The opportunities of agri-carbon markets

A summary

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The opportunities of agri-carbon markets: a summary

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This report summarises the findings of *The opportunities of agri-carbon markets: policy and practice.* The longer report explores agri-carbon measures in more depth, sets out further recommendations and indicates where further research would be useful. It was written in collaboration with researchers from the University of Manchester. It is available to download at www.green-alliance.org.uk

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Introduction

The 2015 Paris Agreement aims to limit global warming to 1.5°C compared to pre-industrial levels by reducing greenhouse gas emissions to net zero, through a combination of emission reductions and carbon removal.

To achieve this, the UK will need to make major changes in the way it uses land. UK emissions from agriculture, land use and peatlands were 58 $MtCO_2e$ in 2017, with agricultural emissions accounting for about nine per cent of the country's total emissions.

The Climate Change Committee says that these emissions could be reduced by 64 per cent by 2050 through a combination of low carbon farming practices, afforestation and agroforestry, peatland restoration, bioenergy crops and by cutting consumption of food responsible for high carbon emissions.[1]

These changes are likely to be stimulated by a combination of government and private investment, eg in new agri-environment schemes and through voluntary carbon markets.

Several voluntary initiatives driving net zero declarations across the private sector, such as the United Nations' Race to Zero campaign and the Science Based Targets initiative,[2] are leading to greater interest in carbon markets.

“Farmers should be wary of selling carbon offset credits to buyers upfront as this could harm their own decarbonisation efforts.”

In the UK, most voluntary carbon offsets are provided by afforestation projects, via the Woodland Carbon Code. Others are delivered through peatland restoration, via the Peatland Code.[3] These voluntary standards provide guidance for project developers to deliver high integrity carbon storage and assurances to voluntary carbon credit buyers that the climate benefits they purchase are real, quantifiable, additional and permanent.

New standards are now being developed in the UK, funded by the Environment Agency’s Natural Environment Investment Readiness Fund. These include the creation of a UK Farm Soil Carbon Code to reward farmers for the carbon sequestration benefits of more regenerative on-farm practices, and a Hedgerow Carbon Code.[4]

Here, we outline the main conclusions of a longer review of the state of the science on a range of opportunities for sequestering carbon on working farms in the UK. We also explore the role of voluntary carbon markets in accelerating carbon sequestration on farms and provide recommendations on the development of a credible agri-carbon sequestration market in the UK.

We conclude that farmers should be wary of selling carbon offset credits to buyers upfront as this could harm their own decarbonisation efforts. It is likely to be more beneficial for them to work together with food businesses to reduce emissions and sequester carbon within the supply chain. This will require new standards that guarantee the permanence and accurate measurement of carbon stored. We recommend new requirements to ensure that those making carbon neutral or net zero claims, through the purchase of carbon credits generated from land, are also reducing their own emissions.

“To reach net zero at a company, UK and global level will ultimately require carbon removal and storage to balance any remaining emissions.”

Understanding carbon markets

Companies and individuals buy carbon credits or certificates to show they are limiting their contribution to climate change. These are used to prove that emissions reduction or carbon sequestration has taken place outside the buyer's own operations. However, they can be created and traded in different ways. Here we explain aspects of how carbon markets work.

Emissions reductions versus carbon removals

Carbon credits or certificates are created by reducing or avoiding emissions that would otherwise have happened, or by taking carbon from the atmosphere and storing it, such as through carbon stored or 'sequestered' in trees or soils. Both are used in voluntary carbon offsetting schemes. However, there is an important difference between the two in terms of their climate impact.

Offsetting, through reduced or avoided emissions credits, still results in greenhouse gases being released to the atmosphere. It just ensures the buyer's continuing emissions are balanced out by a reduction on the seller's part. Using carbon removals instead means there is no net addition of greenhouse gas to the atmosphere because any carbon emitted is removed again and stored.

While businesses currently use reduced and avoided emissions credits to make 'carbon neutral' claims, to reach net zero at a company, UK and global level will ultimately require carbon removal and storage to balance any remaining emissions.[5]

In the UK, the Woodland Carbon Code provides standards for carbon sequestration credits through tree planting. The Peatland Code provides standards for emissions reductions from peatland through restoration. While reduced or avoided

> New codes for soil and hedgerow carbon sequestration will help to increase the amount of verified carbon storage available in the UK."

emissions credits, such as those created under the UK Peatland Code, can play a role in accelerating decarbonisation and reducing total emissions released into the atmosphere, as the UK gets closer to a net zero carbon economy this will no longer be sufficient. New codes for soil and hedgerow carbon sequestration will help to increase the amount of verified carbon storage available in the UK.

Businesses can use carbon credits in different ways

Different types of verified carbon credits and certificates can be used in different ways by buyers. Most people will be familiar with companies buying carbon credits to make offset claims, whereby a product, activity or the whole business is declared 'carbon neutral' or 'net zero' because its continuing emissions have been offset by reductions or removals elsewhere.

However, some schemes create verified emissions reductions or removals that are not sold as offsets. Rather, the buyers of the carbon certificates make claims about having contributed to decarbonisation of the economy but they do not use the certificates directly to offset their own emissions. In the UK, soil carbon schemes like Soil Capital use this approach.[6]

Credits created under the Woodland Carbon Code can be used as offsets for emissions that happen within the UK but must be reported separately from the international carbon credits a company buys.[7] They cannot be sold to offset emissions in other countries.

The difference between insetting and offsetting

There has been increasing interest in the concept of 'insetting'. While offsetting is a relatively familiar term, insetting is less well defined and understood. Usually, it refers to a company buying verified emissions reductions or carbon removals from within its supply chain, or its direct sphere of influence.

For accounting purposes companies' emissions are split into three types:

Scope 1 emissions are those directly created by a company, such as from boilers or vehicles.

Scope 2 emissions are created indirectly, such as emissions from producing the electricity the company uses.

Scope 3 emissions are those the company is indirectly responsible for over the entire lifecycle of its products, including emissions generated in the production of the goods it buys.

A business interested in insetting could buy carbon credits from within its supply chain to offset its scope 1 and 2 emissions, or it could use them to reduce its net scope 3 emissions (ie the emissions of the farm or other supplier that created the credit). The latter approach is more likely to share the benefits of the carbon reduction or removal activity between the supplier and buyer. This is outlined in more detail on pages 16-18.

Selling carbon credits upfront

In the Woodland Carbon Code and Peatland Code, landowners are able to sell all the carbon expected to be sequestered (or emissions avoided) over the entire lifetime of the project upfront as 'pending issuance units' (PIUs). This provides finance for any works required, as well as removing the risk of future price volatility. PIUs are converted into Woodland Carbon Units or Peatland Carbon Units at intervals throughout the lifetime of the project as the sequestration or emissions reductions happen and they are measured and verified. These can then be 'retired' by buyers, ie they cannot then be used by anyone else. Selling PIUs from agri-carbon projects could have a serious impact on the options farmers have in future for addressing their own emissions, as they will not be able to claim the sequestration themselves. We explore this further on pages 16-18.

Regulatory and voluntary markets

Carbon markets can either be voluntary or regulatory. In regulatory markets there is a requirement for the regulated industry to reduce or compensate for their emissions, or they will face a penalty for polluting. The main examples in use are 'cap and trade' systems, such as the EU and the UK Emissions Trading Schemes (ETSs) and the Californian cap and trade programme. These operate with a cap on the overall level of emissions set for all the regulated businesses involved, with participants able to trade to ensure they have a big enough share of the cap to cover their emissions. In the Californian system, participants can meet up to four per cent of their

“

UK credits cannot be sold and used to offset emissions created outside the UK.”

emissions reduction obligations by buying offsets from outside the cap and trade scheme.[8]

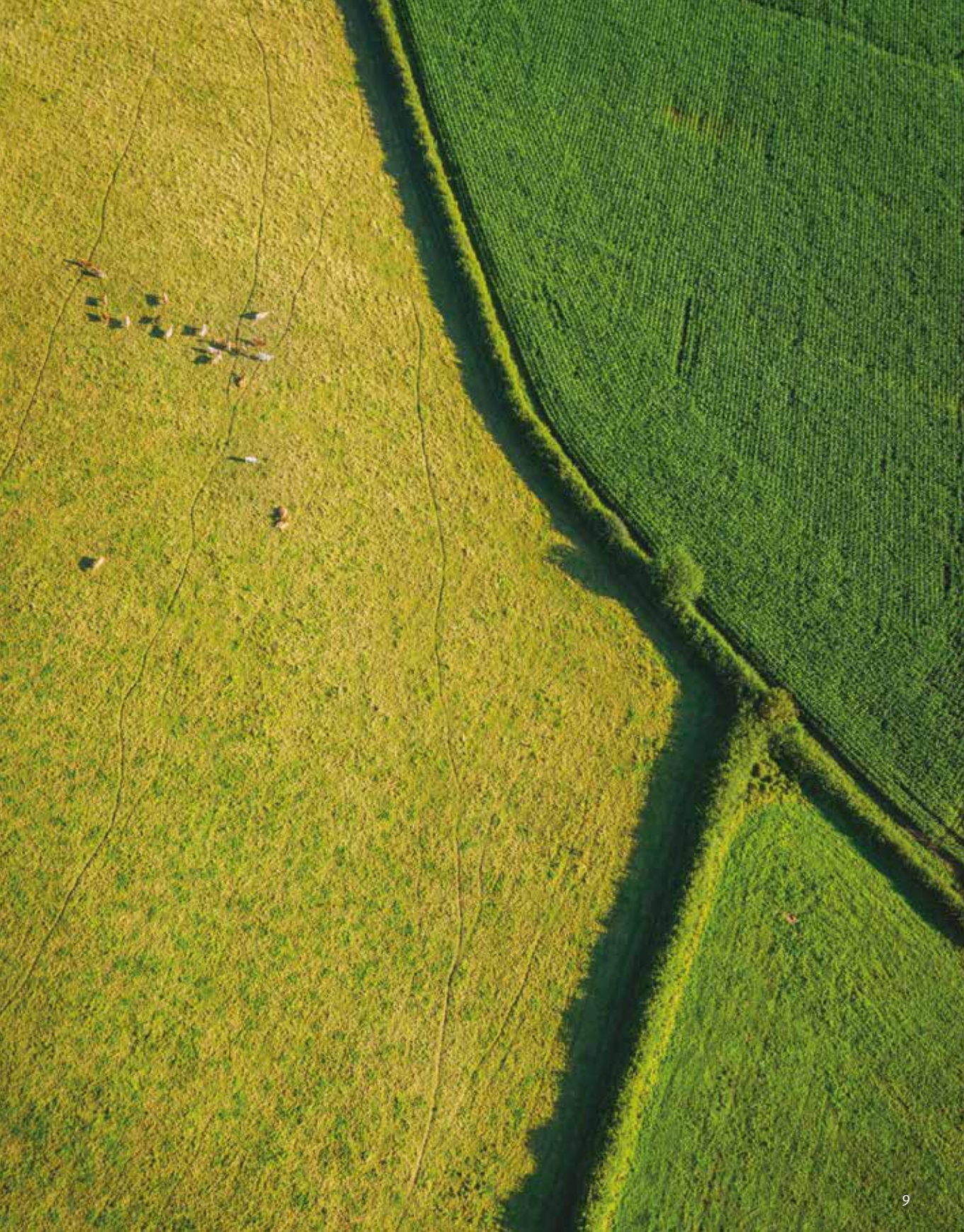
By contrast, through voluntary carbon markets, businesses which do not have formal emissions reduction obligations buy carbon credits to reduce their climate impact and improve their reputation. The global voluntary carbon market has grown in recent years.[9] In the UK, the land and agriculture sector is currently outside regulatory markets. Carbon offset schemes in this sector are in voluntary markets.

International and domestic carbon trading

Carbon credits can be traded both domestically and internationally. This can happen in both regulatory and voluntary markets. For example, the Kyoto Protocol, a 1997 international climate treaty, set up mechanisms for countries to trade carbon reduction credits to meet their obligations under the protocol. These were used in the EU ETS.[10]

Companies can also buy carbon credits created in other countries on the voluntary market. For example, most voluntary carbon credits are created in developing countries, while most buyers are in Western Europe and North America.[11]

In the UK, a decision has been taken not to allow credits created under the Woodland Carbon Code and Peatland Code to be sold and used to offset emissions created overseas, as the government could not count them towards the UK’s own climate goals, making it more difficult to reach net zero.[12] For more about this, see page 22.



The opportunity to tackle climate change

Carbon can be sequestered in biomass, such as in the trees in agroforestry systems and in hedges, as well as in agricultural soils. Emissions from lowland peatlands can also be reduced by raising the water table or converting to paludiculture (farming on wetlands), while full restoration of peatland could lead to carbon sequestration. Afforestation also has great potential for carbon removal.

In future, it may also be possible to store carbon in soils by the incorporation of biochar (charcoal made from agricultural and forestry wastes) on agricultural land, and through enhanced rock weathering.[13] However, these technologies are still in development. Other engineered removal options, such as direct air carbon capture and storage (DACCS) and bioenergy with carbon capture and storage (BECCS) are also in development, although serious concerns have been raised about the sustainability of biomass supply for BECCS when done at scale.[14]

Soil carbon accumulation mainly occurs over a period of around 20 years, depending on the site and intervention, after which the soil becomes carbon saturated. Soil carbon sequestration, along with interventions such as agroforestry and increasing hedges, can be immediately implemented, and could be used to fill the gap in carbon removal capacity until engineered techniques like DACCS and enhanced rock weathering are fully operational.

The overall potential scope and timings of different carbon removal options in the UK are shown on pages 12-13. For the engineered solutions, we show estimates of the maximum theoretical potential for carbon removal. But these do not necessarily consider wider sustainability, economic and

“Afforestation, agroforestry, hedgerows and soil carbon sequestration are all climate solutions that can be deployed immediately.”

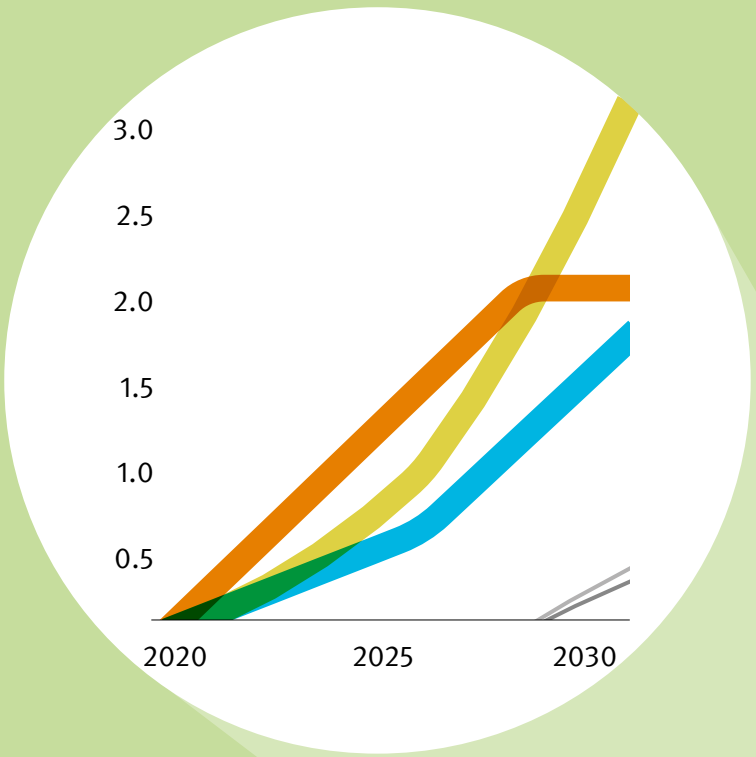
acceptability issues which may all limit deployment and which will need to be fully addressed before technologies can be scaled up. The engineered solutions are also relatively unproven and there is great uncertainty as to how much carbon they will remove (indicated on the right of the graph on pages 12-13).[15]

While engineered carbon removals have the potential to scale up further than afforestation and on-farm measures, before they can be fully deployed, further technical development and careful consideration of their wider sustainability impacts is needed.

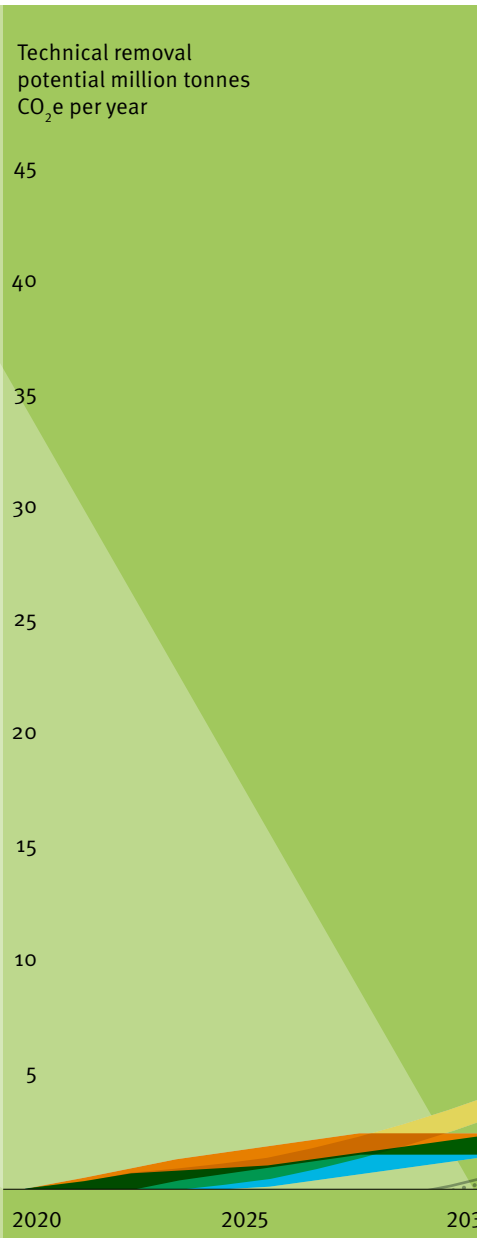
Afforestation, agroforestry, hedgerows and soil carbon sequestration are all climate solutions that can be deployed immediately, while engineered solutions are being developed.

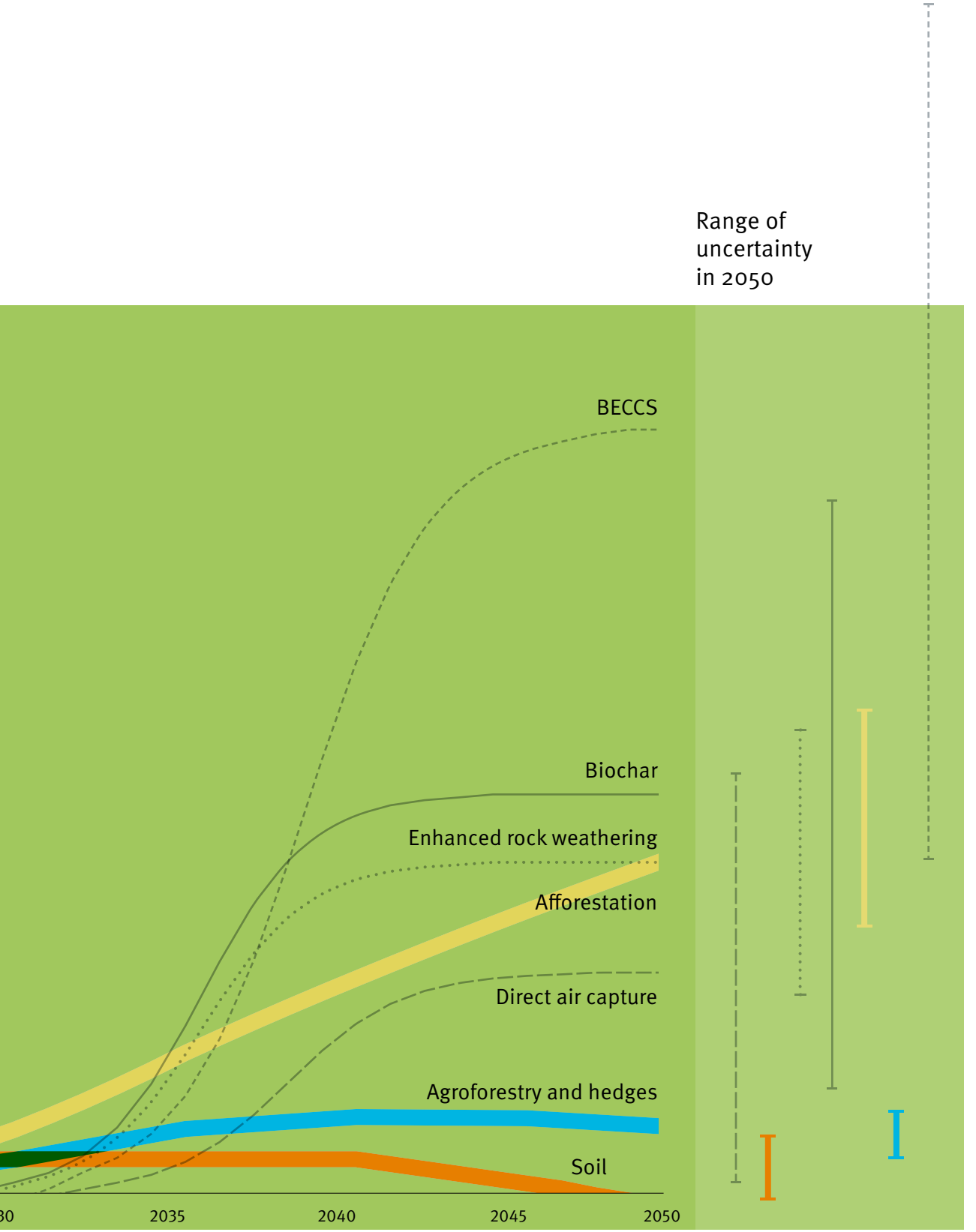
On-farm agri-carbon sequestration can be used in the next decade while engineered solutions are being developed[16]

Trees hedges and soils can start sequestering carbon now



Potential availability and magnitude of carbon removal options




Range of uncertainty in 2050
BECCS
Biochar
Enhanced rock weathering
Afforestation
Direct air capture
Agroforestry and hedges
Soil
30
2035
2040
2045
2050

Voluntary markets for agri-carbon

> “Recently, there have been new opportunities for farmers in the UK to receive carbon finance for carrying out regenerative agricultural practices.”

Voluntary carbon markets have, so far, had a small impact in the UK, although they have grown rapidly in the past few years. Overall, the value of on-farm carbon sequestration could be significant, to the level of hundreds of millions of pounds a year, but it will never replace current levels of public subsidy. The significance of agri-carbon markets will depend on several factors, including carbon prices and demand for the credits. There will always be a need for the government to fund environmental public goods.

The UK voluntary carbon market consists principally of the Woodland Carbon Code and the Peatland Code. But recently there have been new opportunities for farmers in the UK to receive carbon finance for carrying out regenerative agricultural practices, through schemes like Soil Capital, Gentle Farming, and Soil Heroes.[17]

We estimate that only about 600km^2 of land in the UK is being managed under voluntary carbon markets, equivalent to roughly the extent of Greater Manchester, or 0.25 per cent of UK land. This includes planned Woodland Carbon Code and Peatland Code projects, and assumes 147 soil carbon projects at 100 hectares each.[18]

Depending on the sources used, we estimate that maximum on-farm agri-carbon sequestration potential in soils, hedges and on-farm trees could be between 8.9 and 13 million tonnes of CO_2e a year by 2050.[19] However, the lower estimate of our evidence review is far below this, at 1.6 million tonnes CO_2e a year, so there is considerable uncertainty about the potential size of the opportunity.

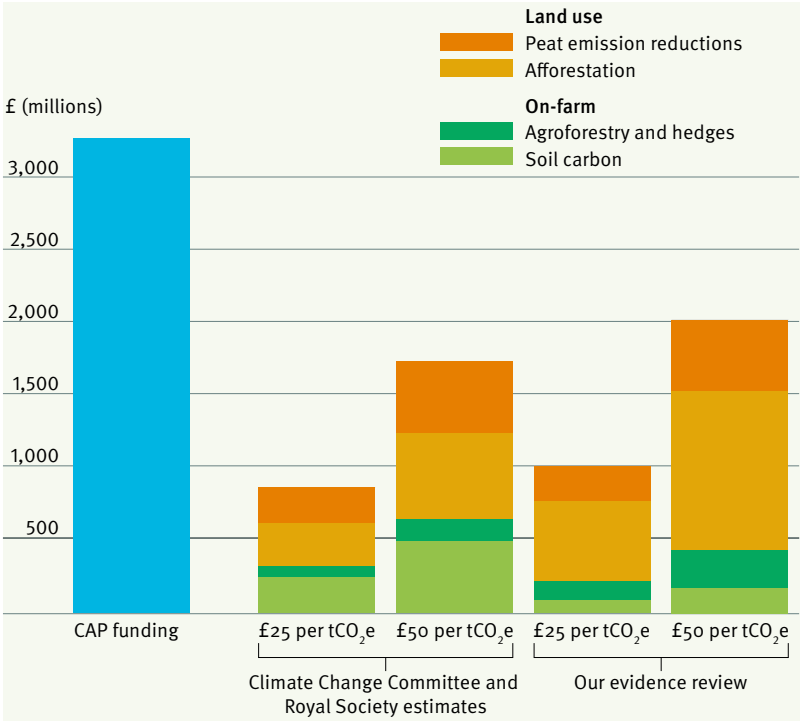
The size of the market may also be limited by the appetite of carbon credit buyers and other funders to invest in agri-carbon sequestration, as opposed to other types of carbon offsetting,

such as from afforestation, peat restoration or international carbon offset credits from schemes like the Gold Standard or Verified Carbon Standard.

Assuming all the available agri-carbon sequestration in our upper estimate of availability could be marketed and sold in voluntary markets at a price of £50 per tonne CO_2e, this would be equal to £650 million, or just under a fifth of the current UK Common Agricultural Policy (CAP) budget .[20] While this could be a significant opportunity, farmers should be realistic about the role voluntary carbon markets could play in their business. This is a high estimate to illustrate that, even in a best case scenario, agri-carbon markets will not replace the need for public funding of environmental public goods on farms.

While these prices may be achieved in voluntary markets in the future, the price in comparative schemes at present is less than half this. A recent government auction for Woodland Carbon Code credits, for instance, had prices at £17-£24 per tonne.[21]

Range of potential annual value of land-based carbon sequestration and emissions reductions by 2050, compared to current CAP payments[22]



Sharing the benefits of agri-carbon markets within the food supply chain

While carbon markets could be a new income stream for farmers, there are also risks. In particular, if farmers sell 'pending issuance units' (PIUs) from agri-carbon interventions upfront, it will be more difficult for them to meet their own climate goals and obligations. Working within the supply chain to reduce emissions and sequester carbon, rather than selling carbon offset credits beyond the sector, can help to avoid this and has other co-benefits.

"Carbon offset credits cannot be used more than once."

Carbon offset credits cannot be used (or 'retired') more than once. If sold, they cannot be counted towards a farm's own decarbonisation efforts or be used by it to make a claim about low carbon or net zero produce. This could be significant if the government or the farm's customers set new requirements around its emissions or the sustainability of its produce. For example, if a food retailer requires a certain emissions intensity from its suppliers, or consumers wish to choose products that make low carbon claims. In this case, a farm which has sequestered carbon but sold it as credits upfront to another business outside the supply chain would not be able to use it to meet the emissions requirements of its supply chain buyers and customers. They would need to make further emissions reductions or sequester more carbon to meet these needs.

This situation could be avoided if the funder of the carbon sequestration activity was a food business in the supply chain seeking to make claims about the emissions of the products it sells, rather than seeking to offset its own direct emissions. Verified carbon sequestration credits could be held and retired by a farmer to make a claim about the net emissions of the farm or transferred to the supply chain company to be verified

and retired by them against their scope 3 emissions (the agricultural emissions embedded in the food products they sell).

By this approach, the benefit of carbon sequestration is shared between the creator of the credit (the farmer) and the funder of the carbon sequestration (the food supply chain business).

The relative benefits of different carbon credit trading options for farmers and supply chain businesses

Carbon credit trading options	Benefit to the farmer (in addition to funding)	Benefit to food and agriculture supply chain business	Co-benefits
Food supply chain businesses work with farmers to finance verified emissions reductions and sequestration to reduce the carbon footprint of the farm and its produce	Low or net zero carbon produce and farm	Low or net zero carbon produce. Scope 3 emissions reduction	Supply chain relationships Buyer has an interest in the resilience of food production
Farmers sell offset credits to the domestic supply chain which retires them against scope 3 emissions (insetting)	Helps to avoid the risk of not being able to meet customers' emissions requirements	Low or net zero carbon produce. Scope 3 emissions offset	Supply chain relationships Buyer has an interest in the resilience of food production
Farmers sell offset credits to domestic supply chain which retires them against scope 1 and 2 emissions (insetting)	None	Lower scope 1 and 2 emissions, but this effectively increases scope 3 emissions	Supply chain relationships Buyer has an interest in the resilience of food production
Farmers sell offset credits domestically outside the supply chain	None	None	None

Why strong standards are important

Carbon removal offsetting schemes can pose risks to the climate if high standards are not followed. This is because there is always a risk of removed carbon being released back into the atmosphere in future, for example if trees die or if management or climatic change causes a release of soil carbon. It is also difficult to measure and verify accurately how much carbon has been removed and stored, including considering all the greenhouse gases involved in the activity. Some carbon removal activities use significant amounts of land, which can have other implications for the environment. Finally, offsetting can lead to increased emissions if there are not robust rules around double claiming and offsets only being used in addition to, not instead of, a company's own emissions reductions.

Permanence

Permanence is an important issue for carbon sequestration schemes, as the future re-release of stored carbon will contribute to climate change. For on-farm agri-carbon schemes, ongoing active management is needed to maintain higher soil carbon and biomass levels, to avoid the reversal of any gains. This will require legal measures to maintain carbon levels. The Peatland Code stipulates a minimum 30 year contract length and international soil carbon standards vary from ten to 100 years.[23]

A pooled buffer of unsold credits is a way of spreading the risk of accidental project failure. This is set at 15 per cent for the Peatland Code and ranges from five to 20 per cent in international soil carbon standards.

“For soil carbon credit schemes, accurate measurement and verification of the amount of carbon sequestered and stored over time is essential.”

For other carbon removal options, the challenges are different. For example, for bioenergy with carbon capture and storage (BECCS), permanence is an engineering problem in CO_2 storage; for enhanced rock weathering and biochar it depends on the physical and chemical properties of the starting material.

Measurement and verification

Management interventions for increasing soil carbon rarely work in all soil conditions. Therefore, local farmer knowledge will be vital for positive outcomes. Maximum carbon gains are likely to be made in areas with low carbon and high clay content. There is also uncertainty about the effect of combining multiple activities in an agri-carbon context, for example combining no till agriculture with cover crops and introducing leys into rotations. For soil carbon credit schemes, accurate measurement and verification of the amount of carbon sequestered and stored over time is essential to the credibility of any project. Reliance on modelled outcomes is not sufficient.

Accounting for all greenhouse gases

Many studies of soil carbon gains only consider carbon storage and do not consider potential changes in N_2O or CH_4 emissions.[24] This is important as, for example, nitrogen addition may be required to create higher potential for carbon sequestration, but this can also lead to increases in N_2O emissions which cause air pollution. Similarly, grazing management can increase soil carbon but not enough to offset the methane emissions from the livestock grazing the land, which is a potent greenhouse gas. For creating carbon credits, it is important to understand the overall greenhouse gas balance of the activity.

Co-benefits and trade-offs

Measures like agroforestry, paludiculture, unfarmed field margins and conversion from arable to grassland or forestry can reduce or alter food production. The potential carbon impact associated with replacing lost domestic production with imports must be considered when assessing the net climate impact of any intervention. On the other hand, measures like

“The UK government has made clear its intention to use voluntary carbon markets to scale up land-based emissions reduction and carbon sequestration.”

enhanced rock weathering, biochar, no till systems and cover crops may all increase yields. Afforestation, BECCS and biochar all require significant land for biomass production.

Avoiding offsets causing more emissions

In a worst case scenario, offsetting schemes can lead to increased emissions, compared to business as usual, if claims are not carefully regulated. Offsetting can cause an increase in the emissions of the carbon credit buyer, either by increasing demand for their products or services, because of the low carbon or carbon neutral claim made, or because the business chooses to buy offsets instead of making their own emissions reductions.

This is a problem if the country where the offset credit was created (the host country) also counts the activity towards its own climate goals. In this case, the host country’s emissions do not change compared to if the offset activity had not taken place, as they would have to do equivalent emissions reductions or carbon sequestration to meet their goals anyway. But the offset credit buyer’s emissions have increased, leading to an overall increase in emissions compared to if the offset had not taken place.[25] This is summarised opposite (scenarios 3-5).

The UK government has made clear its intention to use voluntary carbon markets to scale up land-based emissions reduction and carbon sequestration, such as by tree planting and peatland restoration, and this could be extended to on-farm agri-carbon opportunities, such as soil carbon and hedges.[26] These schemes can only be used to offset emissions that occur in the UK because selling credits internationally would make it harder to meet the legally binding UK net zero target.

In effect, this voluntary market is transferring money from other UK sectors to speed up those land-based activities that need to happen for the UK to reach net zero. So UK voluntary carbon markets serve to provide the finance needed to speed up implementation of carbon sequestration. This is equivalent to scenario 2 opposite. However, there is still a risk that this domestic offsetting could lead to higher emissions, making it more difficult in the long run to reach net zero in the UK (scenarios 3-5 opposite).

Scenarios demonstrating how carbon offsetting could increase emissions

Scenario	Offset is instead of emissions reductions by the buyer	Offset leads to increased demand for buyer's product or service	Offset activity counted towards host country climate goals	Global emissions effect compared to business as usual
1	✗	✗	✗	Less emissions
2	✗	✗	✓	Same emissions
3	✗	✓	✓	Higher emissions
4	✓	✗	✓	Higher emissions
5	✓	✓	✓	Higher emissions

Our recommendations

1. Farmers and food businesses should work together to reduce emissions and store carbon

Food businesses should use on-farm carbon reduction and sequestration measures to reduce their scope 3 (ie supply chain) emissions, instead of using them to offset their scope 1 and 2 (ie their own) emissions.

Companies using agricultural products in their supply chain should support farmers to reduce their own emissions wherever possible. This benefits the company, which can make claims about the sustainability of the agricultural products they are selling, as well as the farmer.

Verified carbon sequestration credits could be used in addition to balance any emissions that cannot be reduced. These could be held and retired by the farmer to make a claim about the net emissions of the farm or transferred to the supply chain company and retired by them to make claims about their scope 3 emissions. This approach ensures the emissions reduction benefit is shared between the farmer and the buyer.

Working with the supply chain to finance verified emissions reductions and carbon sequestration credits retired by the farmer is also more likely to be open to tenant farmers. Their ability to produce and sell carbon credits for offsetting will depend on a range of factors, including the length of their tenancy and the specific arrangements with their landlord around the ownership of carbon assets.

“Improving the evidence base and lowering the costs of measurement and verification will create a stronger market.”

These shared benefits would not be evident if the supply chain business bought carbon credits from the farmer and retired them to offset their scope 1 and 2 emissions, or where credits were sold as offsets outside the food supply chain. In this case, further emissions reductions and sequestration would be necessary for a net zero claim to be made about the farm’s own emissions or the emissions of the product.

2. Strong standards should be developed for agri-carbon sequestration

The quality of agri-carbon sequestration credits needs to be ensured with strong UK standards.

On-farm carbon sequestration presents several challenges if used in offsetting schemes, particularly around additionality, leakage, permanence, and the measuring and verifying of carbon gains. In many cases there will be trade-offs between robustness and practicality. For example, while laboratory analysis of many soil samples is the most reliable and accurate way to measure and verify carbon gains, it is also expensive.

While a range of soil carbon standards exist and are in operation internationally, to date these have been developed and applied outside the UK and are typically not well adapted to UK soils and land holdings.

A UK Farm Soil Carbon Code is currently under development, alongside a Hedgerow Carbon Code. These should increase the confidence of investors, farmers and the public in on-farm carbon sequestration schemes. They should start by setting out standards for actions where there is a strong scientific basis. They should be updated over time as more research is carried out into the efficacy of different interventions and ways to reliably measure and verify them. Improving the evidence base and lowering the costs of measurement and verification will create a stronger market.

3. The government should set strong requirements for buying UK carbon credits

As with the existing Woodland Carbon Code and Peatland Code, agri-carbon offsetting must be used for UK-based emissions only, to avoid reducing capacity to meet net zero. New requirements on those making carbon neutral or net zero claims to reduce their own emissions, before they resort to offsetting, would reduce the risks further.

> "If offsetting leads to more emissions from the credit buyer, those emissions will have to be compensated for in future."

If credits are only sold to compensate for UK-based emissions, the risk of increased emissions because of double claiming is reduced, but not eliminated. All sectors of the UK economy fall under the legally binding net zero target. If offsetting leads to more emissions from the buyer of the credit, or in them avoiding making emissions reductions they would otherwise have made, those emissions will have to be further compensated for in future to achieve the net zero target.

Any new codes developed should be included in the government's emissions reporting guidelines so there is clarity about how credits can be used. It might also be possible to receive carbon finance from companies abroad, provided credits bought are not used to offset the buyer's own emissions but are used to make reputational claims about decarbonisation in farming.

To avoid the risk of offsetting increasing emissions in those sectors using credits, the government should consider new rules for businesses that use carbon offsetting to make carbon neutral or net zero claims, requiring them to cut their own emissions as well. Some existing voluntary schemes, such as the Science Based Targets Initiative and the Carbon Trust's Carbon Neutral certification, already demand that businesses have plans in place to cut emissions as much as possible before using offsets.

Endnotes

1 Committee on Climate Change, 2020, *Land use: policies for a net zero UK*

2 See for example: unfccc.int/climate-action/race-to-zero-campaign; sciencebasedtargets.org/

3 See for example: woodlandcarboncode.org.uk/; www.iucn-uk-peatlandprogramme.org/peatland-code/introduction-peatland-code

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11 S Donofrio et al, December 2020, *State of the voluntary carbon markets 2020: the only constant is change,* pp14-15, Forest Trends

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15 Element Energy and UK Centre for Ecology and Hydrology, October 2021, *Greenhouse gas removal methods and their potential UK deployment. A report published for the Department for Business, Energy and Industrial Strategy,* piii

16 Figures used in this graphic are based on the table, 'Carbon sequestration land use efficiency for different negative emissions technologies', in *The opportunities of agri-carbon markets: policy and practice* (see endnote 23). We assume that deployment of engineered solutions follows an S-curve. For soil, we assume each intervention is implemented on four million hectares of arable land overall, with linear growth up to the end of the agricultural transition in 2028. For agro-forestry and hedges, we assume overall planting on 416,700 hectares and 168,200 hectares respectively happens over the next 15 years, with sequestration following the profile of broadleaf woodland. For afforestation, we assume growth in planting from current rates up to 40,000 hectares a year by 2030 and continuing at 40,000 hectares a year up to 2050, with a sequestration profile typical of broadleaf woodland.

17 For more information, see: soilcapital.com; www.gentle-farming.co.uk; and www.soilheroes.com

18 See existing and planned Woodland Carbon Code projects at www.woodlandcarboncode.org.uk/uk-land-carbon-registry; see existing Peatland Code projects at www.iucn-uk-peatlandprogramme.org/peatland-

code/introduction-peatland-code/peatland-code-projects; assuming 147 soil carbon projects in the Soil Capital scheme at 100 hectares each. This is a very rough estimate as the area of land under soil carbon projects is not known, but this gives an idea of the overall influence that carbon schemes are currently having on UK land.

19 We have two scenarios to illustrate the potential size of agri-carbon sequestration in the UK: 8.9MtCO_2e per year comes from our evidence review (see the table 'Carbon sequestration land use efficiency for different negative emissions technologies' in *The opportunities of agri-carbon markets: policy and practice* (see endnote 23)) and consists of 3.5MtCO_2e per year soil carbon sequestration and 5.4MtCO2e per year in agroforestry and hedges. 13MtCO_2e per year consists of 10MtCO_2e per year in soil carbon sequestration (see: Royal Society, 2017, *Greenhouse gas removal*) and 3MTCO_2e per year in agroforestry and hedges (see the Climate Change Committee's 'balanced net zero pathway').

20 Research by UCL and Trove Research suggests voluntary carbon market prices will need to reach $30-50 per tonne (£23-38) but could reach up to $100 per tonne (£76) for some projects: see trove-research.com/wp-content/uploads/2021/06/Trove-Research-Carbon-Credit-Demand-Supply-and-Prices-1-June-2021.pdf. The regulatory UK ETS was around £50 per tonne for much of 2021, with prices as high as £75 per tonne: see ember-climate.org/data/carbon-price-viewer/. We chose £50 per tonne as a conceivable but high figure that might be reached in voluntary carbon markets, to demonstrate what the maximum realistic value of carbon sequestration for UK farmers and landowners might be.

21 Woodland Carbon Guarantee, see woodlandcarboncode.org.uk/woodland-carbon-guarantee

22 We have two scenarios to illustrate the potential size of agri-carbon and land based sequestration in the UK. One uses figures from our evidence review available in the table 'Carbon sequestration land use efficiency for different negative emissions technologies' in T*he opportunities of agri-carbon markets: policy and practice* (see endnote 23). The other uses afforestation, peatland and agroforestry and hedgerow figures from the Climate Change Committee's 'balanced net zero pathway', and soil carbon sequestration from the Royal Society's 2018 *Greenhouse gas removal* report, available at https://royalsociety.org/-/media/policy/projects/greenhouse-gas-removal/royal-society-greenhouse-gas-removal-report-2018.pdf. The main difference is that the Royal Society soil carbon sequestration figure is considerably larger than our evidence review, while the afforestation figure is larger in our evidence review than the Climate Change Committee's figure.

23 J Elliott, J Ritson, M Reed and O Kennedy-Blundell, January 2022, *The opportunities of agri-carbon markets: policy and practice*, appendix 4, Green Alliance

24 Ibid, section 2.1, 'Assessment of on-farm measures that sequester carbon'

25 H Fearnhough, A Kachi, S Mooldijk and C Warnecke, 2020, *Future role for voluntary carbon markets in the Paris era: final report,* Bundesministerin für Umwelt, Naturschutz, nukleare Sicherheit und Verbraucherschutz, Carbon Mechanisms

26 HM Government, 2018, *A green future: our 25 year plan to improve the environment*, pp48, 146 and 148; HM Government, 2021, *Net zero strategy: build back greener*, p177

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