sandbag
smarter climate policy

Policy Brief

In or Out: What's best for carbon removals and the EU ETS?

DECEMBER 2024

Published in December 2024

Principal Authors:

Adrien Assous, Executive Director, Sandbag

Duncan Woods, Industrial Decarbonisation Analyst, Sandbag

Emma Wikström, Policy Officer, Sandbag

About Sandbag:

We are a **think tank** conducting **data-driven** and **evidence-based** advocacy to improve **EU climate policy**. We combine expertise in **decarbonisation** with **data analysis** to propose policies that drive impactful, cost-effective emissions reductions in the EU and beyond. Through our holistic approach, we make sure our recommendations are not only well-informed and effective but also inclusive, considering economic and geostrategic realities.

Credits:

Image by bluebay2014, Canva Pro Licence

Design by Amélie Trémolières, Communications and Media Officer, Sandbag

Sandbag Climate Campaign ASBL
Mundo-b Matogné. Rue d'Edimbourg 26, Ixelles 1050 Belgium.
EU transparency register no. 277895137794-73

Table of content

Executive summary

As the Commission assesses the potential inclusion of negative emissions in emissions trading, we set out our position: CDR is not ready for inclusion in the ETS, nor is it needed for the market to function until 2040.

CDR technologies which could deliver permanent removals, including Direct Air Carbon Capture and Storage (DACCS) and Capture and Storage of Biogenic CO_2 (BioCCS), still need to mature. These technologies have yet to be demonstrated at scale in the EU and important gaps remain, both in Monitoring, Reporting and Verification (MRV) standards and infrastructure for transport and storage of CO_2. Finally, the sustainability of biomass-dependent CDR needs to be carefully considered; in particular impacts on biodiversity, water use, and land use must be assessed in conjunction with competition for land and demand for biomass from other sectors when assessing the lifecycle emissions of biomass-dependent CDR.

CDR is not desirable for the ETS before 2040

Surplus allowances accumulated in previous years are sufficient to meet demand under the Commission's base policy scenario until 2040. Including carbon removal units in the ETS prematurely could exacerbate oversupply issues that have historically undermined the ETS's efficiency. Attempts to control the supply are unlikely to work in practice, as the flow of issued carbon removal units is hard to estimate before projects are invested in. Keeping the "gross cap" (cap + removals supply) constant would have other negative impacts and would also not work after 2038.

Integrating CDR prematurely would pose a risk to the environment

As long as permanent removal units are not proven to be strictly equivalent to abated CO_2, using them to counterbalance residual emissions in the ETS could lead to spiralling emissions, as investment would likely flow towards the cheapest CDR technologies rather than industrial abatement measures. Using Carbon Contracts for Difference (CCfDs) to balance cost differences between carbon removal units and allowances might exacerbate this issue and further weaken the incentive for industries to reduce their emissions.

Investment (rather than a market) is needed to develop permanent removals

Permanent CDR might be our only chance to achieve long-term climate neutrality and net negative thereafter. Yet, they require investment to overcome the above-mentioned limitations. Market mechanisms alone cannot drive investment in early-stage development or shared infrastructure under uncertain regulatory conditions. Some public funding (i.e. Horizon Europe, Innovation Fund) is already accessible, but a dedicated public investment vehicle is likely needed to fund early-stage projects and infrastructure. Contributions to a public fund could be mandated for ETS polluters, duly mirrored by the Carbon Border Adjustment Mechanism (CBAM) to ensure fair competition.

Uncertainties currently surrounding the development of permanent removals would make inclusion in the EU ETS premature and risky, and could undermine the system's environmental integrity. Nevertheless, exploring and investing in these technologies is essential, as they will be needed to achieve climate neutrality and negative emissions in the long term. Until the existing challenges—such as technological maturity, MRV standards, and infrastructure—are resolved, CDR should remain outside the ETS. With proper investment and development, permanent removals could become viable for a post-2040 market, reducing market instability and aligning with the EU's climate goals.

List of abbreviations

AR6	IPCC's 6th Assessment Report
BECCS	Bioenergy Carbon Capture and Storage
BioCCS	Capture and Storage of Biogenic CO_2
CAP	Common Agricultural Policy
CBAM	Carbon Border Adjustment Mechanism
CCfD	Carbon Contract for Difference
CCS	Carbon Capture and Storage
CDR	Carbon Dioxide Removal
CER	Certified Emission Reduction
CRCF	Carbon Removals and Carbon Farming Regulation
DAC	Direct Air Capture
DACCS	Direct Air Carbon Capture and Storage
EASAC	The European Academies Science Advisory Council
ESABCC	European Scientific Advisory Board on Climate Change
ESR	Effort Sharing Regulation
ETS	Emissions Trading System
EUA	EU Allowance
GGR	Greenhouse Gas Removal
ICMS	Industrial Carbon Management Strategy
ILUC	Indirect Land Use Change
IPCC	Intergovernmental Panel on Climate Change
IPCEI	Important Projects of Common European Interest
LRF	Linear Reduction Factor
LULUCF	Land Use, Land Use Change, and Forestry
MMV	Monitoring, Measurement and Verification
MRV	Monitoring, Reporting and Verification
"QU.A.L.ITY"	Quantification, Additionality, Long-term storage, Sustainability
RED	Renewable Energy Directive
RTS	Removal Trading System
SAF	Sustainable Aviation Fuel
TRL	Technology Readiness Level
VCM	Voluntary Carbon Market

sandbag
smarter climate policy

In or out: what's best for carbon removals and the EU ETS?

1. Expectations and reality

Much has been made of the fact that the cap of the EU Emissions Trading System (ETS) follows **a trajectory that is set to reach virtually zero by 2039.**[1] What will happen to the EU ETS once the cap approaches zero, and how remaining emissions are dealt with after new EU allowances (EUAs) stop being issued, is becoming the subject of growing speculation.

Concurrently, debate is intensifying about **whether, and to what extent, methods of carbon dioxide removal (CDR) should interact with existing emissions abatement policies like the ETS**. The Commission is required[2] to submit a report to the Parliament and the Council by July 2026 on how negative emissions could be accounted for and covered by emissions trading in the EU.

In this policy brief we examine **the future of the EU ETS**, focusing on how to deal with the forthcoming "endgame" and **whether there could be a place for CDR** or, if not, **what an appropriate policy framework for CDR might look like**. We hope this brief will contribute to the European Commission's reflection as it reviews different options for the future of the EU ETS as part of the 2026 revision.

1.1. The EU ETS 'endgame'

The **annual decline of available emission allowances** in the EU ETS is achieved through the application of an annual linear reduction factor (LRF). As set out in the EU ETS Directive, the LRF will be set at 4.4% from 2028, leading to the cap reaching nearly zero in 2039, marking the near end of allowance issuing. The following questions then arise:

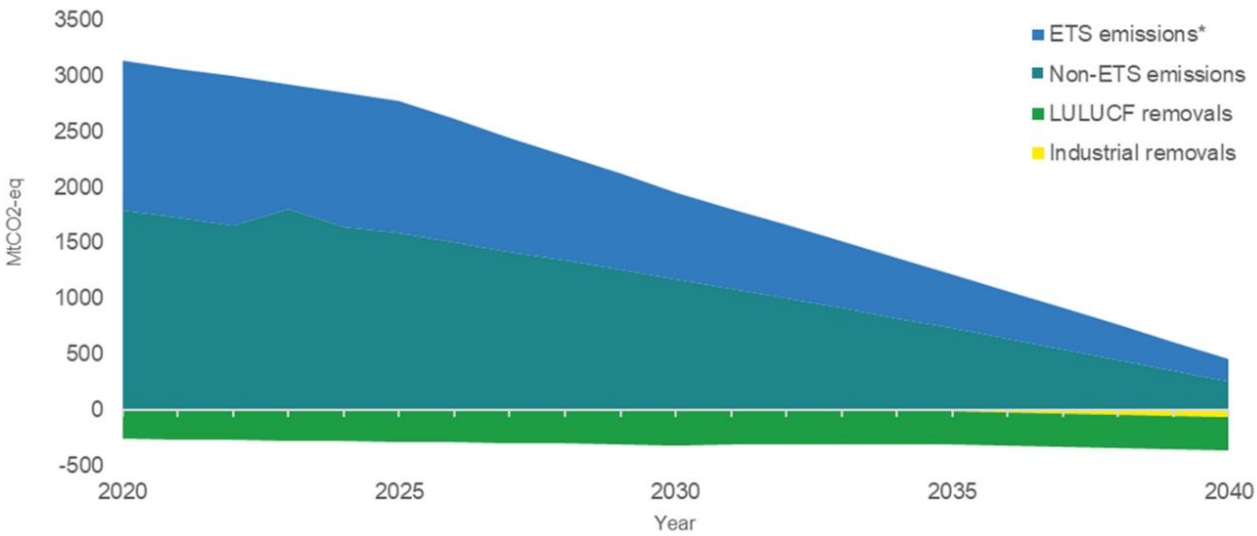
Is this emissions reduction achievable?

Does this line up with expected emissions reductions as set out in the Commission's modelling?

[1] In reality, the total cap will not be zero, as waste incinerators and shipping do not have the same trajectory as the other sectors and some allowances are likely to remain in circulation for compliance purposes.

[2] By Art 30(5)a of Directive (EU) 2023/959 of the European Parliament and of the Council of 10 May 2023 amending Directive 2003/87/EC establishing a system for greenhouse gas emission allowance trading within the Union and Decision (EU) 2015/1814 concerning the establishment and operation of a market stability reserve for the Union greenhouse gas emission trading system (text with EEA relevance) PE/9/2023/REV/1.

In its impact assessment for the 2040 target, the European Commission projected various emission trajectories under different policy scenarios.[3] Scenarios S2 and S3 lead to emission reductions of 88% and 92% in 2040 respectively, as compared to 1990. Given the target finally proposed by the Commission (90%), we have taken the average emission values of those two scenarios in a "central scenario" to represent the projected emissions trajectory for sectors covered and not covered, as well as land use, land use change and forestry (LULUCF) and industrial removals (introduced in more detail in section 1.2.1).



** excluding shipping and municipal waste incineration*

Figure 1: Projected trajectory for EU emissions and removals to 2040, in a 'central' scenario aligning with the proposed 90% net reduction target

Under this scenario, **EU ETS emissions** decrease down to **209m tCO2e** by 2040. **Non-ETS emissions** still reach **615 $MtCO_2e$**, whereas the combination of **LULUCF** and **industrial removals** account for **-363 $MtCO_2$** negative emissions.

These figures highlight the **growing role of carbon removals** in achieving the EU's net-zero goal and raise the question of whether removals should be integrated into the ETS to manage residual emissions, or considered separately under non-ETS or new policy frameworks. Before assessing the merits of their inclusion, it is first important to understand the different types of CDR, the policy framework currently in place and the key issues surrounding their development.

[3] European Commission, *Proposal for a Regulation of the European Parliament and of the Council Establishing a Carbon Removal Certification Framework*, COM(2024) 63 final, February 15, 2024, accessed December 2, 2024, Available here.

1.2. Carbon Dioxide Removal

1.2.1. What is Carbon Dioxide Removal?

The Intergovernmental Panel on Climate Change (IPCC) defines CDR as *"anthropogenic activities that remove CO2 from the atmosphere and store it durably in geological, terrestrial, or ocean reservoirs, or in products".* [4] Methods of CDR vary in many respects, including their maturity, removal process, timescales of carbon storage, storage medium, cost, co-benefits, impacts and risks, and governance requirements.

CDR methods can be crudely divided in two categories (see Table 1). **'Conventional' methods**, primarily consist of land use, land-use change and forestry (LULUCF) activities such as afforestation and reforestation. There are limitations to the scale at which these nature-based removals can be implemented, so **'novel' methods** have recently been gaining attention, with two thirds of all CDR patents filed in the last three years.[5] The table below presents key CDR methods, loosely categorised into these 'conventional' and 'novel' methods.

Table 1: Overview of key CDR methods

Type	Method	Description
'Conventional' CDR methods	**Afforestation**	The process of planting new forests on land that has not previously contained forests.
	Reforestation	The process of planting trees on land that was previously a forest, but has since lost its canopy cover or carbon density.
	Forest management	Stewardship and use of existing forests. To count as CDR, forest management practices must enhance the long-term average carbon stock in the forest system.
	Peatland and coastal wetland restoration	Management measures that aim to restore the original form and function of peatland and wetland habitats to favourable conservation status.
	Soil carbon sequestration	Using land or agricultural practices to increase the storage of carbon in soils.
'Novel' CDR methods	**Direct Air Carbon Capture and Storage (DACCS)**	CO_2 is extracted directly from the air and stored in geological formations deep underground.
	Biogenic Carbon Capture and Storage (BioCCS)	Biogenic CO_2 produced by the oxidation of carbon in plant material (biomass) is captured and transferred for permanent storage. This umbrella term includes Bioenergy Carbon Capture and Storage (BECCS), in which the biomass is specifically burned to produce bioenergy.
	Biochar	A carbon-rich material produced by heating biomass in an oxygen-limited environment. It has the potential to sequester carbon when added to the soil or materials
	Enhanced rock weathering	Mining, crushing, and spreading of silicate rocks, which remove CO_2 from the atmosphere as they weather.

[4] Intergovernmental Panel on Climate Change (IPCC), *Climate Change 2022: Mitigation of Climate Change. Contribution of Working Group III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*, ed. P.R. Shukla et al. (Cambridge: Cambridge University Press, 2022), accessed December 2, 2024, Available here.

[5] Soren Vines, "Three Companies Own 45% of All DAC Patents: A CDR Patent Analysis," *Allied Offsets*, August 5, 2024, accessed December 2, 2024, Available here.

The terms **"permanent"** and **"industrial"** removals are crucial in the context of CDR. **Permanent removals** refer to methods that ensure CO_2 is stored in a stable form for centuries to millennia, minimising the risk of re-release into the atmosphere. These are often associated with methods which rely on geological storage, such as direct air carbon capture and storage (DACCS) or bioenergy with carbon capture and storage (BioCCS), or permanent storage in materials. **Industrial removals** typically describe technology-based approaches (primarily DACCS and BioCCS), which involve engineered systems rather than natural processes. While the terms are sometimes used interchangeably, permanent storage is the key factor when considering the possibility of integration into frameworks like the EU ETS, hence we will usually refer to permanent removals throughout this policy brief.

1.2.2. Origin of the CDR debate

Interest in CDR intensified following publication of the IPCC's 6th Assessment Report (AR6) in 2022[4]. In the report, all modelled scenarios that limit warming to 2°C rely on CDR to **accelerate the pace of emissions reductions, offset residual emissions, and provide the option for net negative CO_2 emissions** in case global temperatures need to be brought back down.

To limit global warming to 1.5°C, AR6 states that some **420-1,100 $GtCO_2$** of CDR would be required by 2100, depending on the pathway followed.[6] At present only around **2 $GtCO_2$/yr** of CDR is taking place globally, almost exclusively through conventional LULUCF methods.

However, the AR6 report also repeatedly warns that **many CDR activities are unproven at scale, and not without risks of harm to humans and nature**. For example, they warn:

> *"afforestation or production of biomass crops for BECCS or biochar, when poorly implemented, can have adverse socio-economic and environmental impacts, including on biodiversity, food and water security, local livelihoods and on the rights of Indigenous Peoples, especially if implemented at large scales and where land tenure is insecure".*[4]

A robust policy framework is therefore essential to ensure that CDR with environmental integrity is supported and deployed at an appropriate rate for the EU to achieve net zero by 2050 and net negative emissions thereafter.

[6] Intergovernmental Panel on Climate Change (IPCC), *Global Warming of 1.5°C: An IPCC Special Report on the Impacts of Global Warming of 1.5°C above Pre-Industrial Levels and Related Global Greenhouse Gas Emission Pathways, in the Context of Strengthening the Global Response to the Threat of Climate Change, Sustainable Development, and Efforts to Eradicate Poverty*, ed. V. Masson-Delmotte et al., Chapter 2: "Mitigation Pathways Compatible with 1.5°C in the Context of Sustainable Development," 2018, accessed December 2, 2024, Available here.

1.2.3. Current EU Policy Framework

The **Carbon Removals and Carbon Farming (CRCF) Regulation,** provisionally approved by the European Parliament in April 2024, was finally green lit by the Council in November.[7] The CRCF represents the most impactful legislation to date in terms of defining what carbon removal in Europe will look like and how it will be certified. The text defines covered carbon removals as *"anthropogenic removal of atmospheric carbon and its durable storage"* and includes a general set of "QU.A.L.ITY" (Quantification, Additionality, Long-term storage, Sustainability) criteria that carbon removal activities must meet. The agreed text extended the scope of the Commission's original proposal, adding soil emission reductions under its scope. Certified units would be differentiated, with four types defined depending on the type of activity (see Table 2).

Table 2: Activities and certified units as specified in the Carbon Removals and Carbon Farming (CRCF) Regulation

Activity	Certified units	Description
Permanent carbon removals	Permanent carbon removal unit	Storage over several centuries, including permanently chemically bound carbon in products.
Carbon storage in products	Carbon storage in product unit	Temporary carbon storage in products beyond minimum period of 35 years, such as buildings.
Carbon farming	Carbon farming sequestration unit	Temporary carbon removals in soils and forests. Activity period of at least 5 years.
	Soil emission reduction unit	Rewetting of peatlands or more efficient use of fertilisers. Activity period of at least 5 years

Following the European Council's adoption of the CRCF, the focus has now shifted to the methodologies for certifying specific CDR activities, which are to be finalised in 2025. In terms of inclusion of CDR in the ETS, the CRCF certainly leaves the door open for this possibility: it is notable that the adopted CRCF text includes many terms from the lexicon of carbon markets – and which are also found in the ETS Directive – such as "operators", "carbon [removal] units", etc. It is fair to assume this is not a simple coincidence.

The **Industrial Carbon Management Strategy** (ICMS), published in February 2024,[8] aimed to promote technical CDR by outlining upcoming initiatives to support the development of BECCS and DACCS and the intention to create a single market for CO_2. The Commission stated it will assess the volumes of CO_2 that need to be removed directly from the atmosphere (industrial carbon removals) to meet the EU's emissions reduction ambitions for 2040 and 2050 and assess overall objectives and policy measures to achieve them. This will include an assessment of how removals and

[7] Council of the European Union, "Council Greenlights EU Certification Framework for Permanent Carbon Removals, Carbon Farming and Carbon Storage in Products," press release, November 19, 2024, accessed December 2, 2024, Available here.

[8] European Commission, *Proposal for a Directive of the European Parliament and of the Council Amending Directive 2003/87/EC to Enhance Cost-effective Emission Reductions and Low-carbon Investments*, COM(2024) 62 final, February 15, 2024, accessed December 2, 2024, Available here.

permanent storage could be accounted for under the EU ETS; the ICMS called on the Commission to *"develop policy options and support mechanisms for industrial carbon removals, including if and how to account for them in the EU ETS"*.

Funding for CDR development in the EU is provided through **Horizon Europe** and the **Innovation Fund**. **Horizon Europe supports research and innovation for emerging CDR technologies, while the Innovation Fund**, financed by EU ETS revenues, focuses on larger-scale deployment projects but at present they are evaluated in the carbon capture and storage (CCS) category and therefore evaluated based on methodologies developed for CCS technologies.

The **LULUCF regulation** sets out rules for accounting of emissions and removals from the LULUCF sector, as well as targets for the sector. The most recent amendment (2023/839) set a target for land-based removals of 310m tCO2e per year by 2030 and keeps the possibility to trade removals between Member States and use surplus annual emission allocations under the Effort Sharing Regulation to reach LULUCF targets. The regulation is due to be reviewed in 2026.

The **Common Agricultural Policy (CAP)**, one of the EU's oldest policies, has undergone several reforms since its inception in 1962. The new CAP for the period 2023-2027 introduced "eco-schemes", which are designed to incentivise sustainable "carbon farming" practices. However, the uptake has been lower than anticipated and the reforms have been described by the European Court of Auditors as *"not matching the EU's ambitions for the climate and the environment"*.[9]

It is also important to consider CDR in the context of the Commission's **2040 climate target**, the proposal for which was published in February 2040.[3] The communication states that, to reach the proposed 90% reduction target in 2040, the level of remaining EU greenhouse gas emissions in 2040 should be less than **850 MtCO_2e** and carbon removals (from the atmosphere through land-based and industrial carbon removals) should reach "up to **400 MtCO_2**". The impact assessment contains some more detailed modelling and shows that annual removals of between **365-391 MtCO_2/y** (S2-S3) will in fact be needed. Taking a central scenario, which aligns with the 90% target, we can deduce that approximately **316m MtCO_2/y** of LULUCF net removals is envisaged by the Commission modelling, which represents a very small increase over the 2030 target of **310 MtCO_2e/y**. Additionally, approximately **33 MtCO_2/y** and **28 MtCO_2/y** of removals is expected to be contributed from BECCS and DACCS respectively.

[9] European Court of Auditors (ECA), *Special Report 20/2024: EU Carbon Markets – Addressing Challenges to Achieve Climate Goals*, September 2024, accessed December 2, 2024, Available here.

1.3. Market or not: What CDR policies need to address

It is important to clarify the objectives of CDR policies, for example whether they should aim for economic efficiency, achieve short-term removals, develop technologies able to achieve long-term removals, meet other environmental objectives or secure a homegrown value-chain in those technologies.

In this report, we will distinguish between **market** and **non-market** approaches. **Market approaches** consist of letting private entities comply with corporate or public policies by buying removal units from sellers. **Non-market approaches** mean that public entities oversee the buying side or provide a different kind of subsidy.

1.3.1. Environmental integrity

Ensuring the environmental integrity of CDR is crucial, especially if counterbalancing residual emissions. If used for this purpose, removals enter into competition with emissions abatement and the net balance between emissions and removals is crucial: the removals must be equivalent to avoided emissions, as otherwise this would incentivise the spiralling up of net emissions.

1.3.1.1. Durability

The extent to which CO_2 can truly be considered 'removed' by CDR is a key issue when considering their potential fungibility[10] with emissions reductions. It is best to think of this using the concept of 'durability', which encompasses the **theoretical duration** of the storage (permanent or temporary) but also the **risk of reversal** of storage.

While nature-based CDR can store carbon for a long time, there is always a risk of reversal through events such as wildfires; risks which are likely to be exacerbated by increasing global heating. This presents several issues such as the need for continual monitoring of these activities (often not an easy task) and liability in case of reversal.

The key question therefore is: *what is an acceptable threshold of durability for considering CDR activities to be acceptable for compensating for 'residual' emissions, for example by integrating into ETS 1[11]?*

Recent research published in Nature modelled a scenario in which net zero CO_2 emissions were achieved globally with 6 $GtCO_2$ per year residual emissions balanced out by CDR.[12] Even a 100-year storage duration for the CO_2 'removed' by CDR, would result in an additional warming of 0.8 °C by 2500 compared to truly permanent storage of the CO_2. This reinforces the importance of ensuring only truly permanent removals (i.e. at least 1000 years) are considered as being fungible with emissions reductions.

[10] Fungibility means one item is replaceable by another identical item or they are mutually interchangeable

[11] ETS 1 is the term used to refer to the original EU ETS which covers emissions from the electricity and heat generation, industrial manufacturing and aviation sectors, and distinguish it from the new ETS 2 covering buildings and road transport

[12] Brunner, Cyril, Zeke Hausfather, and Reto Knutti. "The Future of Carbon Markets: Opportunities and Challenges." *Communications Earth & Environment* 5, no. 1808 (2024): 1–12. Accessed December 2, 2024. Available here.

As shown in section 1.2.3, **the CRCF categorises CDR activity units based on durability**. Only *permanent carbon removal units*, which according to the CRCF *"provide enough certainties on the very long-term duration of several centuries"*, should even be considered for offsetting purposes. Under the CRCF, these permanent removal units could be issued to DACCS, BioCCS and biochar activities. **It is therefore imperative that the CO_2 removal achieved by these activities is truly 'permanent'**.

For **DACCS and BioCCS**, as with CCS more broadly, concerns over the reversal of geological carbon storage must be addressed with careful site selection, robust standards and monitoring. Even in the most well-studied Norwegian offshore geological fields Sleipner and Snøhvit, which have been operating since 1996 and 2008 respectively, *"the security and stability of the two fields have proven difficult to predict"*.[13] Meanwhile a recent study by Öko-Institut stated that, while no carbon storage project has detected CO_2 leakage despite these operational irregularities, *"assuming complete permanence and full containment of CO_2 for a technology that is still in its infancy, and therefore has not yet been proven to be permanent, would be a highly risky proposition"*.[14] While there is broad scientific consensus that well-known reservoir structures that rely on structural and stratigraphic trapping can provide permanent storage, we agree with Öko's conclusion that there is a need for detailed site-specific analysis, comprehensive risk management and the development of comprehensive and robust monitoring, measurement and verification (MMV) to guarantee storage integrity and long-term safety. While the CCS Directive[15] sets a foundational framework for this management of CO_2 storage, this should be kept under review to ensure it is fit-for-purpose. Revision of the Directive to require independent third-party oversight would also help ensure greater transparency and confidence in the permanence of geological storage.

The durability of **biochar** removals is also the subject of scientific debate. Indeed, there is not yet even scientific consensus on the approach to assess the durability of biochar. Some consider an inertinite fraction of biochar which can be considered as truly 'permanent', the amount of which could be determined for each batch through testing.[16] Alternatively others suggest a decay function could be employed, which estimates the remaining amount of biochar after a certain duration based on the expected average temperature for the location of biochar application.[17] Amidst these different approaches, a true scientific consensus on the durability of biochar has yet to be built.

[13] Hauber, Grant. *Norway's Sleipner and Snøhvit CCS: Industry Models or Cautionary Tales?* Institute for Energy Economics and Financial Analysis (IEEFA), 2023. Accessed December 6, 2024. Available here.

[14] Cames, Martin, et al. "Securing the Underground". Öko-Institut, September 2024. Accessed December 3, 2024. Available here.

[15] Directive 2009/31/EC of the European Parliament and of the Council of 23 April 2009 on the geological storage of carbon dioxide and amending Council Directive 85/337/EEC, European Parliament and Council Directives 2000/60/EC, 2001/80/EC, 2004/35/EC, 2006/12/EC, 2008/1/EC and Regulation (EC) No 1013/2006 (Text with EEA relevance) Available here.

[16] Sanei, Hamed, et al. "Geological and Geochemical Characteristics of Coal Deposits." *International Journal of Coal Geology* 281 (January 5, 2024): 104409. Accessed December 3, 2024. Available here.

[17] Woolf, Dominic, et al. "Greenhouse Gas Inventory Model for Biochar Additions to Soil." *Environmental Science & Technology* (2021). Accessed December 3, 2024. Available here.

The issues described above must be resolved to **ensure these 'permanent' removals are truly durable** (i.e. without risk of reversal for at least 1000 years) before they can be deemed fungible with emissions reductions in an ETS.

1.3.1.2. Emissions scope and MRV

Robust definitions of the scope of CDR activities and clear rules for monitoring, reporting and verification (MRV) of their actual net carbon removal benefit, are essential if they are to be considered for counterbalancing any last-remaining residual emissions. Insufficient consideration of these elements could significantly damage the hard-fought integrity of ETS 1.

MRV of permanent removals in the ETS would likely be based on the methodologies currently being established under the **CRCF**, the first-ever government-led regulatory framework to monitor, verify and certify CDR.[18] Draft methodologies for the CRCF were presented by the Commission in October 2024. A detailed assessment of these is beyond the scope of this policy brief. However, there are **concerns that the methodologies do not account for the true net removal "benefit"-** or otherwise- of CDR activities. One notable assessment by Öko-Institut concludes *"the methodologies need considerable improvement to comply with the principles of the CRCF and well-established best practices in carbon crediting"*.[19]

For example, for CDR reliant on biomass (**BioCCS** and **biochar**), upstream emissions (such as fertilising, watering, harvesting and transporting biomass), impacts on land use (see section 1.3.1.3 for further discussion of this) and counterfactuals are not sufficiently considered within the scope of the draft CRCF methodology. These are critical elements to consider and can have a major impact on the net removal benefit. Research has shown how it can take between 30 to 80 years before a BECCS facility actually delivers net negative emissions[20] - which contrasts with the more urgent needs to achieve our climate targets before 2050.

The European Academies Science Advisory Council (EASAC) recommends that to achieve the EU's 2050 targets, *"negative emissions can only be achieved by limiting biomass to that harvested from fast-growing crops on unused or degraded land, or with the limited amounts of forest residues that would otherwise degrade swiftly in situ and are consistent with maintaining biodiversity"*.[21] While some restrictions are in place for the type of biomass that can be used for biochar production, there are none for BioCCS under the draft CRCF methodology. Integration of these activities into the ETS would therefore present a risk of carbon leakage from ETS to non-ETS sectors.

---

[18] To date, most efforts aimed at regulating MRV of CDR have been within the voluntary carbon market (VCM).

[19] Felix Fallasch and Lambert Schneider, "Assessment of the Draft Technical Specifications for Certification under the EU CRCF", Öko-Institut, 2024, accessed December 3, 2024, Available here.

[20] S.V. Hanssen et al., "The Climate Change Mitigation Potential of Bioenergy with Carbon Capture and Storage," *Nature Climate Change* 10 (2020): 1023–1029.S.V.

[21] European Academies Science Advisory Council, "Forest Bioenergy Update: BECCS and Its Role in Integrated Assessment Models", 2022, accessed December 2, 2024. Available here.

Another key issue is **the high electricity consumption of DAC**[22]which could be used more efficiently for emissions reductions, for example by decarbonisation of the electricity grid. The draft CRCF methodology for DACCS and BioCCS presently provides insufficient safeguards against excessive consumption of grid electricity by DAC facilities. Allowing grid average emission factors to be used is likely to underestimate the 'true' emissions of the units, as it does not provide an incentive to cease operation when there is demand for fossil-based electricity. The resultant operation of fossil marginal units would dramatically increase the emissions induced by operating the capture facilities. This increased emissions intensity would not be captured by the calculation of the greenhouse gas emissions associated with these activities so their associated emissions will be underestimated.

These examples highlight the challenges in accounting for the net benefit of permanent removals, and the current lack of robustness of the MRV framework being developed in Europe. Furthermore, even after they have been finalised, **the CRCF methodologies would likely need to be revisited** if permanent carbon removals were integrated into the EU ETS to ensure alignment in scope**.**

The **geographical scope** of removal activities is also worth considering. While the Commission's 2026 review of the potential for CDR inclusion in the ETS is expected to focus only on domestic removals, allowing CDR carried out in non-ETS countries into the ETS has already been proposed by some industry voices.[23] However, integrating foreign-based removal units into the ETS would almost certainly lead to carbon leakage, as some impacts of the removals value chain (e.g. electricity use) would not be properly accounted for.

1.3.1.3. Land use and land availability

The impact of biomass-reliant CDR solutions (especially BioCCS and biochar) on land use must be considered; in particular the risk of increasing competition for agricultural land for food systems and impacting on the natural carbon sink. CDR must be considered in conjunction with demand for biomass created by targets under the Renewable Energy Directive (RED) and increased use for the production of sustainable aviation fuels (SAFs).

Demand for biomass is already significant: in 2021 over **21 Mtoe** of biomass was consumed by EU industry, along with **45.1 Mtoe** in the residential sector, and **33.0 Mtoe** in the energy sector.[24] The Commission's 2040 climate target modelling assumes that the use of biomass will increase by around 30% by 2040 from 2021 levels. According to the environmental risk level indicated by the European Scientific Advisory Board on Climate Change (ESABCC), this

[22] Collins, Leigh. "The Amount of Energy Required by Direct Air Carbon Capture Proves It Is an Exercise in Futility." *Recharge News*, September 14, 2024. Accessed December 3, 2024. Available here.

[23] Ferris, Nick. "Integrating carbon removals credits into EU ETS makes moral and business sense, says BP" *Carbon Pulse*, October 14, 2024. Accessed December 3, 2024. Available here

[24] Council of the European Union. *Addendum to Document ST 14659/2023*. October 23, 2023. Accessed December 3, 2024. Available here.

assumes an overall cap on the gross available energy from biomass at **215 Mtoe** and introduces restrictions on the use of harvestable stemwood, forest residues, and imports of bioenergy.[25]

Emissions of biogenic CO_2 released from large scale energy and industry facilities and biogas production in the EU are estimated to be around **209 $MtCO_2$/y.**[26] The accessible portion of this which could be captured is likely to be significantly lower, when factoring in sustainability aspects (e.g. cost and competition on biomass resources) and other factors (e.g. capture rates, limited operating hours, installation size, transport barriers etc.).

The **PRIMES modelling** carried out by the Commission suggests approximately **33 $MtCO_2$/y** is expected to be contributed from BECCS in 2040.[27] However, the S3 scenario (the only scenario which achieves the 90% reduction target) notably includes additional industrial carbon removals from DACCS as well as use of e-fuels, both of which have "*uncertain deployment prospects*" and "*could be substituted by biomass-based options*", posing risks to LULUCF net removals.[28] Notably in the **POTEnCIA modelling**, where the cap on the amount of sustainable biomass supply for bioenergy is relaxed, up to **80 $MtCO_2$/y** from BECCS is reached.

The mitigation or removals obtained from a high use of bioenergy, including for BioCCS, needs to consider the impact of their use on the LULUCF sector. A prerequisite for the issuance of removal units for BioCCS could be adequate accounting of sectoral leakage effects. The draft CRCF methodology for BioCCS specifies that facilities would not be permitted to claim carbon removal units if biomass consumption rises by more than 25% compared to the period before the activity is implemented. The rationale for this figure is unclear and the CRCF notably does not provide such safeguards for new facilities. To provide more universal safeguards, a more holistic approach to land use is needed. Joined up thinking between policies is required, with accurate accounting of the emissions associated with land use, also considering indirect land use change (ILUC).[29]

[25] European Climate Advisory Board. *Scientific Advice for the Determination of an EU-Wide 2040 Climate Target*. June 15, 2023. Accessed December 3, 2024. Available here.

[26] Rasmussen, Martin Birk, and Johannes Gammelgaard Bøttcher. *The Potential and Risks of Carbon Dioxide Removal Based on Carbon Capture and Storage in the EU*. CONCITO, June 2023. Accessed December 3, 2024. Available here.

[27] Biochar was notably not included in the Commission's modelling.

[28] European Commission. *Commission Staff Working Document: Impact Assessment Accompanying the Document Proposal for a Regulation of the European Parliament and of the Council Establishing the Framework for Achieving Climate Neutrality and Amending Regulation (EU) 2018/1999 (European Climate Law).* SWD(2020) 176 final, September 17, 2020. Accessed December 2, 2024. Available here.

[29] ILUC is market-mediated or policy-driven shifts in land use that cannot be directly attributed to land-use management decisions of individuals or groups.

Pieces of the LULUCF puzzle

Land-based sequestration: EU LULUCF net 'removals' have reduced sharply from an average of -325 MtCO2-eq between 1990 and 2016, to -230 MtCO2-eq in 2021. Changes in forest land are mainly responsible with carbon sequestered by forests decreasing 34% (148 MtCO2-eq) in the last ten years. The LULUCF Directive requires the reporting of emissions and removals and sets Member State-level and EU-wide targets, while the CAP contains some elements intended to incentivise land-based sequestration. However, there is consensus that additional policy is needed to increase carbon storage in forests, peatlands and organic soils. The impacts of climate change on the durability of this storage also needs to be considered.

Agriculture: There is need for reform to achieve more detailed, accurate MRV and reduce emissions from agriculture. Ongoing work mandated by the European Commission on a potential "Agri-ETS" (also nicknamed "ETS3") is currently considering several options, including the establishment of scope 3 emission reduction obligations on downstream food products.

Biofuels: The Renewable Energy Directive imposes specific greenhouse gas savings requirement on a lifecycle basis for biofuel manufacturers receiving state aid, effectively capturing scope 3 on-farm emissions resulting from e.g. crop cultivation. However, this regulation falls short of measuring emissions from the entire sector, as the criteria is based on relative (intensity-based) emissions. It should be complemented to enable the reporting of absolute emissions from biofuel production and imports.

Biomass-based energy: Bioenergy is considered as emissions-free in the EU ETS. However, the combustion of biomass reduces the carbon sink of forests. Scope 3 emissions should therefore be considered in comparison with its alternative role as carbon sink.

Chemicals: The chemicals sector is also expected to drive a significant increase in biomass demand as industries look to replace fossil-based feedstocks in chemical production as they move toward climate neutrality

1.3.2. Technology readiness

Determining what policy framework is appropriate depends on the technological readiness of the activities being incentivised. Market instruments create revenues that are only received once a project is up and running and "delivers" carbon removals. They provide performance-based funding and are appropriate for mature technologies that can rely on the revenues to recover investments. Conversely, **technologies with low readiness typically face a "valley of death" of scarce funding due to high investment risk.** The more appropriate support for these is at investment time, in the form of unconditional grants.

Estimates for the maturity of permanent removals (as defined by the CRCF) are quite variable. However, **BECCS is generally considered the most mature and widely deployed durable CDR technology, with a TRL of 7-9** although scale-up has historically been slow, and planned capacity is modest.[30]

[30] Muhammad Shahbaz, Mohammad Alherbawi, Eric C. Okonkwo, and Tareq Al-Ansari, "Evaluating Negative Emission Technologies in a Circular Carbon Economy: A Holistic Evaluation of Direct Air Capture, Bioenergy Carbon Capture and Storage and Biochar," *Journal of Cleaner Production* 466 (2024): 142800, accessed December 3, 2024, Available here.

A range of DAC technologies exist, with 11 deployed worldwide, six of which are operating at a pilot scale with a TRL of 6 and one operating at commercial scale.[31] Taken together, and including capture and storage of the CO_2, the **TRL of DACCS is around 6-8**.[30] The challenges faced by DACCS project developers include large energy input, high cost, and sorbent requirements.

The Commission's 2040 Impact Assessment recognises *"DAC and BECCS come into play only between 2030 and 2040 allowing the technology to be further developed over the coming years"*. This development is **unlikely to be achieved through a market instrument alone**, especially ETS 1, as these nascent technologies still need to be demonstrated.

1.3.3. Infrastructure limitations

The limits and challenges experienced in industrial CCS (infrastructure bottlenecks, lack of common standards, etc.), will also likely limit the storage potential for permanent CDR which relies on geological storage (DACCS and BioCCS). The more carbon capture takes place across EU industries, the higher the competition will be for CCS and CDR project developers to access the same CO_2 storage reservoirs.

The **Net Zero Industry Act**[32] includes a provision that introduces an obligation for oil and gas producers to develop the EU's CO_2 injection capacity so that it reaches 50 Mt annually by 2030 – but this clause has not yet entered into force, and the obligation would not apply beyond 2030. To realise the 2040 90% emissions reduction target and climate neutrality by 2050, CO_2 storage needs to occur at an even larger scale. In the **Impact Assessment for the 2040 targets**, Scenario S3, which aligns with 90-95% emission reduction compared to 1990, requires almost 200 $MtCO_2$/y additional minimum capacity in 2040 compared to 2030 (243 vs 44 $MtCO_2$/y). Bottlenecks and challenges in accessing storage sites during this decade therefore seem likely.

One of the main issues concerns the high costs involved in the deployment of **CO_2 transport and storage infrastructure**, and the question of who will bear these costs. Transport and storage infrastructure is typically shared between capturing plants, so the real cost of each CDR project includes, on top of the capturing plant cost, a share of the cost of such infrastructure in relation to its use for the project. It is very unlikely that a market instrument would achieve the mutualisation of infrastructure costs, so it would most likely work to secure revenue for the capturing plant (and maybe the last few kilometres of transport), but most of the mutualised costs would involve other types of funding. This is important to consider when market instruments are used with a purpose of economic efficiency, especially if this is done in competition with emission reductions. The costs that will ultimately be financed by the selling price of removal units only cover a relatively small portion of the technology, so CDR market prices will tend to under-estimate the cost of removal.

[31] Lukas Küng et al., "A Roadmap for Achieving Scalable, Safe, and Low-Cost Direct Air Carbon Capture and Storage," *Energy & Environmental Science* 16, no. 10 (2023): 4280-4304, accessed December 3, 2024, Available here.

[32] Regulation (EU) 2024/1735 of the European Parliament and of the Council of 13 June 2024 on establishing a framework of measures for strengthening Europe's net-zero technology manufacturing ecosystem and amending Regulation (EU) 2018/1724 (Text with EEA relevance), Available here

In the short to mid-term, **the EU's CO_2 injection capacity represents a greater limitation than the total storage capacity available**. However, in the long term, storage capacity may become a factor. The theoretical quantity of CO_2 that can be stored permanently in the EU has been estimated to amount to nearly 72 $GtCO_2$, heavily concentrated in northern Europe.[33,34,35,36] By contrast, estimates for the UK and Norway alone show potential of around 78 $GtCO_2$[37] and 80 $GtCO_2$ respectively.[38] While it will likely be possible to access these neighbouring reservoirs, this will of course be subject to negotiation and therefore associated with a degree of uncertainty.

1.3.4. Liquidity

Liquidity measures the ability for buyers and sellers to carry out transactions and it plays a role in achieving economic efficiency. A market functions efficiently if it is "liquid", i.e. if there are buyers and sellers willing to execute transactions at any time. Liquidity can be measured by the difference between asking price and bidding price (the smaller, the more liquid), so that a buyer or an investor in "primary" assets will have confidence in being able to sell on their units (in the "secondary" market) without too much loss related to the transaction itself.

Market instruments have the merit of handling units that can be indefinitely tradable, which encourages the multiplication of transactions, therefore liquidity. However, this is not guaranteed, and some markets are more liquid than others. Conversely, non-market instruments may create some liquidity (through the use of reverse auctions, for example) but this liquidity will always be limited by the absence of a secondary market.

[33] Tumara, D., Uihlein, A., and González, Ignacio Hidalgo, *Shaping the Future CO2 Transport Network for* Europe (Luxembourg: Publications Office of the European Union, 2024), 68, accessed December 3, 2024, Available here

[34] Consoli C. P. and Wildgust, N., "Current Status of Global Storage Resources," *Energy Procedia* 114 (2017): 4623-4628, accessed December 3, 2024, Available here.

[35] Global CCS Institute, *The Global Status of CCS* (Melbourne: Global CCS Institute, 2016), 45, accessed December 3, 2024, Available here.

[36] Vangkilde-Pedersen T., *EU GeoCapacity Assessing European Capacity for Geological Storage of Carbon Dioxide. Final Report: D16 Storage Capacity* (Copenhagen: Geological Survey of Denmark and Greenland, 2009), 30, accessed December 3, 2024, Available here

[37] Pale Blue Dot. *Progressing Development of the UK's Strategic Carbon Dioxide Storage Resource*. 2016. Accessed December 3, 2024. Available here.

[38] Norwegian Petroleum Directorate. *CO2 Storage Atlas: Norwegian North Sea.* 2019. Accessed December 3, 2024. *Available here*.

2. Should CDR be included in the EU ETS?

Proponents of integrating CDR into the ETS argue that it would create additional market liquidity and provide additional flexibility when we reach the last remaining emissions in the system. However, **before integration can be seriously considered, several specific risks and critical factors discussed in Section 1.3 must be addressed**. In particular the quality and permanence of carbon removals must be guaranteed and robust MRV methodologies need to be in place to prevent the creation of perverse incentives leading to spiralling emissions.

Here, we analyse the **expected development of the ETS** and **what could happen if removals were integrated into the ETS** in the coming years.

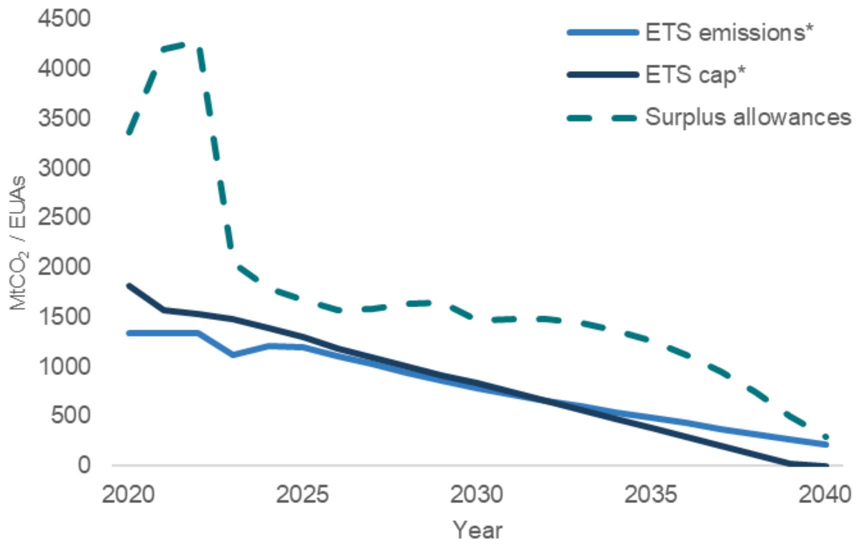
2.1. Supply and demand analysis

The EU ETS sets a constraint through an annual emissions cap but also incorporates mechanisms that allow the banking of unused allowances from previous years and the release of allowances from various reserves. These features are important to consider when assessing the future supply-demand balance in the event of integration of carbon removal units.

2.1.1. Outlook with or without CDR

According to the ETS Directive as it stands, the cap is scheduled to reduce to zero by 2039 for the sectors covered by the scheme except for shipping and municipal waste incineration. In our central scenario, based on the EU's 2040 climate target modelling, emissions from sectors covered by the ETS are projected to go down slightly more slowly, to 209 $MtCO_2e$ in 2040, creating **a deficit of allowances**.

However, **the surplus of allowances inherited from previous years will be more than sufficient to cover the deficit**. We calculated the surplus as the sum of allowances in circulation, those kept aside in the Market Stability Reserve (MSR) and those in the New Entrants Reserve. According to our calculations, there will still be a **surplus of 286m allowances** by 2040 under the central scenario. There is therefore **no need to import CDR to meet the EU ETS cap until 2040**.



** excluding shipping and municipal waste incineration*

Figure 2: EU ETS cap, emissions from covered sectors and surplus allowances (EUAs) under the central (S2-S3) scenario, based on the European Commission's modelling for the 2040 climate target Impact Assessment[3]

It should be noted that the above figures consider net demand from aviation, but not the extra allowances (and emissions) from the shipping and waste incineration sectors. As the addition of this last sector has not yet been proposed, future legislation will be able to ensure that the corresponding supply of allowances will not unbalance the market.

If carbon removal units were imported into the system:

- **If this additional supply is limited to 235m permanent removal units by 2040[39], it would increase the allowance surplus to 511m EUAs**. The impact on allowance prices will be bearish, resulting in lower emissions abatement from covered entities. Given the current lack of evidence that permanent removals will be equivalent to CO_2 abatement, this could lead to higher emissions.

- **If this supply is topped up by additional types of CDR, the surplus could reach much higher levels** and the price of allowances could collapse.

[39] This is an estimate for the total amount of industrial removals (DACCS+BECCS) envisaged by the Commission between 2025 and 2040 in the central scenario, assuming linear deployment between the 2025, 2030, 2035 and 2040 milestones set out in Figure 5 of the 2040 climate target's Impact Assessment's supporting Excel file

2.1.2. Supply control

One proposal to avoid these issues is to have "supply control" tools, whereby **a limit is set on the total number of removal units that can be imported into the ETS** aligned with the EU's climate targets.[40] This would be equivalent to raising the cap, unless an equal number of allowances is removed, as suggested in section 2.1.3.

However, **"supply control" would be hard to set up:**

- If it was done **after crediting** (once the CDR certificate is issued), there would be a **decorrelation between the prices of removal units and EUAs**: only a limited number of already issued removal units would be eligible for the ETS, and this limited fungibility would be priced in CDR prices as a discount from EUA prices. This is what happened in 2008-12 to the Certified Emission Reduction (CER) market, which traded at a growing discount from EUAs as CER supply forecasts got closer to the maximum import amount. This could become highly problematic for CDR project owners if their investments were relatively more costly.

- If it was set **at the crediting stage** (once the project is fully developed), investors in the project would face the risk of their project not yielding any certificate, so they would be **reluctant to invest**.

- If it was set at a **very early stage** (e.g. guaranteeing full eligibility to the project before investment), there would be a risk of either **overshooting the limit** (if this guarantee was given to too many projects) or giving this guarantee to projects that will never reach crediting stage.

2.1.3. Integration while maintaining gross cap

In the UK, the UK ETS Authority is considering reducing the existing cap based on an expected supply of "greenhouse gas removals" (GGRs).[41] In such a system in the EU, for each permanent removal unit entering the EU ETS, one fewer EUA would be released at auction.

This system would **bring the climate benefit of removals on top of the reduction guided by the cap**, so in essence it would increase the ambition of the cap. This would ensure that the extra supply of imported CDRs would not impact the price of EUAs.

However, it would **reduce revenues available to Member States** by the same amount. It would also reduce the amounts available for free allocation for products not covered by the CBAM that require protection against carbon

[40] Concito and Clean Air Task Force, *The Balancing Act: Risks and Benefits of Integrating Permanent Removals into the EU ETS*, December 2024, accessed December 6, 2024, Available here.

[41] UK Emissions Trading Scheme (UK ETS) Authority, *Integrating Greenhouse Gas Removals in the UK Emissions Trading Scheme: A joint consultation of the UK Government, the Scottish Government, the Welsh Government and the Department of Agriculture, Environment and Rural Affairs for Northern Ireland*, 2024, Available here

leakage. Not to mention that this solution **would only work until 2038** if the cap falls down to nearly zero from 2039 onwards.

One options would be to **keep removal units on hold in a reserve for post-2040 compliance**, instead of allowing them into the market before this time. Although this could be possible, there would be limited incentive to invest in activities that will generate carbon removal units until post-2040 rules are known (cap, scope, flexibility mechanisms etc.).

2.1.4. Import of CDR through an intermediary institution

Another suggestion is to import removal units into the EU ETS via an **intermediary procurement institution**. This solution seems to have multiple benefits, thanks to the ability to:

- Control the supply and prevent flooding of the carbon market.
- Invest in ways that can address the limits of market instruments regarding technology readiness and mutualised investment.
- Choose which technologies to invest in, depending on how promising they are.

However, there is also a drawback. The key advantage of using a market is to let its "natural" forces attract private investment where it is most cost-effective, by arbitrage between technologies, and even abatement and offsetting. If procurement is controlled at the onset, this optimisation role is lost and the on-sale of removal units in the market becomes a nice reward but **not a driving force for investment**. In addition, a publicly managed body handling tens of millions of removal units would inevitably suffer from its heavy bureaucratic weight.

It should be noted that such a procurement body would be different from the type suggested in section 2.1.2, whose aim is not to produce large numbers of removal units but to ground-test the technologies and processes.

2.2. Price effects

The carbon market's function is to achieve abatement at the lowest possible cost, and the equilibrium price settles at the marginal cost of abatement. Leaving CDR out of the ETS would make emission reductions in covered sectors the main driver of the carbon price (price of EUAs).

In contrast, letting CDRs into the ETS would let the market "decide" which technologies get developed:

- **If CDR costs are lower than EUA prices**, then **CDRs will be developed instead of (not as well as) industrial abatement**. If the environmental quality of these removals is not exactly equivalent to emission reductions, the climate impact could be disastrous. The case study of New Zealand's ETS is particularly enlightening in demonstrating the risks associated with the inclusion of cheap, nature-based CDR in its ETS.[42] For this reason alone, nature-based CDR shouldn't be integrated.

- **If CDR costs are well above EUA prices**, they will fail to attract investment unless they are otherwise subsidised. **This would miss the initial point** of achieving abatement at the lowest cost, and lead to lower EUA prices and less emissions reduction. It should be noted that a market would discriminate technologies through competition, so that if one CDR technology is reliable (in terms of production numbers) and cheaper than the others, only that one is likely to attract investment.

2.3. Market manipulation risks

Liquidity is sometimes mistaken for abundance of new supply. However, it is not the same thing: a market with no new supply can be liquid, whereas a market with excess supply could be highly illiquid. In the same way, the ETS doesn't need a large supply of tradable units to be a liquid market, as scarce supply should raise prices without hurting liquidity. However, there could be **risks of market manipulation** if the stock of remaining permits reached a level low enough for a few market players to buy them all to create an artificial shortage.

The EU ETS Directive[2] has provisions to fight such manipulations, but they are **neither effective in diagnosis ability nor means of reaction**. Article 29a of the Directive considers abnormal activity if the EUA price has more than trebled in a period of two years, even though such price increase might be justified by high emission levels. The ultimate reaction granted by Article 29a is for the Commission to release a small portion of allowances from the New Entrants Reserve. This could be improved to make sure declining supply doesn't lead to manipulation.

For example, an artificial shortage (otherwise called "cornered" market) can be detected by the shape of its forward curve. The forward curve usually has an upward slope called "contango", meaning that EUAs for delivery next year is more expensive than EUAs for delivery this year, reflecting the interest rates that buyers might earn or save by delaying their purchase between this year and next. In a cornered market, allowance prices for a certain year become more expensive than those for delivery in the following year, causing the backwardation of the forward curve. In reaction to such event, **the Commission could be entitled to "borrow" tradable units** (permanent carbon removal units or EUAs) from the following year.

[42] Organisation for Economic Co-operation and Development, 2024, *OECD Economic Surveys: New Zealand 2024*, OECD Publishing, Paris, Available here.

2.4. Do we need the EU ETS after 2040?

Market manipulation risks before 2040 create the need for the ETS to continue after 2040. Even as emissions from many sectors approach zero, a (smaller) number of allowances will still be issued to cover for the shipping and waste incineration sectors, maintaining the need for robust oversight and market integrity. The continuation of the ETS would help manage residual emissions and prevent manipulation in the carbon market as allowances become increasingly scarce. The scope of ETS 1 could also expand post-2040 to include additional sectors not currently covered or partially covered under ETS 2, such as buildings and road transport. ETS 2, introduced for these sectors in 2027, could also eventually merge or align with the original ETS to create a single carbon pricing framework.

If the other sectors, for which no more allowances will be issued, are to remain in the ETS, they will need to be able to **counterbalance their remaining emissions with permanent carbon removals**. This depends on the maturity and scalability of carbon removals; removal units must be high-quality and verifiable. Integrating removals into the ETS in 2040 could provide a mechanism for these sectors to meet obligations while fostering investment in negative emissions technologies, ensuring the ETS remains relevant as the EU transitions to net-zero emissions.

3. Alternative policies for CDR

From section 2, it appears that integrating removals may be neither necessary nor desirable for the ETS's good functioning until 2040. That is not to say that permanent removals shouldn't be integrated after 2040, nor that CDRs shouldn't be developed at all before that date.

For an economy to reach **net zero**, the logical evolution of permanent removals would be increased deployment while fossil fuels are still used in the economy, followed by a decrease. For the EU to become **net negative**, as is the stated aim, the supply of permanent removals might just need to remain constant after its initial increase. The question is: *what is the best policy regime to develop permanent removals in the next 15 years?*

3.1. Market approaches

3.1.1. Voluntary Carbon Markets

Currently, **one of the primary sources of funding for CDR innovation** are voluntary carbon markets (VCMs). VCMs have seen their collective credibility damaged by high-profile scandals in recent years[43,44] but may be considered a suitable 'proving ground' for CDR activities in the short term if trust can be restored.

The CRCF was introduced with the aim of standardising certification methodologies for removal activities carried out in the EU in VCMs. However, although one of the stated aims of the CRCF was to "guarantee the quality of all carbon removals certified in the EU", **the ability of the CRCF to build trust in the quality of removals carried out in the VCMs remains to be seen**. Even with the CRCF in place, the demand for CDR in VCMs is likely to be weak, unreliable and unpredictable.

Allowing fledgeling methods of permanent removal to develop solely in the VCMs is also **unlikely to create the diverse portfolio of approaches which is desirable**, with cheaper (and likely lower quality) options likely to attract the lion's share of private investment.

3.1.2. Carbon Contracts for Difference

In section 2.1.4 we explained that, if CDR is cheaper than industrial abatement, including carbon removal units in the ETS would simply replace industrial abatement and might provide windfall profit to their developers. Conversely, if CDR is more expensive than industrial abatement, the ETS won't be enough to make those projects happen.

[43] Barbara K. Haya et al., *Quality Assessment of REDD+ Carbon Credit Projects*. (Berkeley: Goldman School of Public Policy, University of California, 2023), 15, accessed December 3, 2024, Available here.

[44] Patrick Greenfield, "Revealed: Forest Carbon Offsets by Biggest Provider 'Worthless'," *The Guardian*, January 18, 2023, accessed December 3, 2024, Available here.

To remedy this latter problem, some stakeholders have suggested[45] that CDR projects could receive, in addition to the price of standard allowances when sold into the market, a top up amount paid by a publicly funded body in the form of **Carbon Contract for Difference (CCfD)**. Granting these contracts through a system of reverse auctions could ensure a profitable business model for CDRs without creating windfall profits. Separate “thematic” auctions could even be applied for projects of different technologies such as BioCCS and DACCS, to make sure that the cost gap between the two technologies doesn’t end up always benefiting the cheaper of the two.

It should be noted that this kind of subsidy is **not an economically efficient way of meeting an emission abatement target**, as the overall cost borne to meet the 2040 cap would be higher than if it were achieved by market forces without this top-up instrument. This kind of subsidy would rather help meeting an objective of technology deployment that achieve a climate target. Such a goal could be justified by the willingness to create a domestic CDR industry value chain – provided that the scheme imposes the use of European technology.

Another weakness of such a system is that, although it addresses offtake uncertainty, it **does not address other obstacles to the development of technologies**, such as low readiness level or lack of transport or storage infrastructure. CCfDs are revenues based on performance (the actual issuance of CDR certificates after removing greenhouse gas from the atmosphere), well suited to mature technologies but less suited to early-stage ones which require unconditional subsidies to face the so-called “valley of death” of financing.

As pointed out by other stakeholders[46], CCfDs also have the inconvenience of **distorting carbon price signals**, as they could create extra inflows of carbon credits in the market, depress prices and ultimately deter emission reduction in sectors covered by the ETS.

3.1.3. Removals Trading System

Some stakeholders have proposed to set up a separate **Removal Trading System (RTS)**[47]. An RTS could put an obligation on covered entities to remove and store specific minimum quantities of carbon. As one possible option, covered entities could be those falling under the ETS (possibly ETS 1 and 2[47]) and fulfil their obligations by implementing carbon removal projects or purchasing removal credits.

There is an important difference between having an RTS applying to entities covered by an ETS, and simply opening that same ETS to removal units. Although the two options could lead to the same net carbon balance, the merit of a separate RTS is its ability to handle two asset types (EUAs and removal units) of different prices. This would prevent

[45] Carbon Gap, "Pathways for Carbon Dioxide Removal in the European Green Deal," *Carbon Gap*, July 3, 2024, accessed December 3, 2024, Available here.

[46] Andrei Marcu et al., *Future of Emissions Trading in the EU: Coverage Analysis* (Brussels: ERCST, 2024), 26, accessed December 3, 2024, Available here

[47] Nils Meyer-Ohlendorf et al., "EU 2040 Climate and Framework: The Role of Carbon Removals," (Berlin: Ecologic Institute, 2023), 15, accessed December 3, 2024, Available here.

removal units from flooding the ETS (at lower costs than EUAs) or having only industrial abatement occurring. It could therefore incentivise CDR even if they cost more to produce than buying EUAs.

However, until there is more visibility on CDR methodologies, technologies and investment, an obligation to source removal units could be extremely challenging for covered entities, even more so than integration with the ETS, where, at least, companies could choose between removal units and EUAs. Setting an RTS (with a “hard” target) would therefore require even more certainty on the maturity and environmental integrity of technologies than an integration of CDR into the EU ETS. Furthermore, if the scope of the RTS is the same as the ETS, an additional burden would be being placed on entities already faced with the cost of reducing their emissions.

The RTS could be an attractive option in the 2030s, provided permanent removals have matured sufficiently in these regards. Compared to integrating removals into an ETS, an RTS would reduce the risk of mitigation deterrence. If implemented, the question would then be whether and how an RTS should merge with the ETS, and over what timescale. Merging would help solve the market manipulation issues highlighted in section 2.3. However, integrating the two systems could be complex and keeping the RTS separate from the ETS could more easily allow us to go beyond net zero. To achieve this, removal obligations would need to be based on criteria other than current emissions. Section 4 discusses further options for changing the criteria for compliance obligations.

3.1.4. A different type of CDR mandate

Alternatively, an **obligation could be imposed on polluters covered by the ETS to purchase a minimum amount of removal units**. For example, in California, a bill was proposed[48] (but ultimately rejected[49]) which would have mandated installations already covered by the California cap-and-trade programme to purchase CDR credits as of 2030. The obligation was proposed to be low initially but would increase over time (from 1% of covered entities’ emissions in 2030 up to 8% in 2035, 35% in 2040 and 100% in 2045).

Such a system is **very similar to an RTS**, except for the absence of secondary trading, so it is likely to result in a **less liquid CDR market**, and would be unlikely to fill the investment gap associated with nascent permanent removals. To plug this gap, the mandate could, instead, be turned into **financial contributions to an investment vehicle** (e.g. proportional to the value of the surrendered allowances), that will invest in permanent removals but is not constrained to the production of a set number of carbon removal credits. To go beyond net zero, this kind of instrument would require the criteria for compliance obligations to change, for the same reasons as mentioned in section 3.1.3.

[48] SB-308 Net zero greenhouse gas emissions goal: carbon dioxide removal: regulations, California Legislative Information, 203-2024, accessed December 12, 2024, Available here.

[49] Michael Toman, Alan Krupnick, Suzanne Russo, Dallas Burtraw, Brandon Holmes, Nicholas Roy, *Developing a Carbon Dioxide Removal Program in California*, October 22, 2024, Available here.

3.1.5. CBAM effects

The EU's **Carbon Border Adjustment Mechanism** (CBAM) will start imposing a tax on emissions embedded in imports that will gradually increase to match the carbon price paid by EU-based producers and prevent carbon leakage. If a new market instrument is created to make those same producers pay extra charges for the purchase of removal units, it may break the balance between carbon charges paid by EU and foreign producers. To prevent this from happening, those extra charges would need to be replicated in CBAM fees as well.

3.2. Non-market instruments

Some stakeholders have argued that markets are unfit for carbon removals[50]. This does not reflect some kind of fundamental incompatibility but rather the current inability of CDR at many levels (undeveloped MRV, technological immaturity, lack of infrastructure, high cost) to deliver their stated goals reliably. Instead, **non-market instruments may be more appropriate** in the near future to encourage investment in these technologies before they reach maturity.

3.2.1. Target-setting

Setting **sector-specific or Member State-level targets**, similar to the Effort Sharing Regulation (ESR), for permanent removals represents a possible top-down approach to driving their development. This would create a signal for market players, accountability, and could be aligned with specific climate targets.

However, determining which sectors or Member States should bear what level of responsibility is likely to be a politically fraught process. Furthermore, **enforcement at national level could be challenging**, as shown by experiences with the LULUCF regulation and ESR (with 19 Member States openly planning to miss their 2030 ESR reduction target[51]). Robust monitoring, penalties, and support mechanisms would need to be put in place if this approach were followed. Alternatively, if the targets were only aspirational, they may not be effective.

3.2.2. Performance-based subsidies

Subsidies consist of **public money transfers to private stakeholders**. For mature technologies, performance-based subsidies such as tax credits or CCfDs may replace or complement commercial revenues. **Public procurement**, where a public entity commits to purchase CDR credits from private developers if/when they are issued, are a kind of subsidy also better suited for mature technologies.

[50] Sabine Frank, "Why Carbon Removals Do Not Belong in Carbon Markets," *Carbon Market Watch*, October 4, 2023, accessed December 3, 2024, Available here.

[51] Transport & Environment, *National climate targets off track: Six years left to course correct and avoid penalties*, June 2024, accessed December 11 2024, Available here.

In the United States, the **Carbon Dioxide Removal Purchase Pilot Prize** is aiming to catalyse the CDR market by allowing companies to compete for funds in return for the delivery of CDR credits to the Department of Energy.[52] Meanwhile the **Voluntary Carbon Dioxide Removal Purchase Challenge** aims to address the non-financial barriers holding back carbon removal credit purchases, including lack of awareness of CDR and lack of transparency in the market.[53]

Similar initiatives could be employed in the EU, for example a **Pilot Procurement Programme** as proposed by Carbon Gap.[54] Such a programme would procure permanent removals on the EU's behalf from suppliers based in the EU, with public funding matched or extended by private investments. This could support a portfolio of CDR methods and procure a range of volumes of removed carbon at different price points.

While there is certainly merit in such a programme, if implemented in the short-term it may face similar challenges to those mentioned in Section 3.2.3 for CCfDs. As the subsidies would be given ex post, they **still require initial investment in the projects**, which might not come easily to projects with high technological or MRV risk and no initial infrastructure. The future use of removal credits (certified under the CRCF) produced by such an instrument must also be carefully considered and clearly communicated to avoid distorting price signals in compliance markets such as the EU ETS, in which removal units might be permitted in the future.

3.2.3. Public investment

Despite having secured offtake conditions through market or non-market instruments, early permanent CDR projects might fail to attract investment for the problems listed above: MRV uncertainty, low technology readiness and insufficient infrastructure. What might most be needed is some kind of venture funding in infrastructure or technology with very uncertain prospects of ever issuing any removal credits. For these, **public investment, rather than procurement, might be needed**.

Public investment is the approach used by EU programmes such as the **Horizon Europe** and the **Innovation Fund**, which already cover some CDR activities, or at Member State level through Important Projects of Common European Interest (IPCEI). However, in these programmes, public money is simply transferred to private owners in the form of grants by authorities which do not retain any ownership, which may turn out as excessive transfers in the case of large infrastructure projects.

[52] U.S. Department of Energy, "Funding Notice: Carbon Dioxide Removal Purchase Pilot Prize," Office of Fossil Energy and Carbon Management, May 30, 2024, accessed December 3, 2024, Available here.

[53] U.S. Department of Energy, "DOE is Helping YOU Buy Good Carbon Dioxide Removal Credits," Office of Fossil Energy and Carbon Management, March 14, 2024, accessed December 3, 2024, Available here.

[54] Francesca Battersby et al., "Introducing an EU Pilot Procurement Programme," *Carbon Gap*, October 24, 2024, accessed December 3, 2024, Available here.

Another system would consist of a **public investment vehicle** making initial investments in projects and taking ownership of their future removal units. For the same reason as with public procurement (see 3.2.1), the removal units produced by such an instrument (if any) could be sold on to the voluntary market or placed in a reserve for **post-2040 compliance** in a future market which includes removals. Although such a fund's revenues are uncertain, a lot of the uncertainty is linked to regulation, which is under the control of the very public authorities that bear the revenue risk.

Investment in infrastructure projects could be open to private investment, despite the uncertain revenue risk, as some revenues might come from carbon capture (rather than removal) projects and/or from the voluntary market. Examples of EU early-stage funding entities include the Innovation Fund, which takes its revenues from the sale of EU ETS allowances. However, as the number of allowances sold each year decreases with the cap, the Innovation Fund's resources will dry out. After that, contributions from schemes such as those described in section 3.1.4 might provide additional resources.

4. Conclusions and Outlook

The development of a robust policy framework is needed to guide the implementation and scaling of permanent CDR. However, a key challenge lies in the fact that methodologies for monitoring, reporting, and verification (MRV) of these activities are still evolving within the context of the CRCF. This creates a **tension between the urgency to establish clear regulations and the need for scientifically sound, standardised MRV protocols** to ensure transparency, accountability, and environmental integrity.

Until the latter is achieved, and the durability of removals properly established, **CDR is not ready for the EU ETS.** The ability of permanent removals to deliver real 'net' removals has yet to be demonstrated at scale, and MRV methodologies are still very incomplete. Furthermore, the transport and storage infrastructure they require is not yet in place. Allowing removal units to enter the ETS would allow project developers to sell removal units to installations covered by the ETS in lieu of emission reductions, as part of offtake contracts. Those contracts are good for mature technologies with relatively predictable output, but this is not the case for CDR.

CDR is also not needed for the EU ETS, at least until 2040. The question of integrating CDRs into the EU ETS was raised as the system's yearly supply of allowances is planned to dry out before 2040. However, we found that the surplus accumulated over previous years, despite the action of the Market Stability Reserve to remove some of it, will be sufficient to meet the market's demand in the Commission's base policy scenario.

The uncertainties surrounding the development of permanent removals make it risky to rely on them for compliance in carbon markets. Conversely, the integration of removal units could perpetuate the oversupply issues that have plagued the ETS for nearly twenty years. Controlling the supply is unlikely to work in practice, as the flow of issued removal units is hard to estimate before projects are invested in. Keeping the "gross cap" (cap + CDR supply) constant would have other negative impacts and would not really be possible after 2038.

Integrating removals into the ETS would also create issues in relation to the price of EU allowances and CDR costs, as investment would likely flow into the single cheapest CDR technology that is cheaper than allowances, if at all, to the detriment of industrial abatement. Evening out cost differences is possible, with the help of Carbon Contracts for Difference, but that could even increase emissions abatement deterrence.

Until the above hurdles are resolved, it is better that removals are not allowed into the EU ETS. A key weakness of market instruments is that, although they address offtake or price uncertainty of individual projects, they would fall short of triggering the initial investment flows needed into common infrastructure or early-stage technology development, let alone in the context of uncertain MRV methodology development. If proven to have environmental integrity at scale, a RTS could be considered to incentivise deployment in the 2030s and **permanent removals could be allowed into the EU ETS around 2040** to reduce market instability and help achieve carbon neutrality goals.

For now, a better solution would consist of **public support at investment stage**. Some technology development is already being aided by Horizon Europe and the Innovation Fund. However, an additional public investment vehicle is likely needed which could make initial investments in projects and take ownership of future permanent carbon removal units. Although such a fund's revenues are uncertain, a lot of the uncertainty is linked to regulation, which is under public authorities' control. Investment in infrastructure projects could be open to private investment, despite the uncertain CDR revenue risk, as some revenues might come from carbon capture (rather than removal) projects.

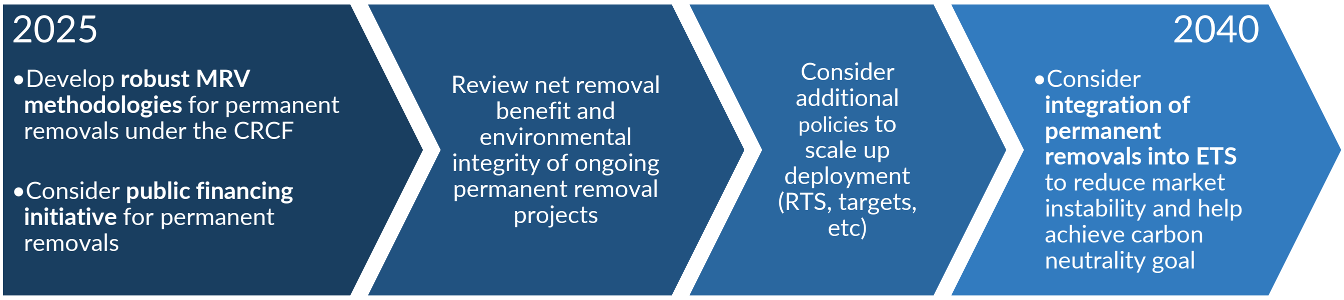


Figure 3. Proposed pathway for development of a policy framework for permanent removals in the EU

Contribution to this public fund could initially come from a **mandate for financial contributions** by polluters covered by ETS obligations and duly mirrored by the CBAM to even out competition. However, as we approach climate neutrality, although it might seem fair to apply a "polluter-pays" principle and force emitters to "over-compensate" their emissions, this approach may result in regressive charges that hit consumers disproportionately.

To go beyond carbon neutrality, money collection should be based on other criteria than direct emissions. Other options include penalties on "imported" emissions from goods consumed in Europe, including revenues from the CBAM, or scope 3 emissions from goods produced in Europe. This latter case could be difficult to implement as monitoring and reporting might be challenging, and would need to be equally replicated in CBAM charges to even out competition. In the long run, as even those net emissions turn negative, other criteria than pollution will be needed to justify contributions to a CDR fund. Wealth or revenues are possibilities which would make climate action closer to a public service.

References

Battersby, Francesca, et al. "Introducing an EU Pilot Procurement Programme." *Carbon Gap*, October 24, 2024. Accessed December 3, 2024. Available here.

Brunner, Cyril, Zeke Hausfather, and Reto Knutti. "The Future of Carbon Markets: Opportunities and Challenges." *Communications Earth & Environment* 5, no. 1808 (2024): 1–12. Accessed December 2, 2024. Available here.

California Legislative Information. *SB-308 Net Zero Greenhouse Gas Emissions Goal: Carbon Dioxide Removal: Regulations.* 203-2024. Accessed December 12, 2024. Available here.

Cames, Martin, et al. *Securing the Underground.* Öko-Institut, September 2024. Accessed December 3, 2024. Available here.

Collins, Leigh. "The Amount of Energy Required by Direct Air Carbon Capture Proves It Is an Exercise in Futility." *Recharge News*, September 14, 2024. Accessed December 3, 2024. Available here.

Concito and Clean Air Task Force. *The Balancing Act: Risks and Benefits of Integrating Permanent Removals into the EU ETS.* December 2024. Accessed December 6, 2024. Available here.

Consoli, C. P., and Wildgust, N.. "Current Status of Global Storage Resources." *Energy Procedia* 114 (2017): 4623–4628. Accessed December 3, 2024. Available here.

Council of the European Union. *Addendum to Document ST 14659/2023.* October 23, 2023. Accessed December 3, 2024. Available here.

Council of the European Union. "Council Greenlights EU Certification Framework for Permanent Carbon Removals, Carbon Farming and Carbon Storage in Products." Press release, November 19, 2024. Accessed December 2, 2024. Available here.

Carbon Gap. "Pathways for Carbon Dioxide Removal in the European Green Deal." *Carbon Gap*, July 3, 2024. Accessed December 3, 2024. Available here.

European Academies Science Advisory Council. *Forest Bioenergy Update: BECCS and Its Role in Integrated Assessment Models.* 2022. Accessed December 2, 2024. Available here.

European Climate Advisory Board. *Scientific Advice for the Determination of an EU-Wide 2040 Climate Target.* June 15, 2023. Accessed December 3, 2024. Available here.

European Commission. *Proposal for a Directive of the European Parliament and of the Council Amending Directive 2003/87/EC to Enhance Cost-Effective Emission Reductions and Low-Carbon Investments.* COM (2024) 62 final, February 15, 2024. Accessed December 2, 2024. Available here.

European Commission. *Proposal for a Regulation of the European Parliament and of the Council Establishing a Carbon Removal Certification Framework.* COM(2024) 63 final, February 15, 2024. Accessed December 2, 2024. Available here.

European Commission. *Commission Staff Working Document: Impact Assessment Accompanying the Document Proposal for a Regulation of the European Parliament and of the Council Establishing the Framework for Achieving Climate Neutrality and Amending Regulation (EU) 2018/1999 (European Climate Law).* SWD(2020) 176 final, September 17, 2020. Accessed December 2, 2024. Available here.

European Court of Auditors (ECA). *Special Report 20/2024: EU Carbon Markets – Addressing Challenges to Achieve Climate Goals.* 2024. Accessed December 2, 2024. Available here.

Fallasch, Felix, and Lambert Schneider. *Assessment of the Draft Technical Specifications for Certification under the EU CRCF.* Öko-Institut, 2024. Accessed December 3, 2024.Available here.

Ferris, Nick. "EU Carbon Market Sees Surge in Offsets Amid Revised Climate Targets." *Carbon Pulse*, October 14, 2024. Accessed December 3, 2024. Available here.

Frank, Sabine. "Why Carbon Removals Do Not Belong in Carbon Markets." *Carbon Market Watch*, October 4, 2023. Accessed December 3, 2024. Available here.

Global CCS Institute. *The Global Status of CCS.* Melbourne: Global CCS Institute, 2016. Accessed December 3, 2024. Available here.

Greenfield, Patrick. "Revealed: Forest Carbon Offsets by Biggest Provider 'Worthless'." *The Guardian*, January 18, 2023. Accessed December 3, 2024. Available here.

Hauber, Grant. *Norway's Sleipner and Snøhvit CCS: Industry Models or Cautionary Tales?* Institute for Energy Economics and Financial Analysis (IEEFA), 2023. Accessed December 6, 2024. Available here.

Hanssen, S.V., et al. "The Climate Change Mitigation Potential of Bioenergy with Carbon Capture and Storage." *Nature Climate Change* 10 (2020): 1023–1029. Available here.

Intergovernmental Panel on Climate Change (IPCC). *Climate Change 2022: Mitigation of Climate Change. Contribution of Working Group III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change.* Edited by P.R. Shukla et al. Cambridge: Cambridge University Press, 2022. Accessed December 2, 2024. Available here.

Intergovernmental Panel on Climate Change (IPCC). *Global Warming of 1.5°C: An IPCC Special Report on the Impacts of Global Warming of 1.5°C above Pre-Industrial Levels and Related Global Greenhouse Gas Emission Pathways, in the Context* *of Strengthening the Global Response to the Threat of Climate Change, Sustainable Development, and Efforts to Eradicate Poverty*. Edited by V. Masson-Delmotte et al. 2018. Accessed December 2, 2024. Available here.

Küng, Lukas, et al. "A Roadmap for Achieving Scalable, Safe, and Low-Cost Direct Air Carbon Capture and Storage." *Energy & Environmental Science* 16, no. 10 (2023): 4280–4304. Accessed December 3, 2024. Available here.

Marcu, Andrei, et al. "Future of Emissions Trading in the EU: Coverage Analysis." *European Roundtable on Climate Change and Sustainable Transition*. Brussels: ERCST, 2024. Accessed December 3, 2024. Available here.

Meyer-Ohlendorf, Nils, et al. *EU 2040 Climate and Framework: The Role of Carbon Removals. Berlin: Ecologic Institute, 2023*. Accessed December 3, 2024. Available here.

Norwegian Petroleum Directorate. *CO2 Storage Atlas: Norwegian North Sea*. 2019. Accessed December 3, 2024. Available here.

Organisation for Economic Co-operation and Development. *OECD Economic Surveys: New Zealand 2024*. OECD Publishing, Paris, 2024. Available here.

Pale Blue Dot. *Progressing Development of the UK's Strategic Carbon Dioxide Storage Resource*. 2016. Accessed December 3, 2024. Available here.

Rasmussen, Martin Birk, and Johannes Gammelgaard Bøttcher. *The Potential and Risks of Carbon Dioxide Removal Based on Carbon Capture and Storage in the EU*. CONCITO, June 2023. Accessed December 3, 2024. Available here.

Sanei, Hamed, et al. "Geological and Geochemical Characteristics of Coal Deposits." *International Journal of Coal Geology 281* (January 5, 2024): 104409. Accessed December 3, 2024. Available here.

Shahbaz, Muhammad, et al. "Evaluating Negative Emission Technologies in a Circular Carbon Economy: A Holistic Evaluation of Direct Air Capture, Bioenergy Carbon Capture and Storage and Biochar." *Journal of Cleaner Production* 466 (2024): 142800. Accessed December 3, 2024. Available here.

Transport & Environment. "National Climate Targets Off Track: Six Years Left to Course Correct and Avoid Penalties." June 2024. Accessed December 11, 2024. Available here.

Tumara, Drazen, Uihlein, Andreas and González, Ignacio Hidalgo. *Shaping the Future CO2 Transport Network for Europe*. Luxembourg: Publications Office of the European Union, 2024. Accessed December 3, 2024. Available here.

UK Emissions Trading Scheme (UK ETS) Authority. *Integrating Greenhouse Gas Removals in the UK Emissions Trading Scheme: A Joint Consultation of the UK Government, the Scottish Government, the Welsh Government, and the Department of Agriculture, Environment and Rural Affairs for Northern Ireland*. 2024. Available here.

U.S. Department of Energy. "Funding Notice: Carbon Dioxide Removal Purchase Pilot Prize." *Office of Fossil Energy and Carbon Management*, May 30, 2024. Accessed December 3, 2024. Available here.

U.S. Department of Energy. "DOE is Helping YOU Buy Good Carbon Dioxide Removal Credits." *Office of Fossil Energy and Carbon Management*, March 14, 2024. Accessed December 3, 2024. Available here.

Vangkilde-Pedersen, Thomas. *EU GeoCapacity: Assessing European Capacity for Geological Storage of Carbon Dioxide. Final Report: D16 Storage Capacity*. Copenhagen: Geological Survey of Denmark and Greenland, 2009. Accessed December 3, 2024. Available here.

Vines, Soren, "Three Companies Own 45% of All DAC Patents: A CDR Patent Analysis." *Allied Offsets*, August 5, 2024. Accessed December 2, 2024. Available here.

Woolf, Dominic, et al. "Greenhouse Gas Inventory Model for Biochar Additions to Soil." *Environmental Science & Technology* (2021). Accessed December 3, 2024. Available here.

sandbag
smarter climate policy