals due to wildfire.

³⁶ [Arnell, Freeman and Gazzard, 2021](#), The effect of climate change on indicators of fire danger in the UK.

Current rates of loss to development were based on observed woodland removal where it was clear that development had replaced woodland or there was clear evidence of soil disturbance consistent with development. Analysis of aerial photography and satellite imagery over the period 2006/7 to 2022/23 provides an estimate of loss to development in under current socio-economic conditions (0.023% of woodland area per annum).

Land area is finite and if the current rate of land use change for non-developed to developed continued (16,000 ha/yr in England),³⁷ all non-developed land would be converted within ~820 years. The central scenario analysis (discussed in greater detail below) therefore assumes the rate of development doesn't remain fixed, though a high development scenario was modelled in which it does.

Impacts Not Included in the Model

Drought, heat stress and flooding were not included in the final model. Although it is likely that climate change, particularly drought, will have impacts on woodland condition, growth rates, and individual tree survival, it is assumed in this analysis that over the long-term there will be no reversals that are not addressed through natural regrowth or replanting with suitable species. This includes replanting with future species that have been selectively bred for increased climate resilience (i.e. technological adaptation).

It is assumed that no WCC projects will be lost to open ground habitat restoration in the future. Currently, a few hundred hectares a year (average of 450 ha/yr over the past ten years) of woodland are restored to priority open ground habitat.³⁸ This reflects previous afforestation programmes that paid less attention to the natural and historic environment. Given the sensitivities and constraints that now apply to woodland creation, it is assumed that no woodland planted under the current regulatory framework will be planted on priority open ground habitat and therefore not at risk of future deforestation to restore priority habitats.

Changes in management regime, as discussed in the Impacts of Management Change section, are not examined here.³⁹ The model issues no further units after 100 years have elapsed. However, the management regime remains the same for a further 100 years (Table 2). As a result, carbon stocks continue to increase until 200 years have elapsed. This represents a conservative estimate of how woodland carbon stocks might be rewarded and managed in a woodland project participating in the UK ETS.

Modelling Future Losses

Future rates of woodland loss in GB and inferred permanence were modelled based on the analysis presented for current rates of permanent woodland loss. Further research is needed to model projected losses under future climate scenarios, furthermore, predicting the

³⁷ [Land use change hectareage 2019 to 2022](#): Statistics on the amount of land changing use in England.

³⁸ Woodland can be cleared in areas where a high-quality open habitat can be restored (for example limestone pavement), this requires an environmental impact assessment.

³⁹ The choice of management scenario in these results reflects how woodland would be incorporated into to the UK ETS, including the impact of any changes needed to ensure that it meets the minimum storage period of 200 years. Without new policy commitments to ensure woodland's long-term management in the ETS, all woodland could in theory enter a clear-fell management regime after 100 years. If this were to happen then 100 years later (200 years into the project) then 36% of the total units issued would have been reversed.

vulnerability of future planting stock in a changing climate presents its own challenges. The model considers three metrics: (1) changes in the carbon stock of all WCC woodlands over time; (2) the number of Woodland Carbon Units issued up to year 100 (the maximum crediting period),⁴⁰ and (3) the quantity of carbon lost to reversal events.⁴¹

Three scenarios were explored in the analysis:

1. **A central scenario:** the current rates of permanent loss to natural disturbance are applied. However, the loss to development declines between 2050 and 2100 to 10% of the current rate and then remains constant at 0.0023% per annum.⁴²
2. **A high natural disturbance scenario:** where high rates of windstorm, pest & disease, and wildfire are projected to become the norm, reflecting the potential impacts of climate change. This uses the maximum-observed rates, identified for each scenario, as the annual rate of loss for every year in the model. This model is not using future climate models to predict the impacts of climate change.
3. **A high development scenario:** where high rates of loss to development (as used in the central scenario) continue past 2050. This implies a long-run rate of loss of 0.023%. This simulates increased demands for new development.

These scenarios were selected to explore the future of woodland longevity, and how this would change if we saw uncontrollable climate impacts, or the controllable, but still high, impacts from human activity.

Economic Cost of Reversals

Carbon that is stored and partially rereleased into the atmosphere at a later date is less valuable than carbon that can be stored permanently. To understand the social value of the risk of reversal, the social costs and benefits of impermanent storage were estimated in accordance with the Green Book.⁴³ Other sources in the literature have followed similar approaches, using the social cost of carbon discounted over time, such as those discussed by Parisa (2022), Balmford (2023) and Groom and Venmans (2023).⁴⁴

⁴⁰ Technically, this is how many Woodland Carbon Units are awarded. This is equal to the carbon absorbed, minus a 20% buffer contribution. Units are only awarded for the first 100 years as this is the maximum WCC contract length.

⁴¹ This does not consider any of the climate change adaptation requirements of new woodlands under forestry regulations today, nor does it include Woodland Carbon Code permanency mitigations or liability measures that would be enforced if woodland entered the UK ETS.

⁴² Long term land use change projections are not available, as a result it is assumed that the rate of woodland loss to development remains constant at the baseline rate until 2050, then declines linearly. In the short to medium term, the assumption of the current rate of development continuing may be pessimistic (in terms of woodland loss) as Biodiversity Net Gain (and equivalent policies in the DAs) is likely to deter development in woodland.

⁴³ [The Green Book \(2022\) - GOV.UK](#): guidance issued by HM Treasury on how to appraise policies, programmes and projects.

⁴⁴ [Parisa \(2022\)](#); [Balmford \(2023\)](#); [Groom and Venmans \(2023\)](#).

For each scenario analysed, we can compare the social value of the carbon stored (taking into account the impact of reversals) with the social value of permanently stored carbon.⁴⁵

The results are driven by two main factors:

1. Increasing carbon values:⁴⁶ The social value of carbon emissions rises over time, reflecting increasing tight emissions reductions targets.⁴⁷
2. Social discount rates:⁴⁸ The rate that society values the present compared to the future is known as the 'social time preference rate' (STPR) and has two component parts:
 - a. 'Time preference' – the rate at which consumption and public spending are discounted over time, assuming no change in per capita consumption. This captures the preference for value now rather than later.
 - b. 'Wealth effect' – this reflects expected growth in per capita consumption over time, where future consumption will be higher relative to current consumption and is expected to have a lower utility.

Results and Discussion

Using remote-sensing datasets (satellite and aerial photography) current rates of permanent woodland loss were determined. These were used with forecast woodland growth rates in three scenarios to explore the permanence of all GB woodland and associated carbon stocks. The results of these analyses are discussed here.

Current Rates of Loss

The observed current and maximum rates of loss of woodland in GB are shown in Table 3. While new woodland is continually being created, the results show that currently approximately 0.038% of all existing woodlands across GB are lost each year to the four causes (Table 3).⁴⁹ This means that if these rates of loss remained constant and assuming no woodland regrowth occurs for the next 200 years, on average, 93% of woodland planted today would still be there in 200 years' time.

The largest driver of permanent woodland loss is development (0.023%), followed by windstorms (0.007%), wildfire (0.006%), and pest & disease (0.003%) which have smaller impacts. Losses to drought and heat stress were not considered here but may worsen under future climate change.

⁴⁵ This metric is reported in the literature on carbon removals. For example, in Balmford (2023) this metric is used and called the Permanent Equivalence. In Groom and Venmans (2023), their Social Value of Offset is a generalised version of this metric.

⁴⁶ Carbon values are used across government for valuing impacts on GHG emissions resulting from policy interventions. They represent a monetary value that society places on one tonne of carbon dioxide equivalent (£/tCO₂e). They differ from carbon prices, which represent the observed price of carbon in a relevant market (such as the UK Emissions Trading Scheme).

⁴⁷ Appraisal carbon values are given in [Valuation of greenhouse gas emissions](#) (2021). Post-2050 carbon values are obtained by applying a real annual growth rate of 1.5% starting from the 2050 value, capped at £500/t (2024 prices) as an assumed upper bound of removals costs.

⁴⁸ Discounting is a technique used to compare costs and benefits occurring over different periods of time on a consistent basis. See the Green Book's [Supplementary Guidance \(2008\)](#) for further details.

⁴⁹ This amounts to 1,296 hectares out of the total 3.24 million hectares in the UK.

Table 3: Rates of permanent loss for all woodland in both the central and extreme scenarios. Current rates are based on losses seen in all woodland in GB. New woodlands are expected to see reduced rates due to better management and species choice.

	Area permanently lost (% /year)			
	Current Rates for all Woodland:	Central Scenario	High Natural Disturbance	High Development
Development	†0 to 0.023	*Declining until 2050 from 0.023	*Declining until 2050 from 0.023	†0.023
Wildfire	0.006	0.006	0.028	0.006
Pest and Disease	0.003	0.003	0.011	0.003
Windblown	0.007	0.007	0.047	0.007
Total	0.038	0.038 - 0.018	0.109 - 0.088	0.038

† Current loss to development rates for WCC woodland is 0 ha/year, therefore the rate of loss in the high development scenario is very high.

* Rate of loss is set at 0.023 until 2050 and then declines linearly to 0.002 by 2100 where it is then fixed for the remainder of the period of analysis.

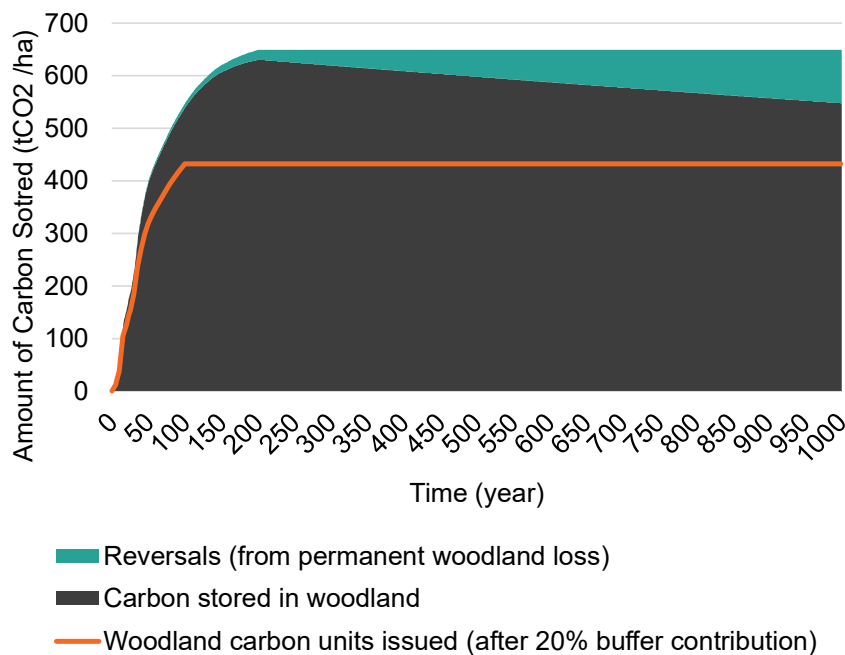
Future Rates of Loss and Economic Value

The modelled rates of future woodland loss are likely to underestimate the permanence of future UK woodland in two important respects. First, the analysis implicitly assumes liability measures, part of proposed permanence framework, fail and are not applied, i.e. the obligation on operators to replace any allowances lost is not enacted. If liability measures were used there would be fewer carbon reversals in the first 200 years as the operator would be required to restock lost woodland, or the operator would have to match their woodland reversals by acquiring equivalent removals elsewhere. Second, these projections do not consider adaptation measures that would occur to reduce reversals, for example species choice informed by climate projections or using decision support systems to reduce wind risk. The UK Forestry Standard (UKFS) and, therefore all WCC projects, are better designed for resilience than the population of GB woodlands that are included in this analysis, the majority of which were established prior to the introduction of the UKFS.

The projected permanence of woodland carbon storage in the central scenario is shown in **Figure 1**. The total amount of carbon physically stored in 1 ha of new woodland rises over time as the trees grow, reaching a maximum of 630 tCO₂ after 200 years (the charcoal area in **Figure 1**). However, only 432 tCO₂ of units are awarded to the project (the orange line), with 20% allocated to the pooled buffer for the first 100 years of growth as this is the current maximum contract length. Finally, reversal events lead to gradual reductions in carbon stored (the teal area).

The results show that over a 1000-year period, the amount of carbon stored remains higher than the removal units issued. Hence each removal unit issued represents continuing carbon storage over the 1000-year period. Extrapolating further, it would take 2,300 years for the amount of carbon stored to fall to below the number of removal units issued (this is the point the teal area drops below the orange line).

Figure 1. Central Scenario: Current Rates of Woodland Loss Continue. The modelled carbon accumulation and reversals (through permanent woodland loss) for a representative hectare of British woodland applying the average, annual losses from the model for all GB woodland.



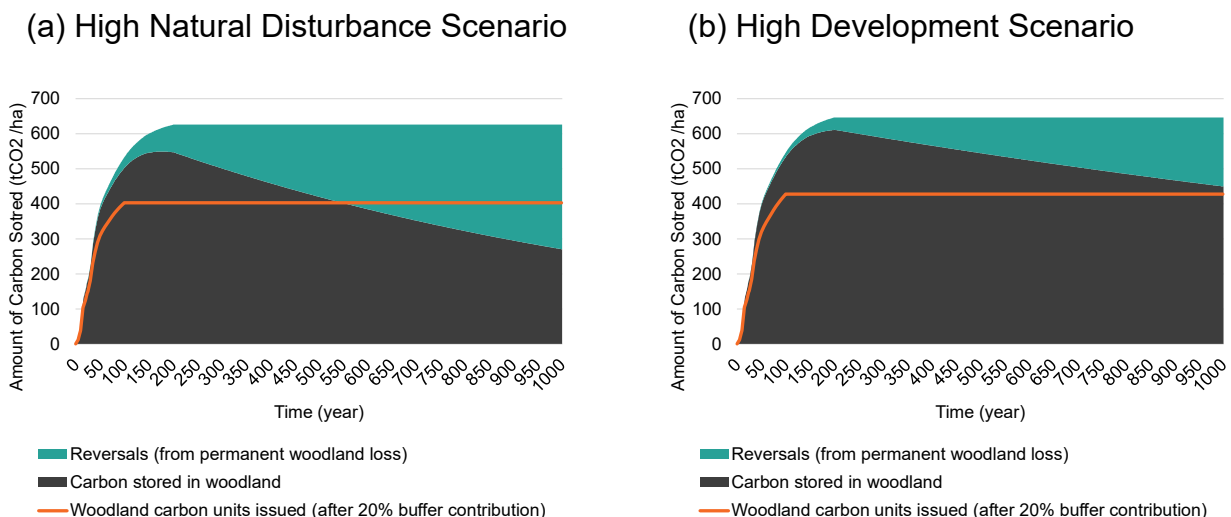
Notes. Permanence of carbon storage for a new UK woodland, representing the average mix of woodland types created under the WCC. Central Scenario: Rates of permanent woodland loss to natural disturbance events (storms, wildfire and pest & disease) remain at their current level for the entire period of analysis. Loss to development remains at the current rate up to 2050, after which it declines linearly to 10% of this value in 2100 and remains at this lower rate for the remainder of the period of analysis.

In terms of economic valuation, the social value of this carbon storage is equal to 98% of the social value of permanent carbon storage. This suggests that, evaluated from the standpoint of today, the social value of these losses is small. It is also significantly in excess of the 80% of the initial storage that is awarded removal units (given the 20% buffer contributions). Hence, the social value of the removal units awarded to the operator is likely to be higher than the social value of permanent storage, as the social costs of reversals are more than covered by the buffer pool.⁵⁰

⁵⁰ For concreteness, suppose a woodland removal project removed 100t today, and was awarded 80 removal units (given a 20% buffer pool contribution). And compare this to a hypothetical, perfectly permanent removal project which removed 100t today, and was awarded 100 removal units. Given the projected rate of reversal in the central scenario, each woodland removal unit has a higher expected social value than each permanent removal unit.

Given the inherent uncertainty over future rates of woodland loss two reasonable worst-case scenarios were explored and are shown in Figure 2. Panel (a) shows a high natural disturbance scenario which reflects the potential increasing losses from storms, wildfire and pest & disease due to the possible impacts of climate change. In this scenario, losses from these causes increase by a factor of 5.4. The scenario uses the largest area of woodland affected by each category of natural disturbance during the baseline period as the annual rate of loss. This results in a significantly greater rate of woodland loss, as a result the carbon stored falls below the number of removal units issued after 500 years.⁵¹ As a result, some removal units begin to no longer represent continuing carbon storage after 500 years. The social value of this carbon storage is 92% of permanent storage.

Figure 2. High Rates of Loss Scenarios. The modelled carbon accumulation and reversals (through permanent woodland loss) for a representative hectare of British woodland applying the average, annual losses from the models for all GB woodland. These scenarios use observed high rates of loss to explore permanence.



- (a) **High natural disturbance scenario:** This scenario uses maximum observed rates of loss as a proxy for possible increasing impacts of climate change on permanent woodland losses. Loss to development the same as the Central scenario.
- (b) **High development scenario:** Central scenario, but with the current high rate of loss to development maintained throughout the model's run.

Figure 2 panel (b), shows a second reasonable worst-case scenario. Here, long-run development rates remain fixed at the high rate of loss currently observed (0.023% /year). This was considered a high rate due the current rate of loss for WCC projects being zero and that if current development rates continue, all land in GB would be developed on, in ~820 years. Over the 1000-year analysis period the amount of carbon stored remains higher than the number of removal units originally issued, meaning those units represent continuing storage over the entire period. The amount of carbon stored is projected to drop below the number of

⁵¹ Total units awarded under the extreme natural disturbance scenario and high development scenario were 403 units /ha and 428 units /ha respectively.

units issued after 1,100 years. The social value of this carbon storage is 97% of permanent storage.

Conclusions

Overall, this evidence suggests that storing carbon in new UK woodlands likely exhibits high levels of permanence. Removal units comfortably represent continuously stored carbon over a 1000-year period in the central scenario. In the most severe of the two reasonable-worst case scenarios (the extreme natural disturbance scenario), removal units still represent continuing carbon storage for 500 years. In all scenarios, the social value of the carbon stored (relative to permanent storage) is greater than the units awarded given the 20% buffer contribution.

Costs, Benefits and Market Impact

Methodology

Defra analysts conducted a cost benefit analysis to inform the Authority's decision to include woodland carbon in the UK ETS. The benefits and costs, including potential non-monetised wider impacts, of meeting woodland creation targets through the ETS are considered against alternative policy scenarios. Woodland creation is modelled to 2050 to align with the end date for UK nations' planting targets, but the costs and benefits are assessed over a 50-year appraisal period (to 2075) given the long-term nature of benefits delivery.

The methodology uses a comparative cashflow analysis to forecast woodland creation, which estimates the profits a landowner would earn if woodland were created on a piece of agricultural land, in comparison to their profit if they continue to farm the land.

To estimate profits from farming, the analysis uses farm-level survey data from the Farm Business Surveys in England,⁵² Wales,⁵³ Scotland⁵⁴ and Northern Ireland.⁵⁵ The model includes different farm types and farms with low- and high-income levels. The model estimates the profitability of two woodland types: large commercial woodlands that generate timber income and smaller woodlands managed for biodiversity or amenity that do not produce timber. The model uses woodland creation cost and grant data for each nation and projections of timber income. Carbon income is also estimated by using the Woodland Carbon Code carbon sequestration values (see previous section) to estimate quantities of removals. These are then monetised as Voluntary Carbon Market (VCM) income or ETS income, depending on the policy option. The analysis uses current Woodland Carbon Code prices⁵⁶ with growth assumptions to estimate VCM income and DESNZ traded carbon values for ETS income. By comparing agricultural and woodland creation income streams, a discounted Net Present Value of woodland creation is calculated, which gives the profitability of woodland creation over and above continuing with the previous use of the land. The model then overlays a behavioural assumption to convert changes in woodland Net Present Value into changes in woodland creation.⁵⁷

The analysis then assesses the social costs and benefits of each policy option,⁵⁸ which are mainly driven by the levels of woodland creation delivery. It also applies a supply constraint (at 10% higher than the nation's woodland creation target), on the assumption that the target was set at approximately the level of what is technically feasible in terms of woodland creation. Various sensitivities, including high/low farm income, different discount rates, and variations in

⁵² [Farm Business Survey for England.](#)

⁵³ [Farm Business Survey in Wales, Statistical Results.](#)

⁵⁴ [Scottish Farm Business Survey.](#)

⁵⁵ [Farm Business Survey in Northern Ireland.](#)

⁵⁶ [UK Carbon Prices – Woodland Carbon Code.](#)

⁵⁷ The model assumes that landowners will respond rationally and proportionately to changes in financial returns. This means that if the financial incentives for woodland creation improve landowners are expected to increase their woodland creation activities accordingly. For example, if the NPV of woodland creation increases by 10%, the model assumes that the demand for woodland creation will also increase by 10%.

⁵⁸ Over a 50-year appraisal period.

ETS and VCM prices, are tested to understand their impact on woodland creation rates and costs.

Policy options in this analysis include:

- a) **Baseline – do nothing:** The continuation of recent grant rates, supported by continued timber and voluntary carbon market (Woodland Carbon Code).
- b) **Increased grants:** Woodland support continues through grants, but their generosity is scaled up to the level needed to meet targets. (This is the alternative way of meeting targets without using carbon pricing).
- c) **ETS inclusion only:** Woodland earns income from ETS for carbon, but all grants removed. (Timber income continues for commercial forests, which earn less carbon income).
- d) **ETS inclusion combined with co-benefit grants (ETS with grants):** ETS income, plus additional grant income, consistent with rewarding woodland creation for its non-carbon co-benefits. (Timber income continues for commercial forests, which earn less carbon income).

Results

Table 4: Assessment of Woodland Options from Defra analysis.

		(A)	(B)	(C)	(D)
	Target	Baseline	Increased grants	ETS only	ETS + co-benefit grants
Quantity of woodland creation by 2050 (thousands of hectares)	927	633	927	651	969
UK cumulative carbon sequestration by 2050 (MtCO ₂)	34	24	33	29	39
Average total grant and carbon incentive (£/tCO ₂)		121	169	114	173
Monetised value of carbon sequestration by 2075 (£bns)		24	34	26	36
Value of co-benefits by 2075 (£bns)		8	12	8	12
Value of social costs by 2075 (£bns)		9	14	7	14
Net Present Social Value by 2075 (£bns)		23	32	27	34

Policy options for woodland creation and their impacts on carbon removal, costs, and benefits. It shows that increasing grants (Option B) achieves higher woodland creation and carbon removal than the baseline but at a lower Net Present Social Value (NPSV) compared to option D. Including woodland carbon in the Emissions Trading Scheme (ETS) (Option C) offers better value for money than the baseline, with lower costs and higher NPSV, while still achieving substantial woodland creation and carbon removal targets. Option D combines ETS with additional grants (Option D) and is the most economically viable and beneficial overall.

Table 4 presents analysis of each option, with results shown at the UK level. However, woodland creation costs and the incentives needed to meet nation's individual planting targets vary between each UK nation. Each of the following results sections shows the average or total figure for the UK and provides an indication of how the results vary between the UK nations. The analysis suggests that woodland creation is most expensive in Wales and planting rates are lower, meaning that a higher uplift in government incentives is required to meet Wales's targets. Woodland creation is least expensive in Scotland, meaning that lower incentives are needed to meet Scotland's planting target.

As shown in **Table 4** the analysis finds that given the high cost of woodland creation, the continuation of current grant rates at the baseline funding level accompanied with the current WCC prices (Option A) is not sufficient to meet woodland creation targets. This is true for the combined targets and for each nation's individual target (see **Table 1**), with delivery ranging from 84% of the target in Northern Ireland to 22% in Wales. Carbon removal and co-benefits are therefore low, driving low overall Net Present Value in this scenario compared to other policy options. This evidence suggests that current incentives are not sufficient to meet the high costs of woodland creation in the UK, which is also reflected by current woodland creation remaining below target levels in each UK nation. This is consistent with evidence presented in the consultation, and further evidence summarised below in the section on Value for money.

Option B shows an illustrative scenario, where the generosity of grants within the current support structure is increased to a level that is sufficient to meet woodland creation targets.⁵⁹ While this results in significant carbon removal benefits and co-benefits, the economic cost of supporting woodland creation in this way is high, and the resulting Net Present Value of this option is lower than achieving the targets through the ETS and additional grants (Option D). The additional uplift to grant rates varies across each UK nation, with a higher uplift needed where woodland creation rates are furthest from targets. Despite relatively high current grant rates, Wales only achieves 22% of its planting targets under current incentives, indicating there are significant non-financial barriers. This means substantial additional income is required to meet Wales's ambitious planting goals, with an average grant rate of £34,400 per hectare needed. In contrast, Scotland only requires grant rates of £5,500 per hectare to meet its targets, as current grant rates are lower, yet woodland creation rates are closer to the target. The average grant rates required to meet Northern Ireland's targets (£6,500 per hectare) and England's target (£14,500 per hectare) sit within the middle of the range.

Option C, where woodland is integrated into the ETS, but all grant funding is removed, delivers some improved outcomes. There is increased carbon removal compared to the baseline, at significantly lower economic cost resulting in higher Net Present Value. However, woodland creation is expensive, and ETS integration alone does not provide a sufficient level of incentive

⁵⁹ This and subsequent scenarios use illustrative levels of grant funding and they are neither a commitment nor an opinion on how much grant funding is expected in the future.

to meet total UK planting targets, with delivery ranging from just 13% of Welsh planting targets, to 110% of targets being met in Scotland through ETS incentives alone. Co-benefits are not rewarded by this option, which results in a sub-optimally low level of woodland creation, which limits the Net Present Value of this option.

In Option D, ETS integration is combined with grants for co-benefits, such as biodiversity. By adding grants for co-benefits in Northern Ireland, Wales and England, this option sufficiently incentivises woodland creation so that all four nations targets are met and exceeded by 10% in Scotland and Northern Ireland. This results in significant carbon removal benefits and co-benefits. Compared to achieving the target through grants (Option B at £15,000 per hectare), targets are achieved in a more cost-effective manner under the ETS plus grants option, with an average social cost of £14,400 per hectare across the UK, average costs range from £8,600 per hectare in Scotland to £17,300 per hectare in Wales. The result is a higher Net Present Value than any other option.

Option D is more cost effective because it is assumed that the ETS will incentivise a greater proportion of larger, productive woodlands on more marginal land, which are less economically costly. Currently the Woodland Carbon Code tends to support larger woodlands than grant schemes.⁶⁰ It is expected that the ETS would continue this trend. The Woodland Carbon Code may be less attractive to smaller woodlands, due to relatively high validation, monitoring and verification costs, which have a greater burden for smaller woodlands.⁶¹ A Forest Research report on establishment costs⁶² finds that larger woodlands lower the overall costs per hectare of woodland creation due to economies of scale.⁶³ That said, the Woodland Carbon Code is currently piloting remote sensing options such as drone and satellite derived data to aid land managers with 5- and 15-year verifications, hopefully reducing costs. The Woodland Carbon Code also allows for grouped applications to spread costs amongst a group of smaller project developers. This should help to ensure that the Woodland Carbon Code is still accessible for smaller landowners, specifically in nations where there is a larger proportion of family owned or individually managed landowners.⁶⁴ Under this option, grant schemes could also be targeted to support smaller landowners to plant trees, mitigating the risk of only large-scale woodlands and helping to maintain cultural heritage across the four nations within the forestry industry.

⁶⁰ For example, in England, the median site size for England Woodland Creation Offer grant schemes is less than 5 hectares (Source: unpublished Stage 2 evaluation of the NCF Tree Programme (ICF)). This compares to an average site size of 14 hectares in projects registered with the WCC in England, as of 31 December 2024 (Source: [Statistics - UK Woodland Carbon Code](#)). Across the four nations, the average WCC woodland site is 43 hectares.

⁶¹ Validation costs are approximately £1,800-£2,500 plus VAT per project, which means that the cost per hectare is higher for smaller sites than larger sites (Source: [Validation - UK Woodland Carbon Code](#)). Validation costs are approximately £1,800-£2,500 per project (Source: [Validation - UK Woodland Carbon Code](#)).

⁶² Soon to be published.

⁶³ As such, the ETS only option (£16,900 per hectare) and ETS + grants option (£17,200 per hectare) have slightly lower costs than the baseline option cost of £17,400 per hectare.

⁶⁴ The [Forest of Marston Vale Group \(UK Woodland Carbon Code\)](#) is an example of a successful group of ten smaller woodland sites working as a partnership across communities. Models like this could be replicated across the four nations under the WCC within the UK ETS.

Benefits

Carbon Sequestration

Nature-based measures, such as planting new woodland, are an integral method of carbon sequestration and a critical component of the UK's pathway to achieve net zero by 2050.⁶⁵ The baseline is projected to remove 24 MtCO₂ by 2050. While this contributes to UK's carbon reduction goals, it falls short of other policy options in the analysis. The increased grants options to make woodland financially viable, is estimated to remove 33MtCO₂ by 2050. The inclusion of woodland into the UK ETS offers a value for money approach to enhance carbon sequestration, by incentivising woodland creation through a mixture of grants and higher private finance. The analysis finds that the ETS with grants option removes the most carbon by 2050 and is a more cost-effective mechanism for delivering carbon savings than the baseline with increased grants (as measured by a lower cost per hectare). This policy option is estimated to incentivise woodland to remove a total of 39 MtCO₂ by 2050, the highest among all the options with total carbon savings over a 50-year period to 2075 also being valued the highest of all options at £36.3bn. Including woodland carbon in the ETS without grant support is projected to remove 29 MtCO₂ by 2050 through leveraging only private finance, offering a cost-effective approach but not delivering sufficient woodland creation or carbon savings.

Co-Benefits

Woodland creation can provide a range of other social and environmental benefits, including improvements in biodiversity, flood regulation, air quality and health benefits, as well as private timber benefits. These benefits have been monetised for each option using Defra's Enabling a Natural Capital Approach guidance.⁶⁶ The baseline scenario provides moderate co-benefits of £8.1 billion over a 50-year period to 2075, primarily through enhancing biodiversity and ecosystem benefits that are already incentivised through the WCC. Through increasing grants (option B), this drives higher levels of woodland creation and increases co-benefits to £11.8 billion, particularly biodiversity benefits (£4.0bn) and air quality improvements (£3.8bn). Option D (ETS + grants) delivers a similar level of total co-benefits (£11.9 billion), but with slightly reduced biodiversity benefits and slightly higher timber benefits due to the higher proportion of productive conifer assumed. Through ETS integration only, there are no specific grants to target environmental co-benefits. As such, woodland creation is not spatially targeted or designed to maximise co-benefits, with only £8.2 billion of co-benefits generated in this scenario.

Costs

Costs to Landowners

For the comparative cashflow analysis, which considers the profitability of the woodland creation from the landowner's perspective, the economic costs include the physical costs of preparing the land and planting the trees, wildlife management and any other activities to ensure the proper survival of the trees in early years. On top of this, landowners will also usually require compensation for any income that they forego from switching their land to tree planting – for example, lost agricultural income from permanently taking their land out of

⁶⁵ [The Seventh Carbon Budget - Climate Change Committee.](#)

⁶⁶ [Enabling a Natural Capital Approach \(ENCA\).](#)

production or a reduction in agri-environment grant subsidies. The current average cost of woodland creation over a 50-year period across the UK varies by woodland type and geographical region, with a central average of £13,800 per hectare. This is split between establishment costs (59%), payments for agricultural income forgone (36%) and diversification income or subsidy payments forgone (5%).

On top of the costs, landowners may also expect an additional payment on top of this to overcome hidden financial costs (e.g. tax implications) and other non-financial barriers - for example, the long-term nature and permanence of tree planting is a clear barrier to some landowners, with a perceived loss of control over land use.⁶⁷ Other farmers view forestry as unprofitable, even when it is more profitable than their current farming business, creating further non-monetary barriers to woodland creation.

Government Incentives

The main incentives available for landowners for woodland creation are timber income, carbon payments and government grant support. For large, productive woodlands with fast-growing species such as Sitka spruce, it is possible for some landowners to make a profit with timber income alone. However, these woodlands would not pass the WCC investment additionality test, which requires a project to prove that it is not profitable without carbon finance or at least is not the most economical option for that land.

Productive woodlands that want to generate both timber and carbon income may therefore have to accept a lower government grant to pass the investment additionality test or change their woodland design to plant a lower proportion of the most productive timber species, to lower their timber income to the level where carbon finance is still required for the project to be profitable. For woodlands participating in carbon markets, this analysis finds that on average approximately 20% of total woodland income will be from timber, with some woodlands generating no timber income at all.

The remaining incentives would be expected to come from carbon payments or government grant income. The analysis finds that these incentives would have to increase by 43% on average for UK nations' targets to be achievable. This means that the combined income from grants and carbon payments must equal an equivalent payment of £173/t of carbon on average across the UK.⁶⁸ However, there is significant variation between nations, with required government incentives ranging from £113/t of carbon to meet Scotland's targets, to £327/t of carbon to meet Wales's targets. Higher incentives are required in Wales because woodland creation rates are furthest from targets, and the analysis assumes that woodland creation will only increase if there is a proportionate uplift in incentive levels. It is possible that incentives will not need to increase as much in Wales as this analysis suggests, particularly if non-financial barriers to woodland creation are removed in the future.

The analysis finds that the current baseline incentives from grants and WCC income total just £121/t, with the majority of this coming from grant funding. Voluntary carbon payments under the Woodland Carbon Code are uncertain and currently too low - analysis presented in the

⁶⁷ [Enabling a Natural Capital Approach \(ENCA\)](#).

⁶⁸ Calculated over a 50-year period, assuming a discount rate of 3.5% and payment when the units are delivered.

consultation suggested Woodland Carbon Code prices of £25/t covered only around 17% of the costs of woodland creation. As such, the baseline option does not meet woodland creation targets. The ETS alone (option C) provides £114/t, which even combined with slightly higher timber income, due to the higher proportion of productive woodlands, is still insufficient to achieve targets. A grant payment equivalent to a UK average of £59/t carbon⁶⁹ is required on top of this carbon income to achieve targets in the ETS plus co-benefits grants option D.⁷⁰

Total Costs

It is important to assess the total social costs to identify the least cost option from society's perspective and to understand the impacts of each option on wider social welfare. The analysis does this by looking at the discounted total cost of woodland creation regardless of whether this is borne by Government or landowners.

Social costs are calculated as the total of establishment costs for planting the woodland itself plus the value of any agricultural income forgone on the land. The cost benefit analysis excludes the value of agricultural subsidy payments,⁷¹ as these would be considered a transfer payment from Government to landowners and so should be excluded from the overall estimate of Net Present Social Value, according to HMT's Green Book appraisal guidance.⁷² When excluding subsidies, the average social cost for UK woodland creation is currently £13,200 per hectare over a 50-year period. There is significant variation across nations, farm types and woodland type. The social cost ranges between £8,000 per hectare, for a large commercial woodland on less productive farmland in Scotland, to £32,600 per hectare, for a smaller woodland managed for biodiversity on more productive farmland in Wales.

ETS integration increases the total quantity of woodland, including amenity broadleaf, mixed and productive woodlands, across all regions. As we move towards meeting UK planting targets, the average cost per hectare is likely to increase once the opportunities on cheaper, marginal land are used up and we need to target more expensive areas for woodland creation. As a result, the social cost of meeting the targets through grants (Option B) is the highest of all options at £15,000 per hectare (average across the UK). Targets are achieved in a more cost-effective manner through a combination of the ETS and grants for co-benefits, with an average social cost of £14,400 per hectare across the UK. This is because it is assumed that the ETS will incentivise a greater proportion of larger, productive woodlands on more marginal land compared to grant funding.

The cost benefit analysis does not monetise some wider social or environmental costs that may arise from tree planting, depending on the prior land use and local context. However,

⁶⁹ No grant is required to meet targets in Scotland, but grants of £10/t, £75/t and £213/t are required to meet targets in Northern Ireland, England and Wales respectively.

⁷⁰ Achieving the target through grants alone may require a lower level of incentives overall, as landowners are likely to be less risk-averse given that grants provide certain, up-front income. The analysis finds an upfront grant payment equivalent to paying £169/t (over the life of the project, as the carbon is stored) is sufficient to achieve all targets for this option. This does not necessarily imply grants are better value for money for the government, as they must be paid up front when the woodland is planted, whereas payments through carbon markets are deferred to when the carbon has been stored.

⁷¹ Although this is included in the comparative cashflow analysis, which considers the financial profitability of woodland creation from the landowner's perspective.

⁷² [The Green Book \(2022\)](#).

further discussion on these impacts is included in the “Non-monetised costs – risks of wider impacts” section.

The ETS with grants option (D) has a slightly higher social cost (£13.9bn) than meeting the targets through increased grants (£13.8n) but it delivers more hectares and has a lower cost per hectare, showing that this is a more cost-effective way of delivering woodland creation at scale.

Net benefits

The analysis suggests that in all options the benefits of woodland creation outweigh the costs, leading to positive Net Present Social Value.⁷³ This is because the value to society of carbon removal, timber production (where applicable), and the co-benefits of woodland creation is higher than the costs of planting and maintaining woodland. Integrating woodland carbon into the UK ETS maximises these net benefits, by maximising the amount of woodland creation and doing so at minimum cost.

Sensitivities

The analysis relies on several uncertain assumptions, which have been tested in sensitivity analysis. These include high/low farm income, different discount rates, and variations in ETS and voluntary carbon market prices. The results show that the ETS alone option (C) is insufficient to achieve planting targets in all sensitivities. Even when applying the higher DESNZ projections of future carbon values, woodland creation rates are only 9% above the central scenario and 200,000 cumulative hectares below UK planting targets by 2050. This further illustrates the need for co-benefit grants in addition to the ETS and shows that the overall risk of woodland removals being oversupplied to the ETS is low.

The analysis is particularly sensitive to the discount rate chosen.⁷⁴ The high discount rate sensitivity has the largest impact on results, with woodland creation under the ETS only scenario being 67% lower than the central scenario. This sensitivity simulates a scenario where all landowners act like private investors, with a high preference for income received today rather than the future. This assumption means that the ETS is now less attractive compared to grants, as carbon incomes under the ETS are received further into the future and are therefore perceived as less valuable compared to upfront grant income. There is mixed evidence on the appropriate discount rate to apply.⁷⁵ In the central scenario, we have applied an assumption towards the middle of the range in the literature, but the ETS could be less attractive if the discount rate is higher than assumed.

⁷³ Wales's NPV is low over 50 years and negative before 2050 due to ambitious woodland creation targets compared to current rates. Despite generous grants, low woodland creation suggests significant non-financial barriers.

⁷⁴ The choice of discount rate has a large impact on the analysis, because the ETS spreads incomes over a much longer period compared to up-front grant funding. A lower discount rate implies a lower value is placed on present incomes compared to the future, which increases the relative attractiveness of the ETS to landowners considering woodland creation.

⁷⁵ Landowners all have different preferences and discount rates, which makes it difficult to choose a discount rate for the analysis that reflects the majority preferences. Within the literature, typical values range from 0% (assuming future and present incomes are valued equally) to 8%, which is more similar to the returns expected for private investments.

Conclusion

The analysis reports estimated costs and benefits from integrating woodland into the UK ETS, compared to plausible alternative options. The results suggest that there is a clear economic case for ETS integration. The analysis also allows us to explore two related questions: (1) Is the ETS the right market for woodland carbon, i.e. does it offer value for money? (2) Could ETS integration result in woodland 'oversupplying' the market?

Value for Money

Some stakeholders have questioned whether the ETS is the right market to incentivise woodland creation, citing a potential mismatch between ETS prices and the costs of planting and maintaining woodland. The specific concern is that ETS prices could be higher than the cost of woodland creation, leading to overly generous incentives and poor value for money for government if woodland is supported in this way. The analysis above can be used to directly explore this question.

Current ETS prices, as measured by the average over the most recent full calendar year (2024), are around £39/t. The price will likely change significantly over the period to 2050. Current DESNZ projections of future carbon values suggest values in the range £44-154/t from 2025-2050. By comparison, the cost of incentivising woodland creation such that governments can meet their targets is on average £173/t, as described above. This could be made up of carbon pricing income or grants for co-benefits.

This evidence, therefore, suggests that the cost of woodland creation may well be higher than ETS prices out to 2050. Hence, the ETS is not projected to over-reward woodland creation if woodland is included in the scheme. In fact, the opposite is true: ETS alone may under-reward woodland creation. It must therefore potentially be combined with additional support for co-benefits (grants or other nature market payments), if the market is to incentivise woodland creation at the efficient level. It follows that the ETS is an appropriate market to reward carbon removals by woodland creation, and (when combined with the right support for co-benefits) offers a solution that is good value for money.

This conclusion is consistent with analysis presented in the consultation, suggesting Woodland Carbon Code prices of £25/t covered only around 17% of the costs of woodland creation. It is also consistent with the current state of woodland creation in the UK: current incentives (including carbon prices of £25/t plus generous grants) are not sufficient for us to meet our targets.

The conclusion that woodland creation costs are likely higher than projected ETS prices is consistent with the results of separate internal analysis by Scottish Forestry. They undertook analysis of the average carbon price needed to breakeven with costs of woodland creation and management. This found that the average required breakeven price was between £177/t and £238/t, depending on the species mix, payback period and profit margin required.

The broad conclusion that ETS inclusion provides good value for money is also consistent with the benefit-cost ratios at a UK level obtained from the above analysis. The ETS only option C and ETS with co-benefit grants option D give benefit-cost ratios of 4.6 and 3.53 respectively,

which are respectively higher than non-ETS options A and B with benefit-cost ratios of 3.6 and 3.4 respectively⁷⁶. This suggests that the ETS offers high value for money, as a way of incentivising woodland creation and associated carbon removal. This result is driven by the assumption that the ETS leads to a greater proportion of larger, more productive woodlands. These are both more efficient (i.e. lower cost) and deliver slightly higher benefits per hectare because of the increased rates of carbon removal with productive conifer woodlands.

Oversupply

Some stakeholders have also questioned whether including woodland carbon removals in the UK ETS could potentially lead to 'oversupply' of woodland removals, which could then destabilise the ETS market. The analysis above can be used as a starting point to explore this question, and the overall conclusion is that market instability as a result of woodland oversupply is highly unlikely, for four reasons.

First, the modelling suggests ETS is unlikely to over-incentivise woodland creation, as outlined above, due to the cost of woodland creation. The ETS only scenario C is projected to under-incentivise woodland creation, meaning targets are not met, neither at the UK level nor in any of the four nations. The ETS with co-benefit grants option D is required to meet woodland creation targets across the four nations of the UK.

Second, even if all woodland targets are met, woodland carbon would make up only a small proportion (approximately 10% by the end of the 2030s) of total ETS allowances in the market.

Third, whatever level of supply of woodland removals ended up entering the market, the Authority's decision to maintain the cap would limit any market impact. It would ensure no source of removals, including woodland, would impact the total number of allowances in the ETS and therefore adversely impact market stability.

Fourth, the Authority will implement a supply control for overall GGRs entering the ETS. If woodland removals were to be included, we could combine this with an additional, woodland-specific safeguard in the form of a Woodland Cap on allowances. This is described further in the Box below. A Woodland Cap would provide a final guarantee, in addition to all other measures, that the quantity of woodland removals entering the system could not exceed a given level and therefore destabilise the system.

A Woodland Cap

If the Authority were to include woodland removals in the ETS, it could do so with additional safeguards in place. This could include a Woodland Cap, a fixed limit on the number of woodland removal allowances that could enter the market over a given timeframe. This would provide a firm upper limit on any future ETS market impacts or wider, non-ETS impacts such as the food production, social impacts and land price effects discussed below.

Non-Monetised Costs – Risks of Wider Impacts

If UK woodland is integrated into the UK ETS, this should only be high-quality UK woodland. This means not only must the woodlands demonstrate high permanence (see *Permanence*

⁷⁶ Calculated over a 50-year appraisal period

section) but also provide wider socio-economic and environmental benefits. The Authority understands the potential concerns raised by the CCC and other stakeholders around wider impacts and has conducted analysis as well as identified safeguards to prevent unintended adverse effects. The following section outlines these in turn.

Poor Quality Woodland

The potential concern identified here is the ETS could incentivise the creation of woodlands with low environmental benefits, leading to increased monoculture creation or a reduction in biodiversity.

This is highly unlikely due to safeguards on UK woodland. Firstly, the UK Forestry Standard sets a firm upper bound of 65% of any one species in a woodland. This ensures woodlands are created with diverse species portfolios, not as monocultures. Secondly, the UK Forestry Standard as well as the WCC requires woodland project owners to carry out Impact Assessments which evaluates the environmental, social, and economic effects of a woodland project, ensuring compliance with WCC standards, engaging stakeholders, and establishing monitoring and reporting systems.

Finally, the WCC incentivises mixed species woodland through their [carbon calculator](#). This establishes, at the beginning of the project, how many carbon units will be issued throughout a project lifetime. Those that will harvest timber or wood products will be issued with fewer woodland carbon units than a nature-focused, highly biodiverse broadleaf woodland. This means per hectare a highly biodiverse woodland receives more woodland carbon revenue than a productive woodland.

In England, there are additional incentives for the delivery of additional ecosystem services in the form of spatially targeted grants. England's woodland creation grant offer (EWCO) currently provides a base payment for any woodland, and then additional top ups for public goods the woodland provides for example £1,000/ha for flood risk reduction, £500/ha for improvements to water quality. Land use and forestry policy is devolved and therefore subject to future decisions by Devolved Governments, but this could be mirrored in the other three nations of the UK.

Food Production

The woodland creation targets (see **Table 1**) for each of the four nations have been set at levels consistent with maintaining food production at broadly current levels. These targets are exceeded in the Climate Change Committee's Seventh Carbon Budget which calls for 37,000 ha/year across the UK, by 2030.⁷⁷

Several reports conclude that the woodland creation targets, and even the higher CCC target, will not disrupt UK food production. The National Food Strategy (2021) found that the 10% least productive farmland grows only 1% of the UK's calories.⁷⁸ By comparison the total woodland creation target represents 5.5% of the UK's total agricultural land. Their report

⁷⁷ [The Seventh Carbon Budget - Climate Change Committee](#).

⁷⁸ [United Kingdom Food Security Report 2024: Theme 2: UK Food Supply Sources](#).

therefore concludes that the UK can grow enough forest on the least productive land to reach net zero targets.⁷⁹

The UK Food Security Report (2024) outlines that agricultural land is on a very slowly decreasing trend, having fallen 3.5% since 2003, and has not impacted UK food production. The report concludes that food production levels could be maintained or moderately increased alongside the land use changes required to meet net zero and Environment Act targets, including woodland creation.⁸⁰

This evidence was supported in the latest internal analysis for Defra's 2025 land use consultation to conclude little to no conflict between land for food production and woodland creation. The safeguards introduced for oversupply, including the Woodland Cap could also provide additional assurance for any remaining concerns surrounding UK food production.

Social Impacts

The Authority applies the principles of the Public Sector Equality Duty in all policy development. In accordance with this the Authority assessed whether more woodland creation could lead to different groups including marginalised communities and protected characteristics being disproportionately impacted. There was no evidence that woodland creation would have adverse impacts on these groups.

During this process, the Authority has been assessing the impact to culture and language due to potential land use changes. The primary focus has been on Welsh language given Wales's official bilingual status. The consultation process has not yet highlighted any evidence of negative impacts to the Welsh language. Work is ongoing to fully assess this, and an update will be provided in a future impact assessment. Responses thus far have suggested that language loss is unlikely, as the forestry sector actively supports Welsh language through community engagement, bilingual signage and education programs in forests.

The [Costs, Benefits and Market Impact Results](#) section of this Annex outlined how large-scale woodlands will be incentivised through some grant structures in the ETS. However, it also notes that the WCC will remain attractive for smaller landowners through targeted grants, and by the Woodland Carbon Code allowing grouped applications to spread costs amongst a group of smaller project developers.⁸¹ This will help mitigate the risk of only large-scale woodlands operating and help to maintain cultural heritage across the four nations within the forestry industry. In Wales this structure could offer opportunities for local forestry, particularly for small Welsh landowners, contributing to the preservation of Wales's cultural heritage within the forestry industry.

⁷⁹ [Agricultural Land Grades – Land Research Associates](#).

⁸⁰ [United Kingdom Food Security Report 2024: Theme 2: UK Food Supply Sources](#).

⁸¹ The [Forest of Marston Vale Group \(UK Woodland Carbon Code\)](#) is an example of a successful group of ten smaller woodland sites working as a partnership across communities. Models like this could be replicated across the four nations under the WCC within the UK ETS.

The safeguards introduced for oversupply, including the Woodland Cap could also provide additional assurance for any remaining concerns surrounding social impacts from woodland creation.

Increased Land Prices

ETS integration could impact the types of land where new woodlands are created, and so marginal land, that is currently low-value land, could increase in price. This would mean that land values more accurately reflect their value to society, including carbon benefits and co-benefits discussed earlier in this section, which are currently underpriced. Local authorities will be involved in land use change processes to ensure this does not have adverse effects on communities.

Carbon Leakage

Carbon leakage here refers to the displacement of carbon emissions due to woodland creation in one area, leading to increased farming or deforestation in another.⁸² For example, if a woodland in location A resulted in either deforestation or significantly intensified agricultural use in location B. The Authority sees carbon leakage occurring due to increased woodland creation as unlikely.

At the project level carbon leakage is mitigated through the Woodland Carbon Code [Project Design Document](#) which records land use change and any impacts it could have on land elsewhere. At a UK level, deforestation is illegal nationwide as part of the Environment Act (2021) and its subsequent amendments that tackle deforestation throughout supply chains.⁸³ Habitat loss is also protected in legislation and impacts surrounding agricultural intensification is managed by Defra to reduce nationwide emissions while supporting agricultural productivity.⁸⁴ Carbon leakage at the international level is likely to also be low. This is due to UK afforestation utilising the low-yield agricultural land meaning there will not be increased pressure on food production (see earlier Food Production subsection) so limited additional agricultural imports will occur as a direct result of increased woodland creation.

⁸² Note this is a different version of carbon leakage compared to the international carbon leakage which, for example, free allocation or carbon border adjustment mechanisms are targeted to prevent.

⁸³ [Due diligence requirements](#) were added to the [Environment Act \(2021\)](#) to tackle illegal deforestation in UK supply chains.

⁸⁴ [https://www.legislation.gov.uk/ukpga/2000/37/Wildlife and Countryside Act \(1981\)](https://www.legislation.gov.uk/ukpga/2000/37/Wildlife%20and%20Countryside%20Act%20(1981)).

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