IN-DEPTH

A guide to the Carbon Dioxide Removals (CDR) market

August 2025

CDR is a critical net zero solution for the air transport industry and necessary to address residual CO_2 emissions in 2050. For this nascent market to be able to play that crucial role in our industry's decarbonization, it must make swift progress in terms of growth and development in the coming years. This document aims to give an overview of the CDR market and how the airline industry interacts with it, highlighting key opportunities and challenges as this essential net-zero solution continues to evolve.

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Executive Summary

Carbon dioxide removal (CDR) is crucial for the air transport industry to the target of net zero CO_2 emissions in 2050. CDR, along with market-based measures (MBMs), will help the air transport industry to counterbalance CO_2 emissions that cannot be easily abated through reduction or replacement of existing energy sources. However, CDR technologies also have other utilities, such as capture of CO_2 feedstock for the production of Power-to-Liquid (PtL) sustainable aviation fuel (SAF). However, CDR is still a nascent market, and there are still many questions about how the CDR market really functions and how the air transport industry interacts with it.

This document explores points for clarity in this space, such as how CDR is differentiated from both technical and policy standpoints, the processes by which CDR credits enter the market, and the major markets and policy frameworks concerning CDR. The document also gives a summary of who the key stakeholders are in the CDR industry across the supply chain, which includes not just suppliers and airlines, but also governance bodies, financiers, and marketplaces. Some key data is also presented on the current state of the CDR market, in terms of how many overall purchases and deliveries of CDR credits have been made thus far and it gives reasoning for why market activity in the CDR industry is generally trending higher and also why purchases and deliveries for CDR credits can vary across different types of CDR credits.

The air transport industry has been an active participant in the CDR market, and this document also outlines some of the current initiatives in this space. Finally, the document concludes by highlighting some key opportunities that the air transport industry can take advantage of in the CDR market, as well as challenges going forward, which will require broad support from stakeholders across the supply chain to be addressed.

Abbreviations

IATA: International Air Transport Association

AR: Afforestation & Reforestation

BECCS: Bioenergy with Carbon Capture and Storage

CBC: Coastal Blue Carbon

CCM: Compliance Carbon Market

CDR: Carbon Dioxide Removal

DACCS: Direct Air Carbon Capture and Storage

ERW: Enhanced Rock Weathering

kt: Kilotonne

MBM: Market-Based Measures

mCDR: Marine Carbon Dioxide Removal

Mt: Megatonne

OAE: Ocean Alkalinity Enhancement

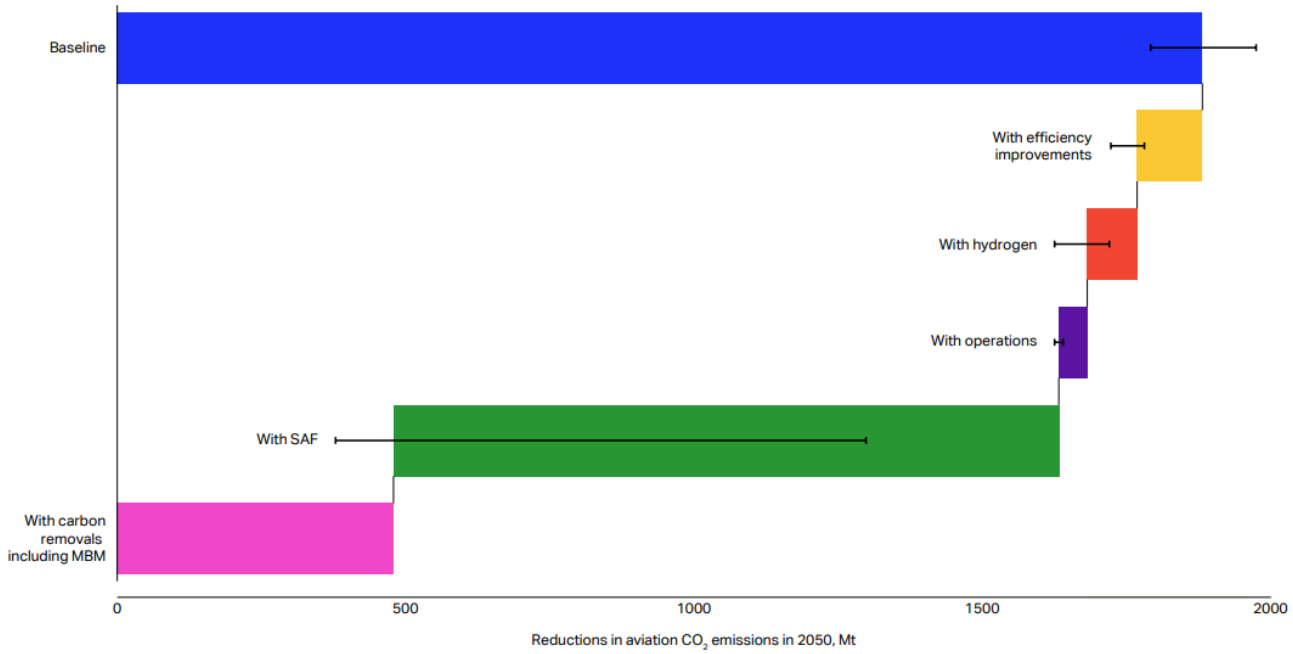
SCS: Soil Carbon Sequestration

VCM: Voluntary Carbon Market

1. INTRODUCTION

At the 77th IATA Annual General Meeting in October 2021, IATA member airlines agreed to commit to net zero carbon emissions by 2050. IATA has published five Net Zero Roadmaps, which outline critical milestones that need to be reached to enable the air transport industry to reach net zero CO_2 by 2050. These roadmaps address actions needed in aircraft technology, energy infrastructure, operations, finance, and policy.[1] The roadmaps detail the emissions reductions stemming from each abatement measure in 2050, to reach the net zero CO_2 emissions goal (Chart 1).

Chart 1: Baseline aviation CO_2 emissions in 2050 ($MtCO_2$) and reductions through the five levers identified[2]



The bars in black represent the forecasted range of emission reductions from each decarbonization lever, depending on the predicted intensity of use of each measure in 2050. Sustainable aviation fuel (SAF) will, in all probability, contribute the most to emissions reductions in the air transport industry in 2050, as much as 62% of total CO_2 emissions. Further necessary but smaller contributions will come from efficiency improvements, hydrogen and electric aircraft, and operational improvements. These measures are commonly known as **in-sector measures**, which help to reduce CO_2 emissions from activities within the value chain of the aircraft operator. However, even after exhausting the emissions-reduction potential of in-sector measures, given the constraints placed on their development and availability, there will still be residual emissions that will need to be addressed.[3] Some of the solutions for addressing residual emissions are the use of market-based measures (MBMs), including high-quality offsets and carbon dioxide removal (CDR) methods and technologies.

[1] **IATA Net Zero Finance and Policy Roadmaps have been updated as of September 2024 (https://www.iata.org/en/pressroom/2024-releases/2024-09-24-01/)**
[2] **Energy and New Fuels Infrastructure Net Zero Roadmap 2 Energy and New Fuels Infrastructure Net Zero Roadmap. (n.d.). Available at: https://www.iata.org/contentassets/8d19e716636a47c184e7221c77563c93/energy-and-new-fuels-infrastructure-net-zero-roadmap.pdf.**
[3] **Riahi et al. (n.d.). SPM 295 3 Mitigation Pathways Compatible with Long-term Goals Coordinating Lead Authors: Lead Authors: Contributing Authors: Review Editors: Chapter Scientists. [online] DOI: https://doi.org/10.1017/9781009157926.005.**

CDR is a set of methods and technologies that capture CO_2 directly from the atmosphere and sequester the CO_2 durably in a suitable carbon sink. There is a wide range of technologies that are available and being developed today (Appendix 1). For the air transport industry to reach net zero CO_2 emissions in 2050, it is important that all decarbonization levers are given high importance, as every measure provides invaluable CO_2 emission reductions or removals. This report describes the current state of the CDR market and identifies challenges and opportunities as this young market needs to build scale.

1.1. What are Carbon Dioxide Removals (CDR)?

CDR refers to technologies, practices, and approaches that remove and durably store CO_2 from the atmosphere. There are three primary principles that must be followed when defining whether a method falls under the definition of CDR:[3]

- CO_2 must be **captured directly from the atmosphere**.
- CO_2 must be **stored durably** after it has been captured, either in reservoirs such as vegetation, soils, geological formations, or the ocean, or in manufactured products. The CO_2 captured and stored may not be reintroduced to the atmosphere.
- CDR only constitutes the removal and storage of CO_2, which occurs through **human intervention**, and not the removal of CO_2 via natural means such as natural forestry regrowth.

1.2. Traditional carbon offsetting and CDR

MBMs are a valuable way of deploying carbon abatement technologies such as CDR. Carbon credits are the most common form of transaction in Market-Based Measures (MBM), and they can be used for both voluntary commitments and regulatory compliance. Carbon credits are defined as tradable rights or certificates linked to activities outside of the organization's value chain that reduce, remove, or avoid emissions to counterbalance the organization's residual emissions. Buyers, including airlines, can purchase these certificates to compensate for their own CO_2 emissions. These certificates are also often referred to as **out-of-sector measures**, since the avoidance, reduction, or removal of CO_2 emissions occurs outside of the value chain of the buyer.[4] Today, a majority of carbon credits in the voluntary and compliance markets are based on the avoidance or reduction of CO_2 emissions, referred to as "traditional carbon offsets" in this report. CDR is also a category of carbon credits, as it is used for counterbalancing CO_2 emissions. However, technical nuances differentiate how traditional offsets and CDR credits help mitigate emissions, leading to differences in characteristics in the market, such as large price differentials.

Traditional carbon offsets operate on the principles of **carbon avoidance and reduction**, rather than removing CO_2 directly from the atmosphere like CDR with the aid of technologies. Some of the most common traditional offsets used in the market today include renewable energy farms, energy efficiency measures in industrial plants, or safeguarding trees from deforestation risk to help prevent emissions being released to the atmosphere that would have occurred in a defined **baseline scenario**.[5] The baseline scenario is one where higher emissions would have taken place if the offsetting project were not put in place. For example, a common type of traditional offset is generated by projects developing renewable energy farms to replace existing fossil energy use for a particular use case. In this case, the baseline scenario would be the CO_2 equivalent emissions generated from the existing use of fossil energy. The carbon credits are therefore generated by the reduction in emissions between the baseline and after the carbon project was implemented, and each credit generated represents one metric tonne of CO_2 reduced or avoided. In contrast, each CDR credit represents one metric tonne of CO_2 that has been

[4] https://climate.mit.edu/explainers/carbon-offsets
[5] https://www.lse.ac.uk/granthaminstitute/explainers/what-are-carbon-offsets/

captured, removed from the atmosphere, and durably stored with a technology or method.[6] This demonstrates that the effectiveness of CDR credits can be technically distinct from traditional carbon offsets.

The key differentiator from traditional offsets is that the use of CDR results in a **net decrease of total anthropogenic CO_2 molecules** in the atmosphere, reducing the warming effect from this lowered remaining concentration of CO_2. Traditional offsets avoid or reduce new CO_2 emissions, preventing a potential addition to anthropogenic CO_2 concentrations in the atmosphere, but do not produce any net removal. CDR can be used to reduce the amount of net CO_2 emissions entering the atmosphere in the short term, even when net zero CO_2 emissions are not met, and used to compensate for legacy emissions in the longer term when an abundant supply of CDR is available. Thus, CDR is essential to achieving an overall net reduction in anthropogenic CO_2 concentrations in the atmosphere, and urgent action is required from stakeholders across the supply chain for a nascent market like CDR to reach its required capacity by 2050.

1.3. Importance of scale-up

According to the Intergovernmental Panel on Climate Change (IPCC), to reach net zero CO_2 emissions across all economic sectors, CDR on the scale of gigatonnes would be required.[7] According to IATA's estimates, about 500 million tonnes (Mt) per year of CDR and other MBM-enabled solutions will be required for the air transport industry alone to reach net zero CO_2 emissions in 2050. The air transport industry will be competing for a significant share with other economic sectors in the limited expected supply of CDR. Fast and immediate action is required to initiate scale-up and ensure the necessary supply is available. However, every CDR method is important to meet a net zero CO_2 emissions goal, with each offering a unique set of strengths in technological readiness level (TRL)[8], cost, and co-benefits, but also risks.[9] The earlier action is taken, the faster new technologies can be improved, key challenges associated with the deployment of first-of-a-kind (FOAK) plants can be resolved, and rapid commercial deployment can take place before 2050.

2. CDR CREDITS

CDR credits are generated as a result of the activities of CDR projects. There are two primary types of carbon markets in which CDR credits are sold: the voluntary carbon market (VCM) and the compliance carbon market (CCM). Today, most CDR credits are sold in the VCM, which is the market where businesses and individuals can purchase credits voluntarily to neutralize their emissions. In the current landscape, there are differences in credits generated between different CDR pathways, both conventional and novel, as well as in terms of how durably the carbon molecules can be stored. This section examines the process of generating CDR credits and their characteristics.

2.1. Generation of CDR credits

Carbon removals generated from projects must go through a series of steps before they can be issued as CDR credits to supply the market (Chart 2). Before CDR credits can be issued, there needs to be an appropriate methodology developed to ensure that the projects that are generating credits meet their intended purpose. Once there is a developed methodology, the project must also undergo validation against the methodology to

[6] Smith et al. (2024). *The State of Carbon Dioxide Removals 2024 - 2nd Edition*. [online] Available at: https://www.stateofcdr.org/.
[7] Riahi, K., Schaeffer, R., Arango, J., Calvin, K., Robertson, S., Sebbit, A., Steinberger, J., Al Khourdajie, A., Chaturvedi, V., Chen, W., Torres Martínez, J., Byers et al. (n.d.). SPM 295 3 Mitigation Pathways Compatible with Long-term Goals Coordinating Lead Authors: Lead Authors: Contributing Authors: Review Editors: Chapter Scientists. [online] DOI: https://doi.org/10.1017/9781009157926.005.
[8] According to TRL is a measurement system used to assess the maturity of a particular technology, with TRL 1 being the lowest level of technological readiness and TRL 9 being the highest, indicating technological maturity
[9] Carbon Dioxide Removal (CDR) Technologies. (n.d.). Available at: https://www.iata.org/globalassets/iata/publications/sustainability/carbon-dioxide-removal-cdr-technologies-facts.pdf [Accessed 4 Jul. 2025].

ensure that the project meets the methodology criteria and verification to ensure that the CDR credits achieve their intended outcomes. Validation and verification are usually conducted by a third-party, also known as a validation and verification body. The following sections outline how these steps are done in practice in more detail.

Methodology development

When offering carbon credits, there must be specified methodologies that ensure the integrity of the market, and this includes methodologies for different types of CDR technologies. Independent registries are often responsible for developing these methodologies, but project developers can also establish their own registries, as part of an independent organization to minimize conflicts of interest. Projects can range from smaller community-level projects to large commercial-scale projects.

Validation of project

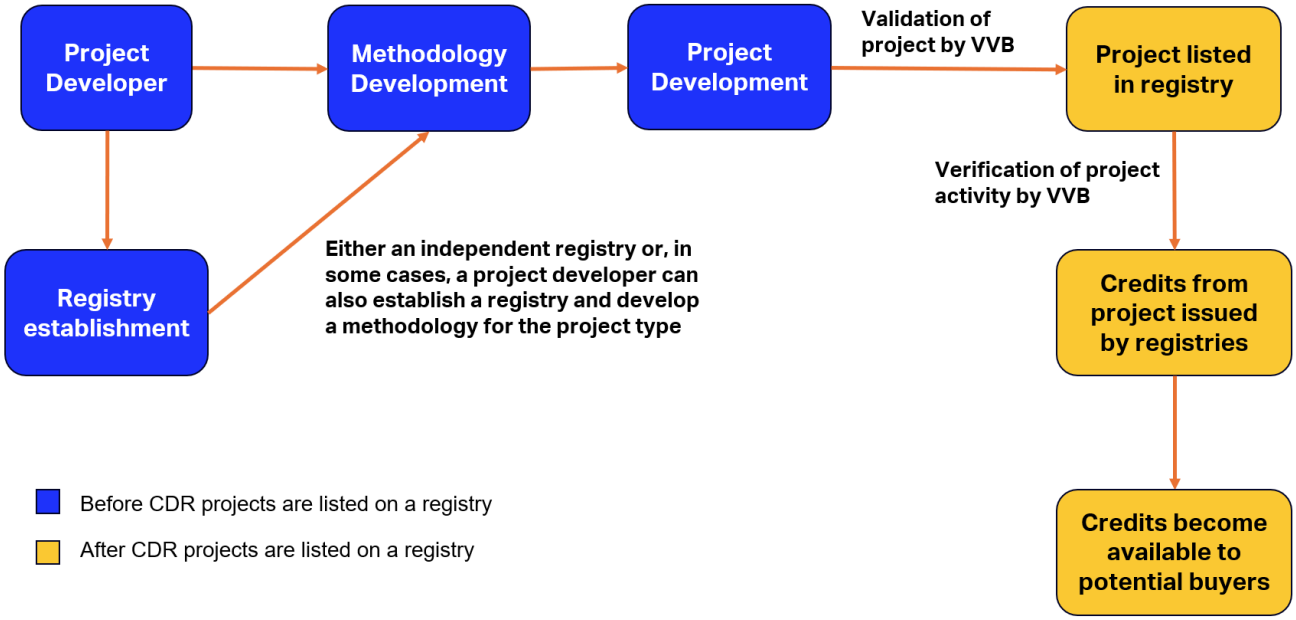
The project developer must file a project registration application with the registry, following the rules and methodologies developed by the registry. Validation then takes place to ensure that it meets the requirements of the relevant methodology. The validation process is usually done by a third-party verification and validation body (VVB), and the registry reviews the application (with documentation usually including a project description document and proof of ownership). Typically, there is a public comment period to provide input on the validation process. The registry makes the final decision regarding approval and, if successful, lists the project in the registry.

Verification of project activity

After the project has been validated, the credits generated must be issued and listed by the registry. Prior to listing and issuing, the CO_2 emissions removal to be performed by the project must undergo verification to ensure that the corresponding CDR credits are achieving their purpose. The project operator usually files a verification report detailing and quantifying the project's CO_2 emissions removal according to the registry's methodology, which is reviewed by a VVB to confirm. The registry reviews the verification report and, once approved, issues the credits, which are listed on the registry. Verification is done periodically, and its frequency depends on how often the project operator files the verification report, which in turn is subject to registry rules. Validation and verification can be done at the same time at the start of the project, but verification cannot occur before the validation.[10]

[10] https://acrcarbon.org/acr-program/acr-standard/

Chart 2: Process of generating CDR credits



2.2. CDR credit characteristics

There are various means of removing and storing CO_2 from the atmosphere that are currently available in the market. Such methods can include high-powered fans to pull ambient CO_2 from the atmosphere, the use of human-induced biomass growth to sequester CO_2 naturally, or enhancing the oceans' capability to act as natural sinks for CO_2 sequestration. Before CDR credits are issued in the market, the CDR project and credits are evaluated on various parameters such as additionality, social and environmental implications, and durability. Among these parameters, the durability of CO_2 storage is one of the most important factors for CDR credits, and it distinguishes CDR from traditional offset credits.[11]

2.2.1. CO_2 storage and durability

Durability, also commonly referred to as permanence, refers to the duration in years that stored carbon can remain sequestered or the risk of storage reversal before that time is up.[3] This metric is one of the most important differentiators between carbon credits generated from different types of CDR technologies. One way to measure durability is to consider the **timescale** for which the emissions will be present in the atmosphere and a similar carbon cycle. For example, fossil CO_2 emissions would require storage in the geosphere and on a geological timescale, since fossil CO_2 emissions would otherwise stay in the atmosphere for the same timescale. The highest durability generally refers to CO_2 stored for 10,000 years or longer, medium durability counts removals lasting for centuries up to millennia, and low durability offers decades up to centuries of storage during which time there is little risk of re-emission into the atmosphere.[3] Different methods and technologies have varying degrees of durability, dependent on the type of carbon storage used (Appendix 1).

CDR credits that are sold in the market are usually computed from the net CO_2 captured and stored during the **life cycle of the project**, and not necessarily the total capture and storage capacity of the project. The formula and methods for calculating net CO_2 captured and stored will vary depending on the technology used and the

[11] **Brunner et al. (2024). Durability of carbon dioxide removal is critical for Paris climate goals.** ***Communications Earth & Environment*****, 5(1). DOI: https://doi.org/10.1038/s43247-024-01808-7.**

registry under which the project is registered. Projects can also run risks of non-permanence of CO_2 storage, whereby CO_2 is re-released into the atmosphere after storage. The registry has the responsibility to ensure that the total issued CDR credits are reflective of the net CO_2 removed over the project life cycle. In the case of significant reversal events, the emitted CO_2 would be deducted from the total output activity of the CDR project, thus decreasing the number of CDR credits that can be issued by the registry. In such cases, the liability for storage reversibility should not fall on the buyer of the credits but on the registry, project owner, or some form of insurer.[12]

2.3. Regulatory frameworks and voluntary actions

CDR can count toward decarbonization targets in different ways in both regulatory frameworks and in the voluntary markets. In the air transport industry's decarbonization, CDR can help meet obligations under the Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA) at the international level, and at the national level, if adopted, obligations under the United Kingdom's Emissions Trading System, for instance, can also be met in this way. Various voluntary schemes also include CDR to meet their decarbonization targets. Increased clarity from policymakers on how CDR will apply to the air transport industry would facilitate more concrete business strategies and plans for CDR credit purchases.

2.3.1. Use of CDR credits in regulatory frameworks

CORSIA

CORSIA is the first global MBM for any sector and offers a harmonized way to compensate for CO_2 emissions from international aviation under the aegis of the International Civil Aviation Organization (ICAO). CORSIA has been applied to Voluntary States for international flights since 1 January 2019, for routes to and from such States, and airlines emitting more than 10,000 tonnes of CO_2 per year are required to report their CO_2 emissions on an annual basis. The aim of CORSIA is to keep international CO_2 emissions below a baseline defined as 85% of 2019 emissions. CDR credits may be included under this voluntary offset standards scheme to meet CORSIA obligations for operators as an out-of-sector abatement measure. [13] As CORSIA is the main tool for decarbonizing the international air transport sector, it is important to ensure that there is a supply of CDR credits in the market to be used as CORSIA Eligible Emissions Units (EEUs) to maximize the overall supply of CORSIA EEUs available to operators. As of July 2025, only two registries have had their CDR methodologies conditionally and fully approved, respectively, for the CORSIA First Phase.[14]At present, both CDRs and traditional offsets are accounted for in the same way in CORSIA, which can be a challenge to the air transport industry (see Section 5.1).

United Kingdom

A proposal to include CDR in the UK Emissions Trading System (ETS) was put forward in 2024, which would help CDR credits become accessible to the UK CCM to bolster market activity for CDR credits from participating sectors. The traditional ETS system makes polluters pay for their emissions using a cap-and-trade system to limit the number of greenhouse gases that can be emitted by an operator, and trading allowances are necessary if the operators exceed the emissions set by the cap. The proposal explores different cap policy options for optimal integration of CDR credits in the UK emissions allowances cap.[15]

European Union

[12] https://isometric.com/writing-articles/raising-the-bar-for-carbon-credits
[13] IATA, (n.d.). *Offsetting CO2 Emissions with CORSIA*. [online] Available at: https://www.iata.org/en/programs/sustainability/corsia/.
[14] https://www.icao.int/environmental-protection/CORSIA/Pages/TAB.aspx
[15] https://www.gov.uk/government/consultations/integrating-greenhouse-gas-removals-in-the-uk-emissions-trading-scheme

The EU ETS has not yet included CDR in its system, but the European Commission is expected to report on how permanent negative emissions could be accounted for and covered by emissions trading by 2026 with a similar intention to that of the UK by introducing CDR credits into the EU CCM to encourage greater market activity.[16] The EU Carbon Removal and Carbon Farming Certification (CRCF), which has now been adopted as a Regulation, is a certification framework to identify high-quality CDR activities within the EU, for use in the voluntary markets, but it is not yet clear what implications it could have on the EU ETS. The EU Land-Use, Land-Use Change and Forestry (LULUCF) Regulation already accounts for LULUCF-based removals. LULUCF removals are typically CDR methods with lower durability, but they are beneficial in that they add to the diversity of removals available in the EU CCM.

Japan

Japan has its own ETS, known as the GX-ETS, launched in 2023 by Japan's Ministry of Economy, Trade, and Industry. It is currently in its first phase of implementation, with a voluntary baseline-and-crediting system from 2023 to March 2026. This could transition into a compliance-based ETS from 2026, though no such decision has been made by the Japanese government at this moment.[17] The GX-ETS accepts CDR credits from three carbon removal methods, including Direct Air Capture and Storage (DACCS), Bioenergy and Carbon Capture and Storage (BECCS), and coastal blue carbon (CBC). CDR projects and methodologies accredited by international compliance standards, such as CORSIA and certain voluntary standards, are recognized under this scheme.[17]

2.3.2. Voluntary actions

In the air transport sector today, most CDR credits are purchased voluntarily. Voluntary purchases are a key component of the emerging CDR market and help drive future policy frameworks. These purchases are often driven by organizations' internal climate commitments, including those of airlines. Such voluntary purchases can also be motivated by efforts to meet voluntary net zero targets under the Science-Based Targets Initiative (SBTi), which recently released a new draft of its Corporate Net Zero Standard as of June 2025, exploring the use of CDR credits in near-term actions that companies can take toward a long-term neutralization goal.[18] Voluntary commitments are important to showcase demand for new markets like CDR, which is important for the sector to grow. To further grow voluntary purchases, there needs to be greater policy signals to make the CDR market an attractive one to invest in.

3. DYNAMICS OF THE CDR MARKET

3.1. Purchasing mechanisms

CDR credits can be purchased through three main mechanisms:[19]

1) **Spot purchases:** CDR credits can be bought and sold with immediate payment and can be retired immediately after delivery. Delivery refers to when credits reach the purchaser, and retirement removes the claimed credit from the electronic registry to avoid double counting. This type of purchase is only possible for CDR credits that reflect removal activity that has already taken place.

2) **Pre-purchases:** A price for a set amount of CDR credits is agreed upfront, and the credits are delivered and retired at agreed-upon future dates, corresponding to removals that will take place in the future. Settlement is required in part or in full prior to the CO_2 sequestration date.

[16] https://tracker.carbongap.org/policy/eu-emissions-trading-system/
[17] https://www.cdr.fyi/blog/japans-gx-league-and-carbon-removal-in-gx-ets
[18] https://sciencebasedtargets.org/news/sbti-launches-draft-corporate-net-zero-standard-v2-for-consultation
[19] https://lune.co/blog/different-ways-to-buy-carbon-explained-from-spot-purchases-to-multi-year-agreements

3) **Offtake agreements:** A price is agreed upfront for a specific vintage year[20], or on an ongoing annual basis for the purchase of CDR credits, which are delivered and retired as per the agreement. Settlement occurs once the CO_2 has been sequestered.

Buyers can trade their credits once they have been issued and delivered to them, but before they are retired.

3.2. Purchasing avenues

There are several avenues by which buyers can purchase CDR credits. Some of the avenues are:

- **Directly from a project developer via a registry** or through a **reseller**.
- **Marketplaces/retailers** that list a wide range of CDR credits available in the market for greater visibility to buyers who wish to skip the additional time required to approach individual suppliers of CDR credits.
- **Portfolio managers** act as neutral, independent advisors, guiding buyers through the complexities of the carbon dioxide removal (CDR) market. They offer tailored advice on which CDR credits to purchase and offer portfolios of CDR credits from different technologies to suit the clients' needs based on a range of criteria. Portfolio managers are responsible for ensuring CDR credits follow due diligence and negotiate with the suppliers on behalf of their clients. They typically take a small commissioning fee for their services.

3.3. Stakeholders supporting the CDR industry

Numerous stakeholders play important roles in the market without transacting directly, such as those that support the CDR market in other aspects, including educational resources, collaborative engagements, and financial support. Stakeholders are often not limited to a specific function but perform many different roles in support of the CDR industry.

3.3.1. Supporting CDR credit integrity

Measuring, Reporting, and Verification (MRV)

Entities developing CDR MRV standards are important to quantify accurately the climate benefits of using a CDR technology, to hold CDR project developers accountable for their removal claims, and to be used for the allocation of direct policy support to specific technologies. Registries are also key to creating trust and credibility in the market, guaranteeing buyers that CDR credits are representative of their climate impact and preventing over-crediting. This is especially important for the development of novel CDR projects such as DACCS, which is only starting to be deployed commercially, and where the effective allocation of policy support is key to growing the market.[21]

Carbon Credit Rating Agencies

Protocols and methodologies vary across registries, complicating the task of comparing and assessing projects. To address this gap in the market, carbon credit rating agencies have emerged, whose primary role is to assess the probability that one carbon credit truly represents one tonne of CO_2 reduced or removed. Rating agencies typically assess both traditional offsetting projects as well as CDR projects. The ratings are assessed on a

[20] **The year in which the carbon credit is issued**
[21] https://www.wri.org/technical-perspectives/measurement-reporting-verification-of-carbon-removal

project-by-project basis and according to a scoring system. The higher the score or grade given to a project, the greater the likelihood that the project will deliver one tonne of CO_2 reduced or removed per credit issued.[22]

Governance Standards for Carbon Markets

Often in the VCM, the registries issuing the credits are also accredited by an internationally recognized governance body, whose role is to define high-quality carbon credits in the market. These independent governance bodies have guidelines that aim to set a global standard for the quality of carbon credits and maintain the integrity of the VCM. Typically, these guidelines aim to ensure that the CDR project is delivering its intended environmental impact, and the CDR credits themselves are appropriately assessed and quantified against verification criteria such as additionality and permanence. The main purpose of such organizations is to create harmonized integrity standards across the VCM and increase transparency of the market.[23] In the CCM, similarly, the governing body can be a State or international organization, such as ICAO with CORSIA, providing these CDR credits to the market.

3.3.2. Other supporting stakeholders

Financing

Financing is one of the critical factors to scaling up the CDR industry and ensuring that there is an abundant and robust supply of CDR credits available in the market. There are various organizations that assist in financing CDR in all aspects, from R&D to project development. Investments for CDR have come from private equity, public or quasi-public entities, corporations, angels or private venture capital, and the financial sector like banks, among others.[6] Some initiatives include tax credits and public grants from governments to fund CDR projects, demand coalitions to facilitate bulk purchases of CDR credits and philanthropy from non-governmental organizations (NGOs). All financing participants and initiatives are important to support a new and emerging sector like CDR, particularly for CDR projects still in the R&D stage or early stages of commercialization.

Education

Bridging the many gaps in knowledge on CDR among the general public and even participating stakeholders helps to foster informed decisions and opinions on the topic. Think tanks, non-profit institutions, and universities are among the important stakeholders in this space, which provide educational material about different aspects of CDR, including market analysis, policy analysis, and techno-economic assessments. Universities are also key to advancing research on new CDR technologies and improving existing ones.

4. STATUS OF THE CDR MARKET

CDR is a nascent, but evidently growing market, illustrated by market data available on purchases and deliveries of credits. The size and trends of the CDR market can broadly be divided into two categories: conventional and novel CDR. Conventional CDR refers mainly to well-established technologies and methods with mass commercial deployment, like afforestation & reforestation (AR) or soil carbon sequestration (SCS). These methods have had steady demand and low prices. However, novel CDR refers to emerging and still developing technologies that have not yet reached mass commercial deployment like DACCS, BECCS, and Enhanced Rock Weathering (ERW).[6] The novel CDR technologies are typically much more expensive than conventional CDR and have lower quantities of credits available for immediate purchase. The following sections examine the current

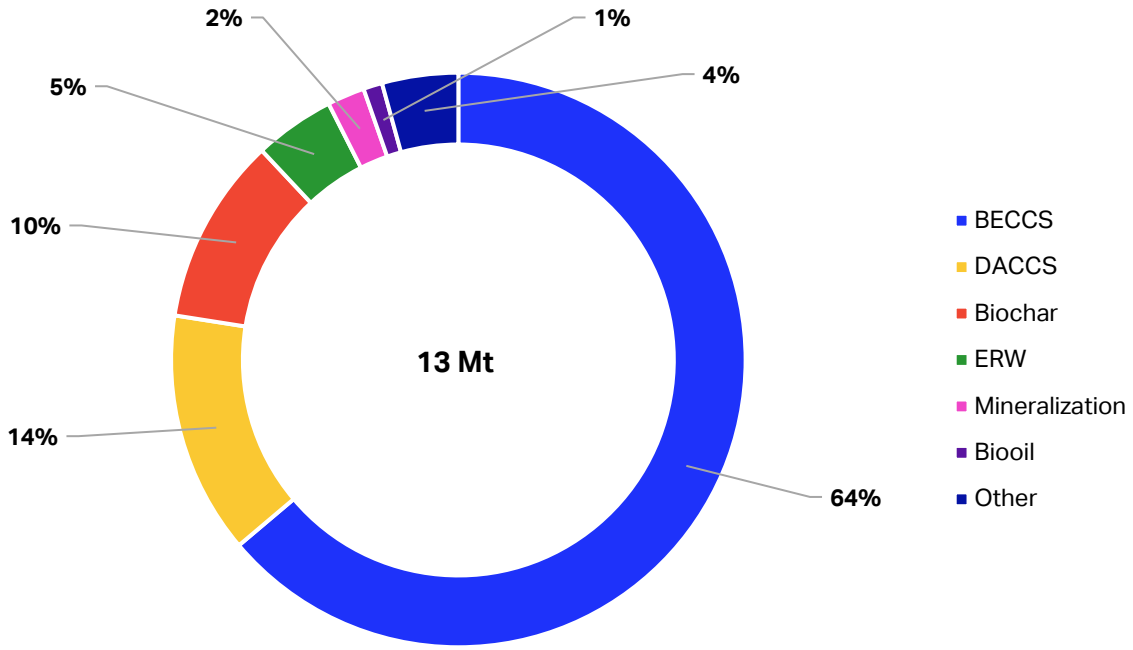
[22] **Carbon Market Watch. (2023).** ***Rating the raters: Assessing the quality of carbon credit rating agencies - Carbon Market Watch.*** **[online] Available at: https://carbonmarketwatch.org/publications/rating-the-raters-assessing-carbon-credit-rating-agencies/ [Accessed 3 Mar. 2025].**
[23] https://www.whitecase.com/insight-alert/integrity-voluntary-carbon-market-draft-core-carbon-principles

market situation of mostly novel CDR technologies, as these technologies have the most room to grow in the future and consequently require more support from different stakeholders.

4.1. Demand and supply

The current demand for CDR credits mainly comes from the voluntary carbon market (VCM) and facilitates a much greater demand for conventional CDR credits (20 Mt in 2023) compared to novel CDR (5 Mt in 2023).[6] However, the demand for novel CDR is growing: Total purchases of novel CDR credits grew from only 4.6 Mt of CO_2 in 2023 to nearly 8 Mt of CO_2 purchased in 2024.[24] BECCS has the largest percentage of purchases made, and while mostly a result of a single purchase, it is also a result of having relatively cheap credits and a supply of different types of credits available in the market. Purchases of DACCS credits are mainly indicative of offtake and pre-purchase agreements. Biochar purchases mainly reflect spot purchases of credits, as biochar has an abundant supply of issued credits after sequestration has taken place (Chart 3).[25]

Chart 3: Purchases of novel CDR credits (tonnes of CO_2) by technology since 2023 and 2024[25, 26, 27, 28, 29]



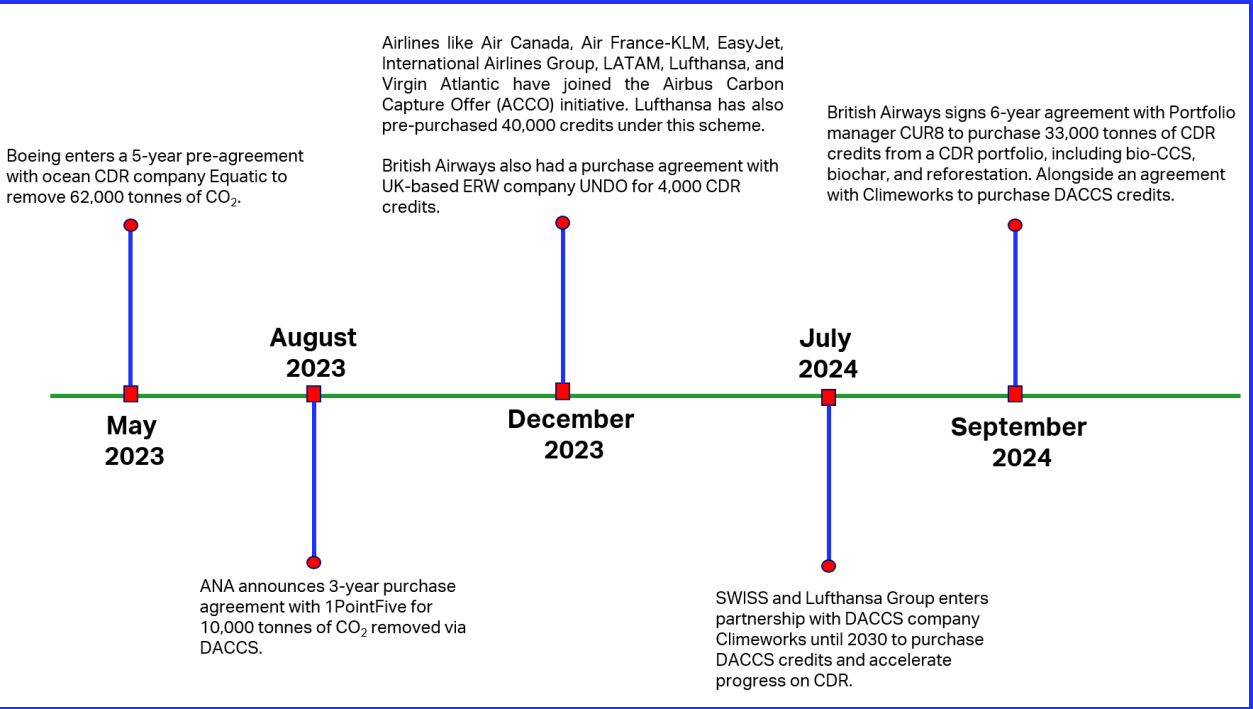
Source: CDR.fyi

[24] https://www.cdr.fyi/blog/2024-year-in-review
[25] https://www.cdr.fyi/blog/2023-year-in-review
[26] https://www.cdr.fyi/blog/2024-q1-durable-cdr-market-update-blossoming-biochar
[27] https://www.cdr.fyi/blog/2024-q2-durable-cdr-market-update-microsoft-market-maker
[28] https://www.cdr.fyi/blog/2024-q3-durable-cdr-market-update-time-to-build-the-base
[29] https://www.cdr.fyi/leaderboards

Box 1: Air transport sector market initiatives in CDR

The air transport sector has active participants in CDR purchasing and other various market initiatives (Chart 4). Most initiatives have come about since 2023, highlighting that this is still an emerging market and is in line with the general trend in the market, showing that purchases for CDR credits, especially novel CDR, have risen tremendously since 2022. While most initiatives have seen an investment in novel CDR technologies, primarily DACCS, in recent months, there is commitment shown to adopting investment in a portfolio of different technologies and methods, like afforestation and biochar.

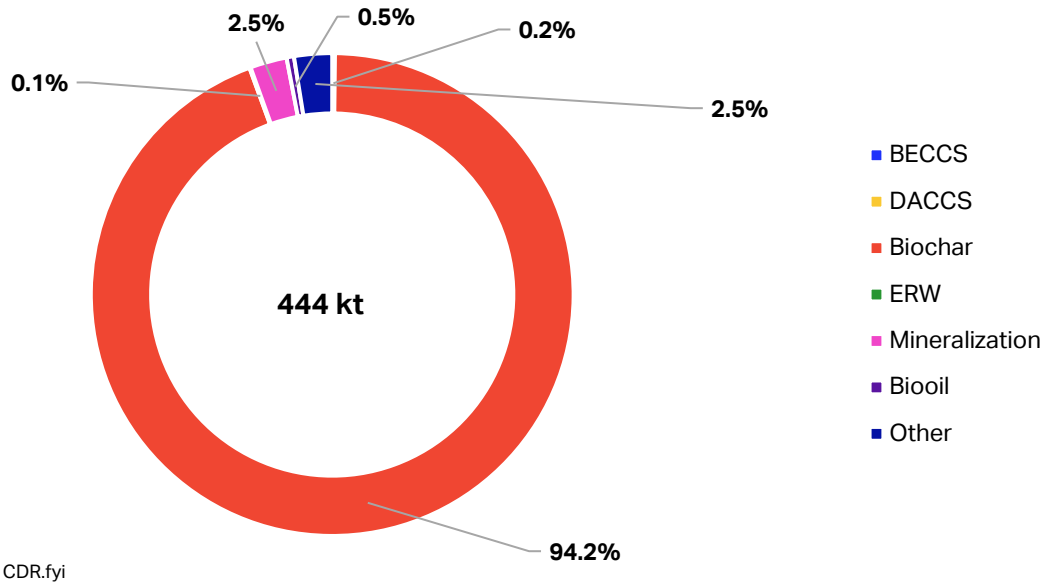
Chart 4: Timeline of the aviation sector's initiatives with the CDR industry



4.2. Deliveries

The delivery of CDR credits reflects the supply side of the market, indicating how many CDR credits are reaching the purchaser. Deliveries for most novel CDR technologies are lower in the short-term, as most of them are not generating credits today, and purchases are mostly done through a long-term pre-purchase or offtake agreements. However, this trend has also been shifting as more projects come online and are able to supply credits, given that the deliveries of novel CDR credits in 2024 totaled 319 kilotonnes (kt), an increase from 145 kt delivered in 2023.[25] Currently, the vast majority of novel CDR credits delivered come from biochar, which has the greatest spot market supply (Chart 5).

Chart 5: Deliveries of novel CDR credits (tonnes of CO_2) by technology in 2023 and 2024[24, 25, 26, 27, 28, 29]



Source: CDR.fyi

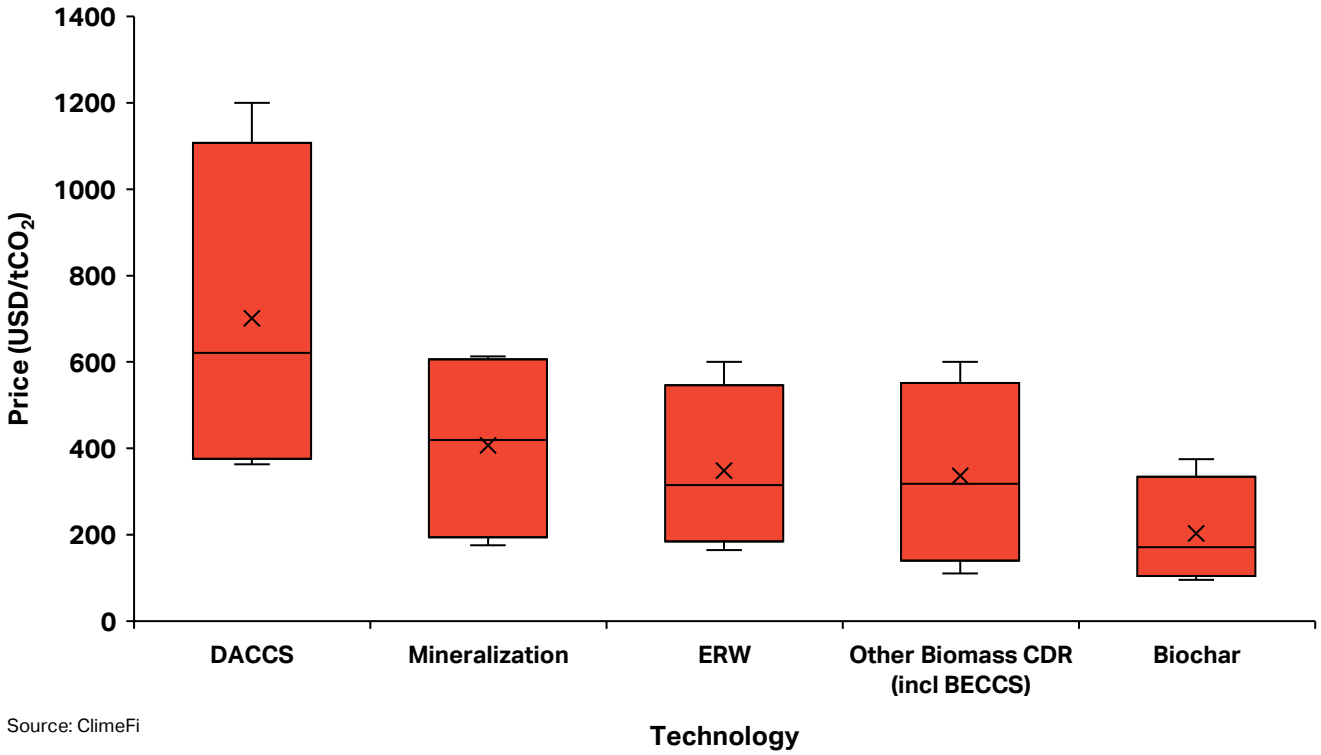
Biochar accounts for the overwhelming majority of CDR credits being delivered since 2023, mainly because it is a more technologically advanced CDR method that has been commercially established for a longer time. Thus, suppliers can deliver to the customer in the same year, enabling more spot purchases to be made. For other types of credits, like BECCS and DACCS, the delivery volumes for the same year are low, even though purchase volumes are high. This reflects that these are less commercially established technologies, and suppliers are unlikely to deliver those high credit volumes shortly after purchase. Since 2023, only 301 tonnes of DACCS credits and no tonnes of BECCS credits have been delivered.[30] This trend is also supported by purchases made by the aviation sector, which constitute many pre-purchases and offtake agreements for novel technologies like DACCS. Many buyers of these technologies will purchase CDR credits, with an expected delivery date beyond the current year, even as far away as 2035.[25] The delivery of these credits is expected to increase in the coming years as projects start to come online.

4.3. Pricing trends

Generally, the prices of CDR credits are higher than traditional offset credits. Conventional CDR methods have lower market prices than novel CDR methods, but even these were priced between USD12 and 16 per tonne of CO_2 removed on average in 2023, which is still approximately three times more than the price of a traditional offset credit in the same time period in the VCM.[6] As of 2024, the price for novel CDR credits ranged between USD95 and 1200 per tonne of CO_2 removed in the VCM, including both spot and offtake prices, indicating a much higher price than for traditional offset credits (Chart 6).[31]

[30] https://lune.co/blog/whats-the-difference-between-expost-exante-and-prepurchase-carbon-credits
[31] https://resources.climefi.com/v/2024-review-dghy3w/bc63e619-f817-4126-89a0-d63ef0d108ec

Chart 6: Estimated range of price per tonne of CO_2 removed by CDR novel technology in 2024[31]



Source: ClimeFi

Some of the credits from these technologies, e.g., biochar, are more indicative of the current spot prices, due to the high availability of these credits in the current spot market, as discussed in the previous section. Prices of other types of credits, such as DACCS, are more indicative of prices paid for offtake agreements and pre-purchasing credits, as there is a scarce supply of these credits in the current spot market, while prices of ocean-based CDR technologies are more difficult to determine due to their lack of commercialization and low technological readiness level (TRL). The average selling price of ocean CDR credits is approximated to be about USD803 per tonne of CO_2 removed, based on market data[31], mostly in the form of pre-purchases or offtakes. Therefore, the data shows that novel CDR technologies generally have higher prices, primarily due to premature technologies and/or a lack of economies of scale. Since the novel CDR market is not liquid, price fluctuations for CDR credits are common. While still a nascent market, it is evidently growing, with more purchases and deliveries of credits being made each year, and prices for technologies like DACCS have seen significant decreases over the years.

The Boston Consulting Group (BCG)[32] estimates that an average price of below USD200 per tonne of CO_2 is required to drive significant demand in emissions-intensive industries with high relative marginal abatement costs. Prices for novel CDR still need to come down significantly over the next few years to remain competitive and unlock demand. Public funding will be key to driving initial scale-up and reducing risks for private investors, who may be hesitant to invest in novel CDR due to low TRLs and lack of commercial availability. As technologies mature and more project plants are deployed, more funding will also be required from private investors.[33] Buyers'

[32] **BCG Global. (2023).** ***Climate Needs and Market Demand Drive Future for Durable CDR.*** **[online] Available at: https://www.bcg.com/publications/2023/the-need-and-market-demand-for-carbon-dioxide-removal.**
[33] **ClimeFi. (2024).** ***ClimeFi releases 'Bridging the CDR Financing Gap - The Comprehensive Guide' - ClimeFi.*** **[online] Available at: https://www.climefi.com/blog-posts/climefi-releases-bridging-the-cdr-financing-gap-the-comprehensive-guide [Accessed 3 Mar. 2025].**

willingness to invest in pre-purchasing and offtake agreements in these technologies and projects becomes increasingly important to assist project developers in securing bank loans and de-risk future investments.[34] Prices are naturally expected to go down as economies of scale are built and costs of deployment go down.

5. CHALLENGES & OPPORTUNITIES IN THE AIR TRANSPORT INDUSTRY

This document has explored the basic definitions of CDR, as well as the difference between these and traditional offsets. The generation and trade of credits stemming from CDR projects has also been explained, along with ways in which these credits can help decarbonize the air transport industry. The high cost of novel CDR technologies is still a challenge, and more so in a sector with tight profit margins and with competing and complementary solutions for decarbonization. This section concludes this document by exploring future remaining challenges for the sector, but also future opportunities, some of which are still untapped to their full potential.

5.1. Challenges

Accounting for CDR contributions

It is important to recognize that, ultimately, CDR is one of the mechanisms that will be used to remove the air transport industry's **own residual** emissions. Currently, there are gaps in GHG accounting frameworks to account for in-value chain and out-of-value chain removals.[35] To track progress toward net zero CO_2 emissions in 2050, the air transport industry needs consistent methodologies and reporting mechanisms to track its contributions from the different decarbonization levers. For example, IATA's TrackZero methodology is one way to track contributions from the different decarbonization levers, including SAF and offsets. Here, the methodology also acknowledges the need for a universal set of CO_2 accounting rules and principles with respect to CDR.[36]

High-cost barriers and deliverability risk

Some key risks to the air transport industry include the high cost of financing CDR and non-delivery risks when projects fail to deliver the purchased CDR credits by the delivery date. These risks are particularly relevant for novel CDR technologies, which are costly and typically involve credit purchases through pre-purchase or offtake agreements. Given that airlines cannot shoulder cost burdens alone due to tight profit margins[37], further support from governments and public entities in the form of grants, tax credits, public procurement schemes, ease of access to loans, and financing purchasing incentives can help get more projects off the ground, enter the market and bring costs down. Deliverability risks can also be addressed through constructing favorable purchase agreements or pursuing demand-side carbon credit insurance schemes.[38] Without such incentives, it is difficult to justify CDR credit purchases from a business perspective.

Policy bottlenecks

[34] https://www.bcg.com/publications/2023/solving-direct-air-carbon-capture-challenge
[35] In-value chain CDR in a company refers to CDR utilized within the value-chain of a company, while out-of-value chain removals refer to removals that occur outside of the company value chain. Discrepancies can arise on whether out-of-value chain removals can be accounted for in a company's emissions portfolio.
[36] IATA (2024). Progress Tracking Methodology Background. Available at: https://www.iata.org/contentassets/b3783d24c5834634af59148c718472bb/net-zero-tracking-progress-methodology.pdf.
[37] IATA (2024). *Global Outlook for Air Transport Deep Change*. [online] IATA. Available at: https://www.iata.org/en/iata-repository/publications/economic-reports/global-outlook-for-air-transport-june-2024-report/.
[38] https://www.kita.earth/

The lack of standardization in evaluating CDR credit quality can make it challenging for buyers to determine the types of credits to purchase, especially when making voluntary purchases. Synthesized standards are recommended to boost confidence in these markets. International carbon markets like CORSIA can also face ambiguity in how corresponding adjustments for credits are made when the geographical boundaries for which these removals occur are not clear.[39] For example, CO_2 removed and stored via specific technologies such as open-system ocean-based CDR and ERW can cover a large geographical area and cross-jurisdictional boundaries, and it can be difficult to determine how much of the activity occurs within the host country.

5.2. Opportunities

Synergies between CDR and SAF

Captured CO_2 from technologies like DACCS can be a valuable source of feedstock for producing SAF via Power-to-Liquid (PtL). CDR can also potentially be used within GHG life-cycle accounting for SAF and other aviation fuels, to make these fuels more competitive in terms of carbon intensity. Similar policy frameworks include the California Lower Carbon Fuel Standard (LCFS), which allows transportation fuels whose life-cycle emissions have been reduced through DACCS to become eligible for credit generation, and these DACCS projects do not need to have a fuel component to be issued credits.[40] The EU Renewable Energy Directive (EU RED), also recognizes the role of carbon sequestration[41] to reduce the carbon intensity during the production of renewable fuels, including SAF.[42]

Diversifying CDR investment

Diversifying investments in CDR technologies can ensure a balance between utilizing current and developed CDR technologies and enabling up-and-coming technologies to grow. CDR technologies like biochar and even conventional CDR methods like afforestation/reforestation and soil carbon sequestration are viable in the short term, offering tangible and high co-benefits, and are cost-effective despite shorter durability (see Section 2.1). Making small, but meaningful investments in novel CDR like DACCS could also be crucial for bolstering market demand for these credits and allowing this sector to grow.

Increasing credit supply in the CCM

CDR is important to bridge the demand and supply gap in CCMs like CORSIA. Actions that can be taken to support more CDR credits, and generally more EEUs in CORSIA include encouraging a greater diversity of carbon credits that registries can issue, including CDR. There is an increasing awareness of how Letters of Authorization (LoAs) are issued and how corresponding adjustments are made with governments and other stakeholders.

6. CONCLUSION

CDR will remain critical to addressing the industry's residual CO_2 emissions alongside other MBMs in all net zero transition scenarios for the air transport industry. However, as this report outlined, the current market for CDR is still nascent, particularly for novel CDR. While the data shows that the market has been growing, there is still more that can be done for the air transport industry to be a more active participant in the market. As discussed throughout the document, to enable this to happen, numerous stakeholders across the industry will need to

[39] **Corresponding adjustments, in the context of CORSIA, is an action taken by a host country via a Letter of Authorization (LoA) that ensures that the traded emission units to meet CORSIA compliance are correspondingly deducted from the Nationally Determined Contributions (NDC) of the host country from which the credits originate.**

[40] **https://ww2.arb.ca.gov/sites/default/files/2020-07/2020_lcfs_fro_oal-approved_unofficial_06302020.pdf**

[41] **Carbon captured and storage from the source of production, not from the atmosphere as with CDR**

[42] **European Union, (2023). *Directive (EU) 2023/2413 of the European Parliament and of the Council of 18 October 2023 amending Directive (EU) 2018/2001, Regulation (EU) 2018/1999 and Directive 98/70/EC as regards the promotion of energy from renewable sources, and repealing Council Directive (EU) 2015/652*. [online] Available at: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=OJ:L_202302413.**

strengthen collaboration and dialogue to resolve some of the key issues facing the air transport industry and also leverage and maximize the opportunities between the CDR and air transport industry.

APPENDIX 1

List of common CDR technologies and their typical CO_2 storage characteristics

Table 1: List of common CDR technologies and their durability

Technology	Description[43]	Storage Type[3]	Durability in years[3]
Enhanced Rock Weathering (ERW)	Acceleration of the natural geologic weathering process through the spreading of finely ground alkaline materials in agricultural, urban, or forest soils, where it reacts with CO_2 and water to produce dissolved inorganic carbon	Ocean reservoirs	10,000 +
Direct Air Carbon Capture and Storage (DACCS)	Using engineered system to pull ambient air from the atmosphere and capturing CO_2 via chemical interactions with a suitable sorbent/solvent, which is then stored in geological reservoirs or mineralized.	Geological formations, minerals	10,000 +
Mineralization	Enhancing the natural capacity of alkaline feedstock to passively react with atmospheric CO_2 – through crushing, grinding, spreading, heating, or other physical and chemical means – to form carbonate materials.	Minerals	10,000 +
Bioenergy with Carbon Capture and Storage (BECCS)	Thermal conversion of biomass (either dedicated feedstock or waste) to generate electricity/fuels that produces CO_2, which is captured with point-capture CCS technology and stored in geological reservoirs or mineralized.	Geological formations, minerals	10,000 +
Direct Ocean Capture and Storage (DOCCS)	Electrochemical processes that split water from oceans, lakes or other bodies of water into acid and base streams, then use the acid stream to push dissolved CO_2 out of the water	Geological formations/ocean reservoirs	10,000 +

[43] **RMI. (n.d.).** ***The Applied Innovation Roadmap for CDR.*** **[online] Available at: https://rmi.org/insight/the-applied-innovation-roadmap-for-cdr/.**

	to be captured, and finally, recombine the acid and base streams to re-neutralize the water and return it to the source.		
Artificial Upwelling/Downwelling	Upward/downward transfer of surface and deep ocean water to stimulate growth of phytoplankton on the surface that removes CO_2 from the atmosphere and pushes CO_2-rich surface water to the deep ocean	Marine sediment	100s to 1,000s
Ocean Alkalinity Enhancement (OAE)	Direct addition of alkaline materials to lakes, oceans, rivers, wastewaters, or other bodies of water to increase the alkalinity of the water and its capacity to absorb CO_2	Ocean reservoirs	10,000 +
Biochar	Thermal conversion of biomass while excluding oxygen, optimized to produce solid char in open or controlled environments	Soil and sediments	100s to 1000s
Afforestation/Reforestation (AR)	Deliberate establishment of forest ecosystems on previously degraded or unforested land to act as natural CO_2 sinks.	Vegetation, buildings, soils	10s to 100s
Coastal Blue Carbon (CBC)	Deliberate establishment of marine vegetation and organisms to act as natural CO_2 sinks.	Vegetation	10s to 100s
Soil Carbon Sequestration (SCS)	Implementation of agricultural practices that build up organic soil carbon content	Soil and sediments	10s to 100s

GLOSSARY

In-sector decarbonization measures: A measure applied to a process within the value chain of the company/entity to reduce or remove CO_2 emissions.

Out-of-sector decarbonization measures: A measure applied to a process outside of the value chain of the company/entity to reduce to remove CO_2 emissions.

Registry: A standard-setting organization that registers carbon-crediting projects and issues carbon credits. They have a means to register, track, and make publicly available information on carbon crediting projects, issue carbon credits and enable the transfer of carbon credits between different accounts, and cancel or retire them.[44]

Vintage year: It can either refer to the year in which the emissions reduction or removal associated with the carbon credit occurred or was issued as a credit.[44]

Credit Issuance: The instruction by the relevant authority in a carbon crediting program to create and serialize a specified quantity of carbon credits in a registry account.[44]

Credit Delivery: When the carbon credits issued by a registry are transferred to and reaches the account of purchaser of the carbon credits.[44]

Credit Retirement: The permanent removal of a carbon credit in an electronic registry, after a party has claimed the associated avoided/reduced or removed emissions. This is done to prevent another party from claiming the same avoided or removed emissions again.[44]

Durability: duration in years for which carbon dioxide is securely stored in a reservoir without risk of reversal.[45]

Validation: The process by which auditors confirm that a carbon crediting project meets all eligibility criteria for registering with a registry.[44]

Verification: The process by which auditors confirm that a carbon crediting project has been properly monitored, and that avoided/reduced emissions or removals achieved by the crediting project have been properly quantified in accordance with registry rules and standards.[44]

Project developer: The project developer refers to the legal entity requesting the registration of a crediting project and issuance of carbon credits. The crediting project developer may be a public or private entity.[44]

Traditional Carbon Offsets: Carbon credits which are issued based on avoidance or reduction of greenhouse gas emissions.[44]

Carbon Removal Credits: Carbon credits issued from technologies, practices or approaches that remove and durably store CO_2 from the atmosphere.[44]

Carbon Avoidance/Reduction: The negative change in greenhouse gas emissions caused by an intervention relative to the intervention's baseline scenario.[44]

Net-zero emissions: net-zero emissions are achieved when anthropogenic emissions of greenhouse gases to the atmosphere are balanced by anthropogenic removals over a specified period.[44]

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[44] https://offsetguide.org/glossary-of-terms/
[45] https://www.carbon-direct.com/insights/accounting-for-short-term-durability-in-carbon-offsetting

Market based measures (MBMs): Provide financial incentives and disincentives to regulated entities towards desired behavior, e.g. lowering emissions. These measures can be implemented to reduce damage to the environment.[46]

Leakage: An unintentional increase in emissions or decrease in removals caused by an intervention, relative to the intervention's baseline scenario, which typically occurs at sources or sinks physically separate from the location where the intervention is implemented.[44]

Reversal: The occurrence of an event in which some of the stored carbon resulting from a CDR project are subsequently re-released into the atmosphere.[44]

Value-chain emissions: A company's scope 1,2 and 3 emissions as defined by the GHG Protocol Corporate Accounting and Reporting Standard.[47]

Insetting: Interventions along a company's value chain that are designed to generate GHG emission reductions and carbon storage, and at the same time create positive impacts for communities, landscapes and ecosystems.[48]

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[46] https://www.icao.int/environmental-protection/CORSIA/Pages/CORSIA-FAQs.aspx
[47] https://sciencebasedtargets.org/beyond-value-chain-mitigation
[48] https://www.insettingplatform.com/insetting-explained/