Removal reconsidered: Carbon Dioxide Removal in the Voluntary Carbon Market

BeZero

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About BeZero Carbon

BeZero Carbon is a global ratings agency for the Voluntary Carbon Market. Its carbon credit ratings allow all market participants to price and manage risk. BeZero's carbon ratings and research tools support buyers, intermediaries, investors, and carbon project developers.

Founded in April 2020, its 90 strong team combines climatic and earth sciences, sell-side financial research, earth observation, machine learning, data and technology, engineering, and public policy expertise. Its head office is in London, with people working from five continents.

Abbreviations

ACR - American Carbon Registry

ACX - AirCarbon Exchange

BECCS - Bioenergy with Carbon Capture and Storage

BEIS - Department for Business Energy and Industrial Strategy

BNEF - BloombergNEF

CAR - Climate Action Reserve

CCUS - Carbon Capture Use and Storage

CDR - Carbon Dioxide Removal

CfD - Contract for Difference

DAC - Direct Air Capture

ETS - Emission Trading Scheme

GGR - Greenhouse Gas Removal

IPCC - Intergovernmental Panel on Climate Change

LCFS - Low Carbon Fuel Standard

MRV - Monitoring, Reporting & Verification

NBS - Nature-based Solutions

NPV - Net Present Value

p.a. - per annum

SBTi - Science Based Targets Initiative

TSVCM - Taskforce for Scaling Voluntary Carbon Markets

VCM - Voluntary Carbon Market

Executive Summary

We are currently at a watershed moment for our climate. The Intergovernmental Panel on Climate Change (IPCC) stated in 2022 that the Earth stands a 50:50 chance of passing 1.5 degrees warming within the next five years. A gargantuan challenge to reach net zero emissions lies ahead and to have any hope of meeting it, unprecedented levels of capital will be necessary.

While governments have a role in steering the way to net zero and helping to de-risk projects, this transition cannot be successfully financed by the public sector alone. The global economy needs to find ways to catalyse private finance for the climate challenge. One key avenue for financing the net zero transition is through the power of the voluntary carbon market (VCM).

At present the VCM is dominated by avoidance credits - credits which correspond to emissions reduction such as avoided deforestation. Roughly 93% of the VCM is currently avoidance credits and 7% is removal. Removal credits correspond to credits that absorb CO_2 back from the atmosphere such as afforestation. Of these removals, less than one per cent are from engineered removal - a term used to encompass removal methods such as biochar or direct air capture, for example, that utilise technology to remove carbon.

But this is set to change. To come close to limiting warming to 1.5 degrees, the IPCC has made clear that large-scale carbon dioxide removal (CDR) is unavoidable, with removal of up to 10 gigatonnes required annually by 2050 from nature based (NBS) and engineered methods. This will likely influence the make-up of the VCM, with removal having an increasing credit demand. In line with data from McKinsey and the TaskForce for Scaling Voluntary Carbon Markets (TSVCM), our analysis projects that by 2030 as much as 56% of credits on the VCM will be removal credits, with their share in the VCM increasing further towards 2050. Of this 56%, analysis projects over half could be from engineered removal credits.

For this to happen, the price per tonne of carbon removed via engineered CDR needs to come down significantly. The current cost of direct air capture ranges from $320-$2,050 per tonne and the cost of biochar ranges from $100-$590 per tonne, compared with $3-$50 per tonne for NBS removal. If engineered CDR is to scale as the IPCC projects, it will need to become more cost competitive.

To enable this cost curve to come down, engineered CDR credits need to be brought into the wider ecosystem of the VCM. At present 96% of these credits have come from bilateral purchases - directly between suppliers and buyers - 89% of which were not ex-post credits but future credits, meaning they do not represent carbon that has been removed but rather forward sale a commitment to remove carbon in the future. This system of donations from big purchasers sets the precedent but will not be enough to scale the market to the level necessary.

Mechanisms of the VCM can help bring down costs of engineered CDR by providing an arena for competition, increasing demand and therefore supply in the years ahead. There are three things that need to happen to achieve this.

First, the accreditors and the developers need to work on methodologies for these new and nascent technological methods to measure and certify carbon tonnage removed by different projects. None of the major registries - Verra, Gold Standard, American Carbon Registry (ACR), Climate Action Reserve (CAR) - currently have engineered CDR credits on the market. Methodologies are an important step for developing strong monitoring, reporting and verification (MRV) standards across CDR. They are currently being explored and developed. This needs to happen at pace to assist in the scaling of this new market.

This rise of CDR accreditation will likely propel the use of intermediaries and marketplaces. Since 2020, a number of key players such as CBL, AirCarbon Exchange (ACX), Cloverly, Patch and Puro.Earth have emerged with an emphasis on selling and exchanging engineered CDR credits. As engineered CDR projects become accredited these kinds of companies will be important parts of the ecosystem, opening up the CDR market, meaning more companies and individuals can become customers.

Second, engineered CDR projects need to be brought into the ratings process. To be eligible for a BeZero Carbon Rating, credits need to be ex-post (credits for activity that has already happened), third party verified, implement an additionality test and have relevant data publicly available. At present, no CDR companies are in this category.

Third public finance and policy support are critically needed to quicken the pace of innovation and bring down the cost curve. These technologies by nature are uncertain and require investors that are open to risk. To assist in the financing, governments have a role to play in de-risking these solutions, either in the form of a Contract for Difference (CfD), direct subsidy or regulatory support, such as participation in the compliance market.

The challenge to scale CDR from basically zero to about 165 billion tonnes in just thirty years is a monumental task. To achieve it, CDR companies must integrate and embrace the VCM infrastructure. If they do, costs could be reduced, capacity could be increased and gigatonnes of CO_2 could be removed from the atmosphere.

The Scene

1. The Voluntary Carbon Market (VCM) is dominated by avoidance credits.

The VCM is an unregulated and business-led market which enables businesses, governments, nonprofit organisations, universities, municipalities, and individuals to purchase credits for climate-positive action or to offset their emissions outside a regulatory regime.

At present, the market is small, worth around $1 billion, but it is set to grow. A report from the UN's Principles for Responsible Investment claims that the nature-based carbon market could generate $800 billion in annual revenues by 2050 (Vivid Economics, 2020).

There are two key categories of credits within the VCM: avoidance and removal. The former relates to emissions that are avoided from being released into the atmosphere, for example, protection from deforestation or renewables development. The latter relates to net negative emissions, such as afforestation or direct air capture (DAC).

At present, the avoidance credits dominate the market. The VCM is currently 93% avoidance credits and 7% is removal.[1] The removal section is dominated by nature-based solutions (NBS) - those that replicate the natural processes of the carbon cycle by storing carbon in biological matter. Of these removal credits: 66.3% of credits is afforestation and reforestation, 24.5% is improved forest management, 7.3% is carbon sequestration in agriculture and less than 1.5% is ecosystem restoration (Climate Focus, 2022).

2. The market is set to shift towards removal and away from avoidance credits in years to come.

In theory, we could decarbonise to net zero with emission reductions alone. But, this is extremely unlikely as it would mean the complete decarbonisation of the global economy. As the IPCC set out in their AR 6 Working Group III Report, while the majority of reductions will come from emissions avoidance, many industries such as agriculture, shipping, and aviation will be difficult to abate in a climate-relevant time frame. These industries have residual emissions that will remain beyond 2050 and cannot be compensated by avoidance.

As a result, large sections of the global economy will rely on removal at an immense scale (IPCC, 2018). The Climate Change Committee - the UK government's advisory board on climate change - forecasts that one sixth of all carbon abatement will need to come from removal by 2050 to put the country on track for net zero (Climate Change Committee, 2020).

[1] This 93%/7% projection from the Climate Focus dashboard includes improved forest management as a removal credit, but it is normally classified as an avoidance credit.

The climate models need to be reflected in the VCM if the market is to play a role in hitting global climate targets. This is echoed by the Oxford Principles for Net Zero Aligned Offsetting, which recognises these drawbacks of avoidance offsetting and say credit purchasers "should increase the portion of their offsets that come from carbon removals, rather than from emission reductions" (Smith School, 2021).

Our analysis of IPCC, BloombergNEF (BNEF) and the Taskforce for Scaling Voluntary Carbon Markets (TSVCM) models finds that by 2030, with a projected market size of 1.5-2 billion tonnes p.a. 44% of the VCM will be avoidance credits and 56% will be removal. Of this removal percentage, more than half of the credits have the potential to be engineered carbon dioxide removal (CDR). By 2050, the market size will be 3-13 billion tonnes p.a, increasing in size 100 fold from 2020 (McKinsey & Company, 2021; Taskforce for Scaling Voluntary Carbon Markets, 2021). With cumulative removal projected to be about 165 billion tonnes between now and then, the share of removal credits in the VCM will also increase (Energy Transitions Commission, 2022).

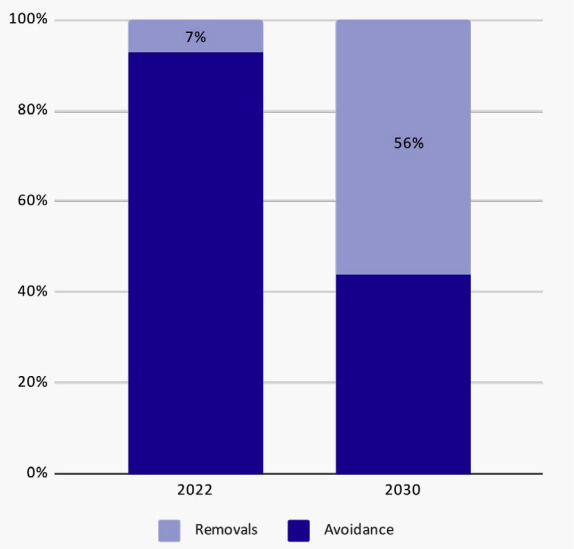

Figure 1. Avoidance versus Removals credits in the VCM.
The TSVCM projects removal to have an increasing role in the VCM.

3. This shift will include an influx in engineered CDR credits as nascent projects increase retirements.

Of the removal currently available in the market, nearly all - 99% - of them are NBS (Climate Focus, 2022). These removals are important. By protecting and restoring natural carbon sinks, they also have potential to provide a large number of co-benefits in line with Sustainable Development Goals (SDGs). These include benefits for biodiversity, water supplies and providing local communities with a source of income.

Independent projections predict this proportion will shift towards engineered removal. The TSVCM estimates an increase to 1.5-2 billion credits traded p.a. by 2030. If this were to happen, experts anticipate that engineered CDR will increase to 30-100 million credits by 2030 from 0 credits in 2022 (engineered removal credits are not currently an available option through the VCM registries) (Hoglund & Mitchell-Larson, 2022). They also project that the proportion of CDR credits in the VCM will increase towards 2050.

There are two reasons why engineered removal is likely to overtake NBS in time.

(1) First, as BeZero - and others such as Verra, Gold Standard and Puro. Earth - set out, permanence is one of the key factors when assessing the quality of a carbon credit. Some CDR methods, such as DAC, forecast over a 1000 years of permanence in geological storage. Carbon sequestered in biomass and soils, as for NBS, is potentially more prone to near-term reversal, for example through drought, fire, pests, or future demands on the land and resources.

(2) Second, engineered CDR can be highly scalable. By 2050, we need 70-225 $GtCO_2$ of cumulative removal (Energy Transitions Commission, 2022). If this was to be solely fulfilled by afforestation, for example, it would require 500-1500 million hectares of land, almost the entire land area on Earth.[2] If this was to be fulfilled by direct air capture, it would require just 100-300 thousand hectares of land (Lebling et al, 2022).

But to get there, significant efforts are needed to scale the CDR industry. At present, engineered removal is immature and consequently have high costs associated with their development. For example, the cost of DAC ranges from $320-$2,050 a tonne and the cost of biochar ranges from $100-$590 a tonne. Comparatively, NBS removal ranges from $3-$50 a tonne.

As this report will set out, the role of engineered CDR in the net zero transition is set to grow, but current methods of credit purchasing are limiting to growth. To unlock this new market and increase the diffusion of these solutions, VCM market mechanisms need to be developed alongside government support. If this can be achieved, CDR can be an important tool to keep warming below 1.5 degrees.

[2] Assumes sequestration rate of 10t/ha per year; Earth's total land area is 14,900 million hectares so this would be 30-100% of total land area.

The Problem

1. The market for engineered removal is growing rapidly but supply is still low.

In the last three years, the industry has experienced extremely high growth. In the mid 2010s, the CDR industry barely existed, with most companies which existed still in the research and development (R&D) phase. Today there is billions of capital flooding into this emerging sector, with a number of start-ups gaining good traction with investors. This growth has been spearheaded by the company Stripe, who were the first company to pre-purchase CDR credits in 2020 and in 2022 founded the Frontier Climate Fund.

A number of methods have emerged as potential growth areas. These include:

- Biochar
- Bio-energy with Carbon Capture and Storage (BECCS)
- Bio-oil
- Direct Air Capture with Carbon Storage (DACCS)
- Engineered Macroalgae
- Enhanced Weathering
- Mineralisation (Concrete)
- Ocean Alkalinity Enhancements
- Soil Carbon Sequestration[3]

But the supply of credits is very low at present. In 2020, 2021, and 2022 (Q1/Q2) just 59,000, 11% of total credit purchases, were ex-post removal credits. The overall number of credits purchased from engineered CDR was over 525,000, but this includes ex-ante credits, meaning the carbon has not actually been removed yet. Of all these purchased engineered CDR credits, the majority - 83% - were from DAC credits, 3% were enhanced weathering and 8% were from biochar (Robert Hoglund, 2022). In this same time period, 9.7 million credits were retired from NBS removal and 315 million avoidance credits were retired (U.C. Berkeley's Voluntary Registry Offsets Database, 2022).

The demand for CDR credits outstrips supply at present, but is still relatively low in comparison to the wider VCM. So far, a selection of corporate pioneers, mostly from the technology sector, have created the bulk of the demand. This group of CDR customers, which includes Microsoft, Shopify, Stripe, Airbus, Bank of Montreal and others, have a desire to be a first mover and leader in the carbon removal space and have been buying both ex-post and ex-ante credits. So far, an estimated $53 million has been spent on CDR credits, all of which has taken place in the last two years.[4] The breakdown of these purchases is illustrated in Figures 2 and 3.

[3] For more detail on different methods of carbon removal, click here.
[4] It should be noted that this estimate is based on limited data and is likely to be higher.

Corporate net zero initiatives will further increase demand. Corporates have been a key purchaser of these engineered CDR credits, with Microsoft, Shopify and Stripe - the largest corporate buyers - purchasing 16,000, 40,000 and 12,000 tonnes of CO_2, respectively. The movement towards CDR is reflective of corporate activity in the VCM, where they are a key end user of credits. For years, avoidance and NBS removal credits have been used to meet carbon neutrality claims. The most widely recognised body for approving companies' 1.5°C-aligned carbon reduction targets, the Science Based Targets Initiative (SBTi), does not allow companies to use carbon credits to account for emissions reductions in near term targets. However, the SBTi's criteria for setting net zero targets allows companies to neutralise residual emissions once they have reduced their own emissions as close to zero as possible. This is going to create an increasingly high demand for carbon removal credits as companies approach their net zero target year, with this early corporate activity demonstrative of what will come. To meet this increasing corporate demand, the supply of engineered removal needs to commensurately develop in the near term.

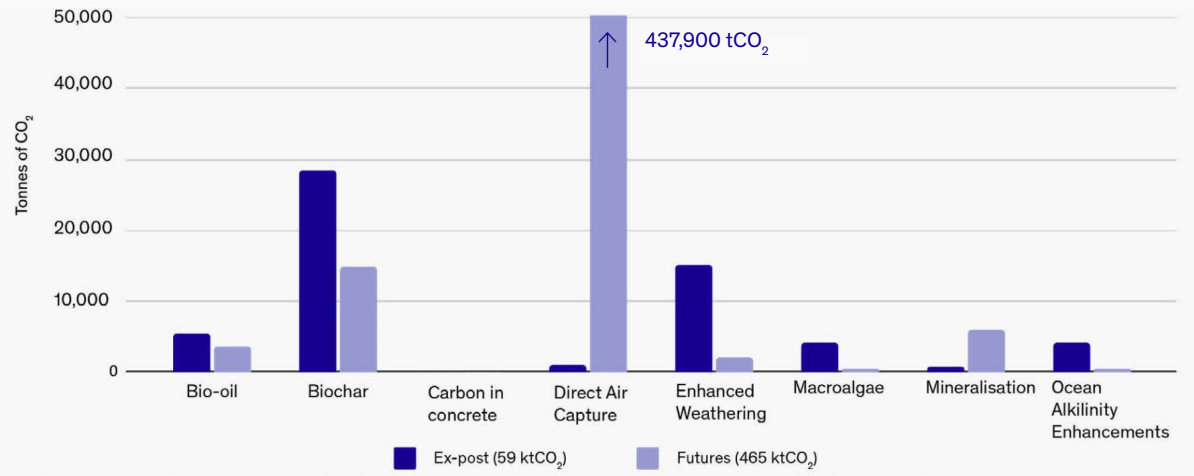

Figure 2. Engineered removal credit purchases by method. This only includes purchases of engineered removal credits that have a transparently reported removal tonnage. Some companies claimed to purchase credits but have not made it clear what volume of credits they have purchased. Airbus made a purchase of 400,000 DAC credits from Carbon Engineering and 1Point5 - the largest engineered removal purchase - extending beyond the scope of the graph. Suppliers who claim to be delivering removal but do not publicly publish retirements have been grouped under futures as there is no proof of delivery (Robert Hoglund, 2022).[5]

[5] This data is sourced from a public database and may be missing some purchase agreements.

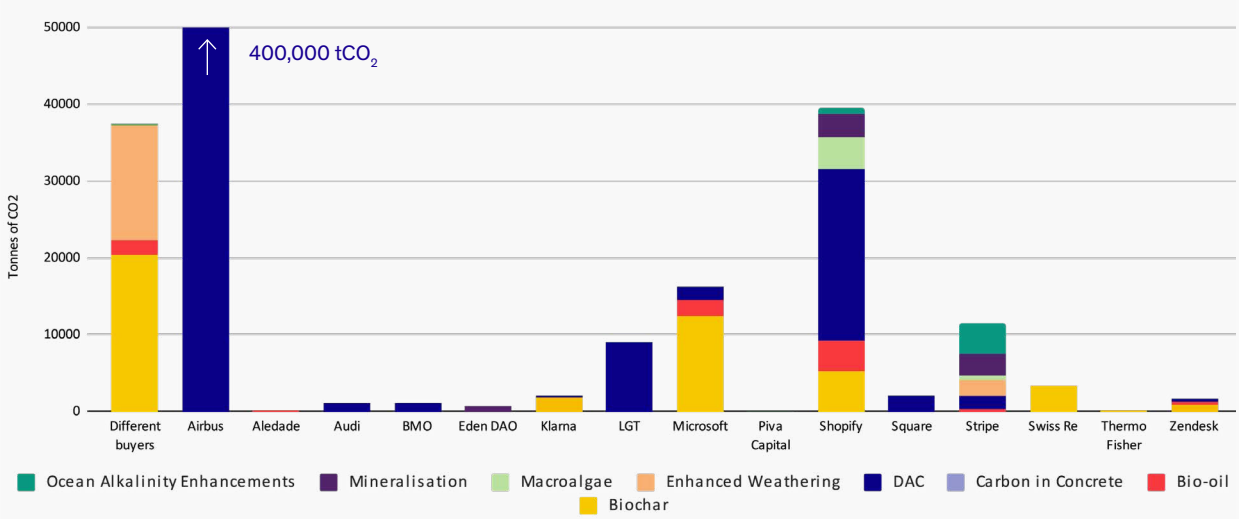

Figure 3. Engineered removal credits by buyer. Current purchasers of engineered CDR by removal method. This figure presents purchases that have a transparent removal tonnage with credit purchase, excluding early stage investments. The different buyers category includes purchases made on small-scale carbon marketplaces like Climacrux, Patch and Puro (Robert Hoglund, 2022).

2. Government and regulatory support is helping to build investor confidence.

Engineered CDR is nascent, as such private, future purchases alone will not be sufficient to scale the sector. Early stage public sector support is necessary to develop the industry. In the United States (US), there has been a large push from both federal and state governments to support CDR. In the 2021 Infrastructure Bill, $3.5 billion was set aside for four DAC Hubs, as well as $115 million for DAC innovation support. On top of this, the bill included a large scaling up of the 45Q tax credit for CDR. At a state level, the Low Carbon Fuel Standard (LCFS) in California has been pivotal in getting CDR companies off the ground, providing a $200 credit available nationally.

In the United Kingdom (UK), the Government pledged £1 billion for Carbon Capture, Usage and Storage (CCUS), which includes support for CO_2 infrastructure for both removal and CCUS. As part of this, there has been a series of initiatives to kickstart the CDR industry including but not limited to: the Department for Business Energy and Industrial Strategy (BEIS) Greenhouse Gas Removal (GGR) & DAC Innovation Fund; GGR Directorate Hub and Demonstrators; BEIS CCU Demonstration Innovation Fund; Cluster programme and the Woodland Carbon Code. Overall, the funding for the industry has totalled more than £1.15 billion.

This funding is largely directed towards project demonstrations, and has yet to be matched by policy and regulatory support. Although signs that this support is in development is seen by a BEIS consultation that has been launched for business models for CDR with the inclusion of technologies such as DAC as a possible option.

In the European Union (EU), a series of funds have been launched between 2019 and 2022, including the European Green Deal and Investment Plan, the Innovation Fund and the Horizon Europe Fund. In total, more than €1.1 trillion has been invested in climate change mitigation. Whilst not directly in support of CDR, it is indicative of the growing number of funding opportunities that CDR projects can utilise.

Alongside this funding, the EU is actively exploring regulatory change to incentivise the development of CDR. Most importantly, plans for a Carbon Removal Certification Mechanism are in motion with the aim to be operational by 2028. There are also plans to direct CDR credits into the EU Emissions Trading Scheme (EU ETS), the largest regulated carbon market in the world.

Governments have been spurred on to action due to the rising public support of CDR. Polling from BeZero Carbon and Stack Data Strategy in 2021 found that nearly nine in ten people (86%) want the UK Government to invest in carbon removal. 45% of people would want this even if it impacts business revenue. More recently, in the US, Data For Progress polling in New York state finds that 72% of voters approve of the state legislature passing a bill to accelerate the development of carbon removal approaches and technologies.

While public support for CDR is emerging in certain regions, active regulation and policy to support its deployment is not commensurately available. Private investments are escalating but remain cost-restrictive and predominantly represent commitments to future removal supply. Integrating engineered CDR into the VCM could help to reduce their costs and support the transition from ex-ante to ex-post, thereby permanently retiring carbon in line with global net zero targets. Additionally, it can help nations to proactively align with increasingly utilised trans-national credit trading mechanisms.

3. The market needs to develop if the price is going to come down at the rate necessary.

At the moment, the vast majority (96%) of credits are bought bilaterally, from CDR suppliers to consumers, not through an intermediary. This means that those who are purchasing the credits potentially have the internal resources to do due diligence on each of the projects and then pay relatively high prices on top of that for the credits. This is why the companies which have purchased these credits to date tend to be large corporations such as Airbus, Microsoft and Bank of Montreal.

Of these credits, 11% are ex-post. This low number is due to the lack of projects that are already up and running in the CDR space. Once more projects are live, this make-up of the market will shift.

Alongside this market for ex-post credits is the sale of ex-ante credits. These commit suppliers to the removal of carbon in the future but are purchased today - known as offtake credits. In effect, these purchases act as donations, they are not corresponding to market demand. Early stage financing is important to overcome the learning curve of technological development. To prove success, projects need to be operational, and without forward financing in the form of ex-ante credits this is not possible. Companies are even coming together to support this: Frontier (Stripe, Shopify, Alphabet, Meta and McKinsey) launched an Advanced Market Commitment ($925m) in 2022; Next Gen CDR Purchase Facility (South Pole, Mitsui, Boston Consulting Group, LGT, UBS, Swiss Re) in 2022.

This current system - purchase of offtake credits at high price - will be unlikely to sustain itself going forward. By 2030, engineered CDR demand is projected to be between 30.7-623 $MtCO_2$ p.a. with supply projected at 210-450 $MtCO_2$ p.a. (Karla et al, 2022). If the high end of demand is achieved there will be a short supply of 173-413$MtCO_2$ p.a., which significantly impacts the ability to achieve a global net zero.

4. At current rates, the cost of these CDR technologies will remain expensive.

There are a number of data sources that set out the potential cost trajectories of CDR in the coming years. Here, we evaluate the projections made by the TSVCM, IPCC and BNEF.

According to the TSVCM, engineered removal is anticipated to consist of about 30-100 million credits by 2030. If this scale was met by currently available credits it would cost $13.5 - $45 billion using Climeworks DAC credits, $530 million - $1.75 billion for Woodland Carbon Code (UK) NBS credits, and $150 - $500 million for an avoidance credit available in the VCM.[6]

[6] This assumes costs for Woodland Carbon Code remain at an average of £13.50 per credit, VCM remains at an average of $5 per credit and that Climeworks credits decrease from $600-$300 per credit during this period (per Climeworks projections).

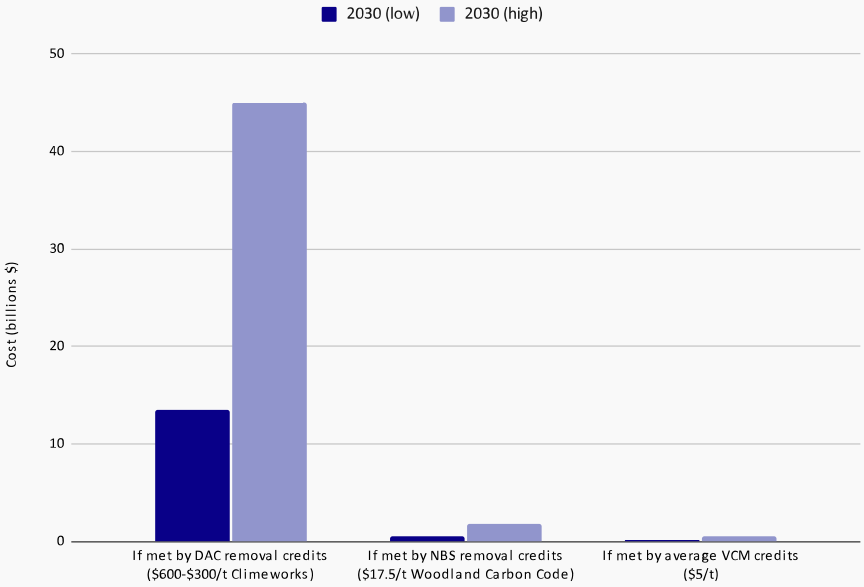

Figure 4. Cost of projected engineered removal credits in 2030 if offset by different credits. Cost to meet the TSVCM's projected 30 million (light blue) - 100 million (dark blue) durable credits by a Climeworks DAC, Woodland Carbon Code NBS, and average VCM avoidance credit in billions USD.

If nothing changes and these costs remain at current pricing until 2050, the annual cost to remove the projected 165 billion tonnes of removal by 2050 will be excessively high. Using solely a Climeworks DAC credit at near term pricing would cost up to $60 trillion. Whereas meeting this with today's Woodland Carbon Code NBS credit or an average VCM credit would only cost $3 or $1 trillion cumulatively, respectively. Engineered CDR is financially no comparison for these cheaper credit options. These costs to remove the 165 billion tonnes of CO_2 that the IPCC projects are not accurate but rather reflect a potential financial burden engineered CDR could place on society with no interventions. It is likely that other factors will influence the price per tonne.

With no intervention to the current system, NBS credits are likely to experience steady price increases in the coming years. However, as land use requirements increase there will be a financial burden associated with competing supply for increasingly limited land, causing larger price increases towards 2050. BNEF projects that by 2050 the average cost of a VCM credit, either avoidance or NBS, will reach $47 per tonne, assuming that engineered removal does not have a high integration into the VCM and there is a lack of regulation within the VCM.

For engineered CDR, as the market develops technologies will benefit from economies of scale subjecting themselves to a learning rate. This is the rate technologies' cost can decrease as their output increases. As engineered CDR supply increases and projects are deployed, the cost will decrease. Based on research from Azarabadi & Lackner, the effective learning rate for DAC is assumed to be about 21% (Azarabadi & Lackner, 2021). After a period of price reduction it is likely the credits will level out in cost. There is consensus in the engineered CDR industry that these credits will see price decreases before settling at around $100 per tonne (National Academies, 2019; Gertner, 2019; Keith et al, 2018; Lackner et al, 2014).

On top of this, it is unlikely that any removal method, NBS or engineered will be used alone, as both of these projections have posited. Rather they will be used in a collective. By utilising these assumptions for NBS and engineered CDR credits that will impact the price per tonne, the costs for removal will be influenced.

BeZero analysis of IPCC projected global emissions for three different emission scenarios, seen in Figure 5, projects the annual cost to neutralise these emissions with removals. In a net negative scenario for 2050 annual costs are forecasted in excess of $160 billion, for an intermediate scenario $3.5 trillion, and for a very high emission scenario $6.5 trillion. These numbers assume a portfolio of methods (NBS 40% and DAC, Biochar, Enhanced Weathering 20%). In a non-portfolio approach these costs could reach as high as $8.5 trillion p.a. by 2050, as seen in Figure 8. These costs continue to assume that these credits are purchased through bilateral agreements and continue to operate outside the VCM.

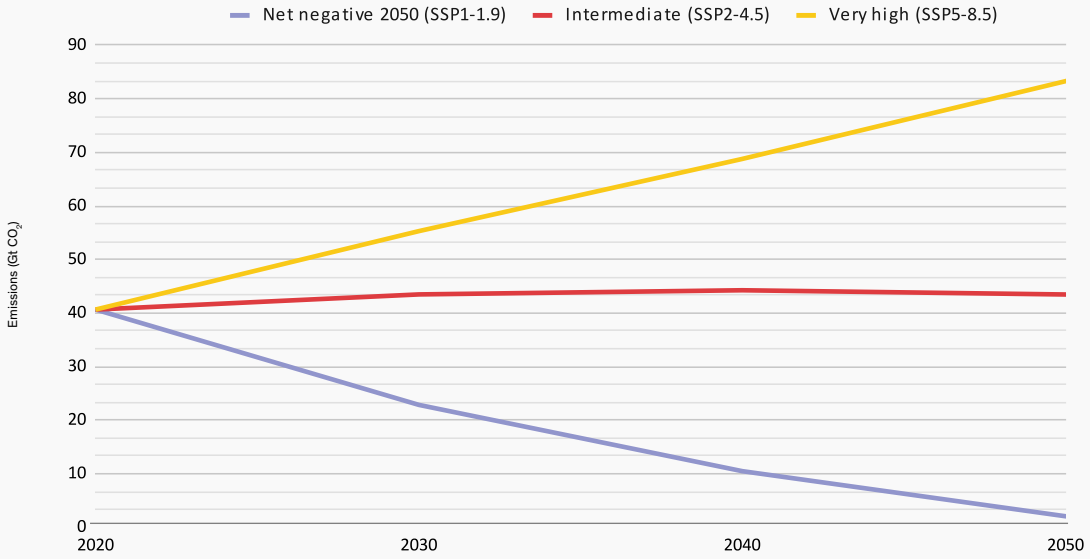

Figure 5. IPCC Projected Global Emissions Pathways. Projections of future annual CO_2 emissions from the IPCC's 6th Assessment Report.

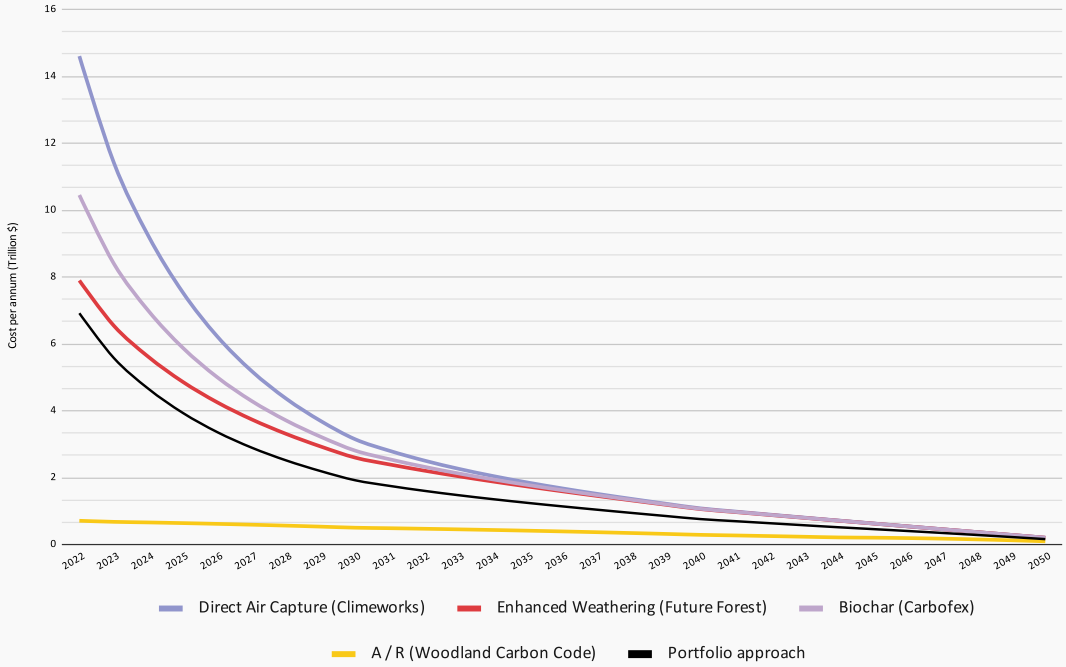

Figure 6. Net Negative by 2050 scenario

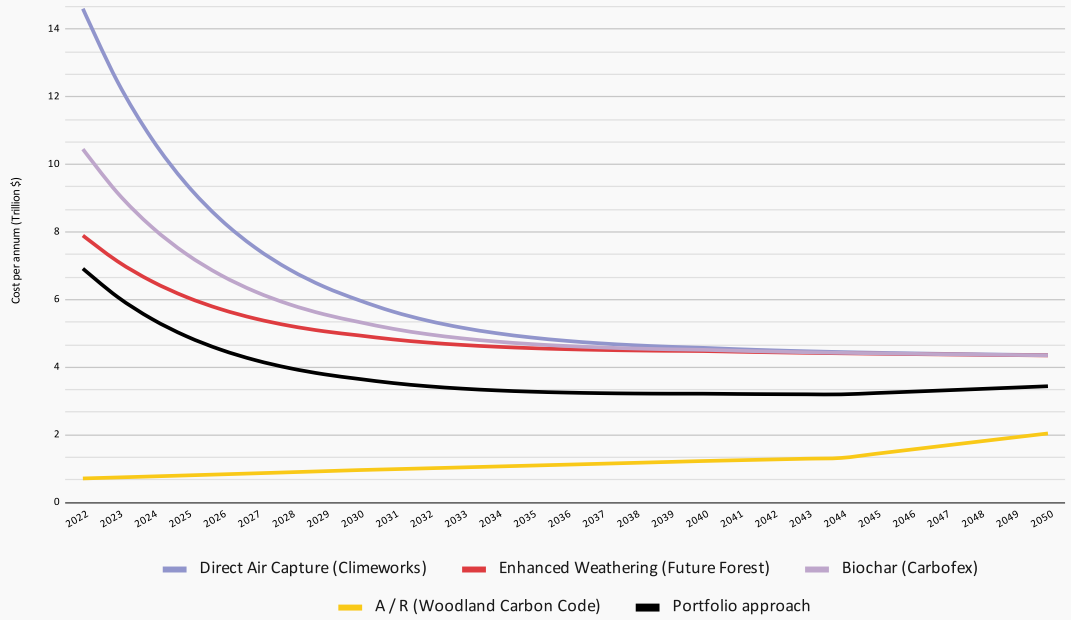

Figure 7. Intermediate emissions scenario.

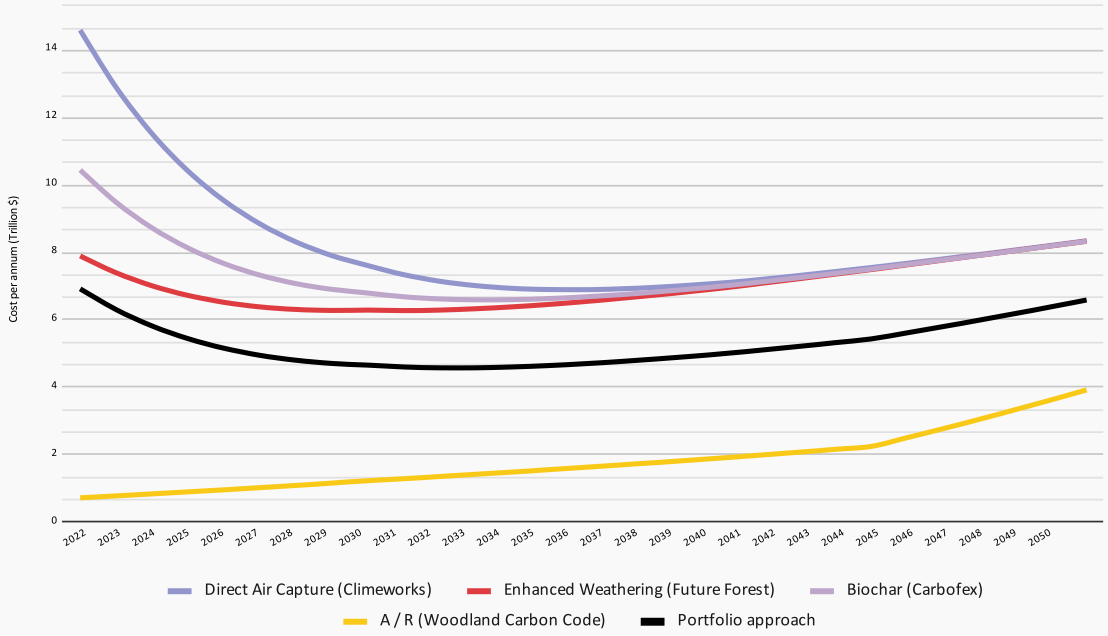

Figure 8. Very high emissions scenario

Figure 6-8. Annual cost in different emissions scenarios of removing global emissions. Annual cost to removal total global emissions in 3 IPCC emissions scenarios (net-negative, intermediate and very high emissions) by engineered CDR credits (DAC, Enhanced Weathering, Biochar), a NBS credit and via a portfolio approach of NBS and engineered CDR credits (40% NBS, 20% DAC, Enhanced Weathering and Biochar) adjusted by published method data and discount and inflation rates per method. The starting credit prices use data from Climeworks for DAC, Future Forest Company for Enhanced Weathering and Carbofex for Biochar, three suppliers that have delivered ex-post removal.

This analysis looks beyond the 165 cumulative billion tonnes of CO_2, and instead looks at the emissions that persist above a net zero scenario annually from now to 2050. The data is demonstrative of the importance of decarbonisation first. The more emissions that persist to 2050 the greater the financial burden on society. Additionally, it demonstrates the potential near term cost reductions of this developing technology set. But these reductions can only be yielded by growing the industry. Doing so requires support greater than the current system.

5. The cost curve needs to be accelerated downwards.

As the previous section set out, the costs of engineered CDR, that could scale to 165 gigatonnes cumulative removal by 2050, are set to be too high on current trajectories. This analysis shows that the cost per year in 2050 to neutralise remaining emissions beyond net-zero targets could be as high as $8.5 trillion USD. This is unlikely to be met entirely by removal with decarbonisation and offsetting strategies in effect, but this demonstrates the financial toll this could place on businesses and governments alike.

To avoid this global financial burden, mechanisms of the VCM can support the emergence of CDR projects. Project suppliers should be encouraged to bring their methods into the VCM. Bringing CDR into the VCM can have four key positive spillovers:

(1) Competition: implementing market structures allows supply to compete for demand, creates technical innovations and overcomes existing infrastructure gaps by incentivising action.

(2) Resilience and stability: they can protect developers from shocks (financial crashes, environmental disasters) that can burden supply. They also protect suppliers from volatility. Without markets they could die out.

(3) Integration: suppliers are developing all over the world but are disconnected in a globalising society. Additionally, resources are not centralised, requiring a decentralised mindset in CDR. The market creates a common space for supply and demand to merge.

(4) Accessibility: price of engineered CDR is currently restrictive to large buyers only (such as Stripe and Microsoft). Market mechanisms increase inclusivity and accessibility of engineered CDR creating a more equitable foundation for a scale-up. They also provide market signals and allow public policy and regulation to support these signals (International Finance Corporation, 2018).

Box 1. Cost curve case study: Solar PV

(1) Solar photovoltaic's (PV) development is recognised as a model for low carbon technology innovation.

(2) Different nations supported and developed niches throughout the latter part of the 1900s. There was publicly provoked competition on the supply side to provide a low carbon low cost energy source.

(3) The increased global connectivity in the early 2000s saw these localised innovations brought together, making it accessible globally.

(4) Today, costs continue to decrease because of economies of scale, innovation in manufacturing, equipment and business models, as well as increased access to financing.

(5) The levelised cost of electricity (LCOE) fell 92% from 2010-2019 to a price of $40/MWh (Irena, 2019).

(6) In How Solar got so Cheap: A model for low-carbon innovation, Greg Nemet shows innovation comes in three parts (1) Create a technology (2) Build a market and (3) Make it cheap.

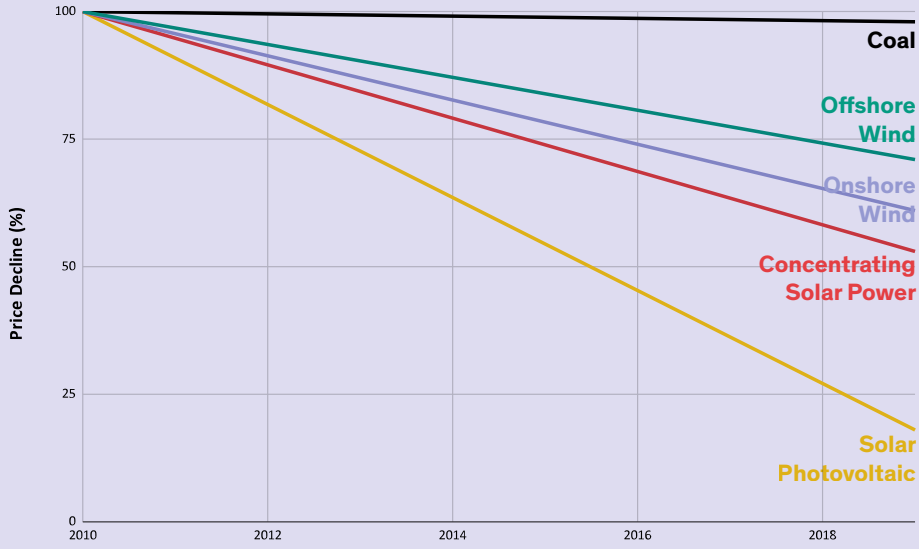

Figure 9. Cost reductions of different energy sources. The decreasing cost of renewable energy compared with coal. Data for all renewable energy technologies spans from 2010–2019 (Irena, 2019). Data for coal spans between 2009–2019 (Lazard, 2019).

Solar is a powerful example of how the cost of a technology can be drastically reduced. Following Nemet's three principles of innovation for CDR, the first stage is complete: technologies have for the most part been invented. The next step is to create the market mechanisms which will in turn bring the costs down. As a real, competitive market emerges for CDR, bilateral purchases need to be reduced and the proportion of credits bought from intermediaries and within the wider infrastructure of the VCM needs to rise. If this can be achieved, it will democratise the purchasing process and dramatically increase the amount of actors in this market, which will be crucial if the CDR market is to reach gigatonne scale.

6. Conclusion of the problem

Purchasing engineered removal credits through the current bilateral approach, directly between supply and demand, is really a form of early stage investment. It is helping to kickstart the market for CDR but it is not helping to bring the costs down or helping it to scale efficiently. If we continue to focus on early stage investment, and keep CDR separate from the opportunities of the wider VCM, there will likely be a slow scale up. This is because the due diligence and research required to forge bilateral purchase agreements is only possible for a small number of well resourced buyers.

To unlock the growth of the sector necessary, the market for CDR - within the framework of the VCM - needs to be developed. If this can be achieved it will increase competition - bringing down the price - while also improving resilience, integration and accessibility of the market.

The Solution

1. Accreditation needs to improve

To be valuable and tradable, credits need to demonstrate a level of integrity. Accreditation is necessary to demonstrate feasibility, durability and viability and maintain standards across this emerging marketplace. It can facilitate third-party insight on different offset projects, ensuring impartiality.

Avoidance and nature-based removal credits are able to claim integrity through the current ecosystem of registries. These registries have a series of peer-reviewed methodologies which apply to these types of credits.

At the moment, the key registries either do not have methodologies in place for CDR, or they are in the infancy of the development. Gaining the stamp of approval from the most established and respected registries in the market will increase the confidence of buyers, especially those with fewer resources who are not able to do project specific due diligence.

A number of registries dominate the market and could envelope CDR into their inventory. These include but are not limited to Verra, Gold Standard, CAR and ACR. These four independent registries have provided a third (36%) of all credits issued and as many as two thirds (53%) of 2020 issued credits (World Bank, 2022).

Table 1. Removal methodologies in the 4 key carbon credit registries (VCM Primer, 2022; Climate Focus, 2022).

Registry	Share of issued credits	Share of registry's credits that are removals	Relevance for engineered CDR
Verra	68.5%	5.6%	No methodologies for engineered CDR.
Gold Standard	20.1%	4.2%	No active methodologies for engineered CDR, but a carbon in concrete methodology in development (accelerated carbonation of concrete aggregate).
CAR	8.3%	9.7%	No active methodologies for engineered CDR, but a biochar methodology is in development.
ACR	3.1%	25.0%	No methodologies for engineered CDR.

This lack of coverage has led to a rise of newer and smaller registries focused on removal. Puro.Earth, for instance, provides a marketplace and registry for removal and has risen as the leading registry specified for the CDR industry. They provide Puro Standards for Biochar and wooden building elements, providing methodologies where the 4 key registries are currently lacking.

As more engineered CDR focused methodologies and registries emerge there are concerns over the credibility of these new methods. To provide this credibility to projects, and ultimately ensure high-integrity developments, information must be transparently reported, which requires marketplaces and stand-setters to provide clear registries of all retired CDR credits.

To facilitate CDR incorporation into the leading VCM registries, a number of things need to happen:

(1) Data transparency needs to improve. If projects are to be accredited and featured on established registries, they will need to publish their issuances and retirements over time. On top of this, the projects need to become more transparent around the carbon leakage of their projects. The publication of verified data for both of these sets of numbers is vital. At present, very few engineered CDR projects publish this data in the public domain - Charm Industrial a notable exception - and therefore do not meet BeZero's minimum qualifying criteria.

(2) Monitoring, Reporting and Verification (MRV) needs to improve and become standardised across the sector. The MRV of these methods is a fundamental challenge the sector faces. At present, many projects either haven't done a life cycle analysis or have only done one internally. This is particularly challenging for some hybrid solutions such as ocean alkalinization and enhanced weathering due to the difficulty in monitoring and reporting the data. To be brought into the wider VCM, CDR companies need to work at pace to have third party verified life cycle analysis for their projects. If achieved, this would be an important step towards accreditation and ratings.

(3) Additionality testing needs to become the norm. The key accreditors - and ratings providers - require an assessment of additionality for their credits. This could come in a number of forms, as set out in best practice VCM methodologies. CDR projects must foresee the needs for such a test and build it into their own methodologies. This will subsequently support their supply to be accessible through other pathways, such as compliance schemes which require this type of testing. If further balkanisation of the CDR market takes place, this could create problems. Too many sources of information and data can lead to inconsistencies and uncertainties, potentially damaging the market confidence. On top of this, as the intersection between private

and public accreditors becomes more important post-Article 6, there will be a growing debate over which registries and accreditors will be allowed into the new framework.

CDR solutions need standardisation within the current framework of accreditors. Without the inclusion into the current VCM infrastructure, the market will struggle to have access to the large pool of buyers currently active in the VCM. At the moment, these buyers are mostly purchasing avoidance credits because the price per credit for removal is high, but also because there are few accredited removals available. This must change and bringing CDR into these frameworks will be crucial to this development.

2. Ratings need to be implemented

While accreditation is crucial to the development of the market, it is inherently binary by nature. Projects are either accredited or they are not. But, within the market of accredited projects, there is a wide variation in the risk of carbon efficacy, with some projects having a far higher risk of not returning a tonne of carbon removed or avoided.

This has caused a lack of correlation between price and quality in the VCM. Over time, as the adoption of carbon credit rating increases, it will become an increasingly important element to determine their pricing, with a more coherent relationship between quality and price as a result. Credits are often rewarded not on their carbon efficacy but on the branding and co-benefits associated with the credit. This trend would be particularly counterproductive for many CDR projects which have very high additionality and permanence, but not as high co-benefits such as DAC.

Ratings can address this market failure. As CDR projects are expensive, as we discussed earlier in this paper, it is important that their relative risk is demonstrated in a way that allows customers to understand the reason behind their prices. Implementing ratings into the market will be crucial to enabling the orderly development of the CDR market.

Some CDR credits have the potential to be assigned one of the top BeZero Carbon Ratings - AAA and AAA+ - on the framework. This is in part due to some methods, such as direct air capture, having strong levels of additionality and permanence, as well as a low over-crediting risk.

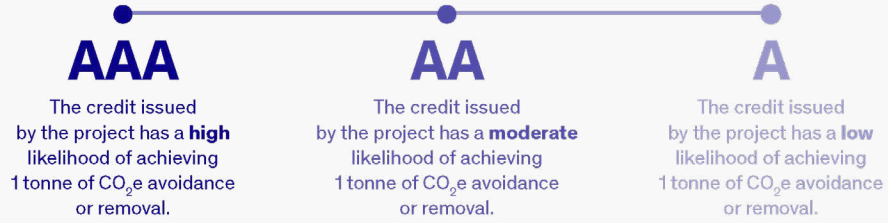

Figure 10. BeZero Carbon Ratings

3. Strong public sector support is needed

Making engineered CDR available through the VCM cannot be the only mechanism for bringing the cost down. In the near term, this strategy alone risks inflating the costs of the entire VCM, causing nature based projects and offset credits to become increasingly expensive as the average cost of a credit would increase.

Financial support is necessary. The public sector has been pivotal in bringing down the cost curve in green technologies such as with solar and wind. For instance, the contracts for difference (CfD) in the UK, implemented as a subsidy for offshore wind, brought the cost down from £140–150/ MWh for projects allocated in 2013, to £39–41/ MWh for projects allocated in 2019 (Onward, 2019). This kind of long term contract to ensure a strike price for investors could be an effective solution for the CDR sector and would help alleviate some of the investor insecurity that is often seen.

Regulatory support is also necessary. As already mentioned, business models are currently being explored across the EU, UK and US to incentivise the take up of CDR. These include some CDR technologies into regulated markets such as the EU ETS. Such an inclusion would drastically improve the legitimacy and verifiability of some of these technologies, consequentially improving their own role within the VCM.

Governments have an important role in fostering innovation. This is no less true in the case of CDR development. Policymakers can help to de-risk these new technologies, improving demand and enhancing the VCM in the process.

Conclusion

Conclusion

Vast amounts of carbon removal are needed, that much is certain. The IPCC has said we need as much as 10 gigatonnes of carbon removal per annum - from both nature and engineered solutions - if we are to keep warming to 1.5 degrees.

It would cost the public sector worldwide enormous sums of money if governments attempt to do this alone. For any emissions scenario beyond net zero, the cost of removal could be several trillions of dollars per year. This burden must be shared between the public and private sectors.

To scale CDR, the sector needs to go beyond its current nascent state and become enveloped into the VCM. First, data transparency and systems for MRV need to be developed. Second, methodologies with the key registries are needed. Third, projects need to become eligible for ratings.

If this can be achieved, the market can go from being worth billions today, to trillions of dollars in 2050. This dramatic scale up is crucial if we are to have any chance of limiting global warming to 1.5 degrees.

Updates and Reviews

Version number	Date	Description
1.00	22/06/22	Initial release
1.01	23/06/22	The percentage of removal credits in the voluntary carbon market was corrected to 7% from 19%, and the share of avoidance credits was corrected to 93% from 81% (in text, p.5 and p.8, and in Figure 1, p.9). To reflect this, the total share of 2020 issued credits was corrected to 53% and the data in table 1 was updated to show the 'Share of registry's credits that are removals' as 5.6%/4.2%/9.8%/25.0% for Verra/ Gold Standard/ CAR/ ACR (p.24).