



Carbon Dioxide Removal Guide

Developed through the Mission from MaRS program



Executive Summary

Experts agree, carbon dioxide removal is needed for 1.5 °C

If we are to limit global warming to 1.5 °C, Carbon Dioxide Removal (CDR) is poised to play a key role in global decarbonization.

And in vast quantities that require rapid development and long-term growth to meet projections

Estimates on the quantity needed depend on the scenario. The CDR Primer found that scenarios that limit global warming to 1.5 °C by 2050 included CDR deployment falling between 1.3 and 29 GtCO₂/year, with most falling between 5 and 15 GtCO₂/year.¹ It's believed that only a few tens of thousands of tonnes of CDR occur today and we must scale rapidly to meet estimated capacity requirements.

CDR can help your organization get to net zero but also provide other benefits

If your organization has a net zero goal and reduce your footprint as much as possible but will likely need CDR to neutralize the unabatable emissions. Some in the market are beginning to recognize that CDR can be more than just a tool to decarbonize but also drive an opportunity to drive value to customers, kickstart a new market to sell to and potentially save costs in decarbonization.

Your organization can play a role to develop the market while setting yourself up to succeed in the long-term

A number of different roles can be played to help scale the market including: technology development, CDR advocacy and offtake.

1. cdrprimer.org/read



“Achieving Net Zero could turn an existential risk into the greatest commercial opportunity of our time”

Mark Carney

UN Special Envoy on Climate Change

Addressing residual and legacy emissions

What is Carbon Dioxide Removal?

Carbon dioxide removal (CDR) can be described as “activities that remove carbon dioxide (CO₂) from the atmosphere and durably store it in geological, terrestrial, or ocean reservoirs, or in products.”¹

A portfolio of CDR solutions exist today, ranging from innovative technologies like Direct Air Capture (DAC) and storage, to nature-based techniques like afforestation. However, any natural uptake of CO₂ not directly caused by human intervention is excluded from the definition. For example, naturally occurring carbon sinks, like wetlands, would need to be enhanced in some way to be considered a form of CDR.

When paired with secure, long-lived storage, CDR can be deployed to capture and address residual emissions with an equivalent amount of CO₂, resulting in no net increase in atmospheric GHG concentrations (i.e., net zero, see Figure 1).

1. quote from cdrprimer.org

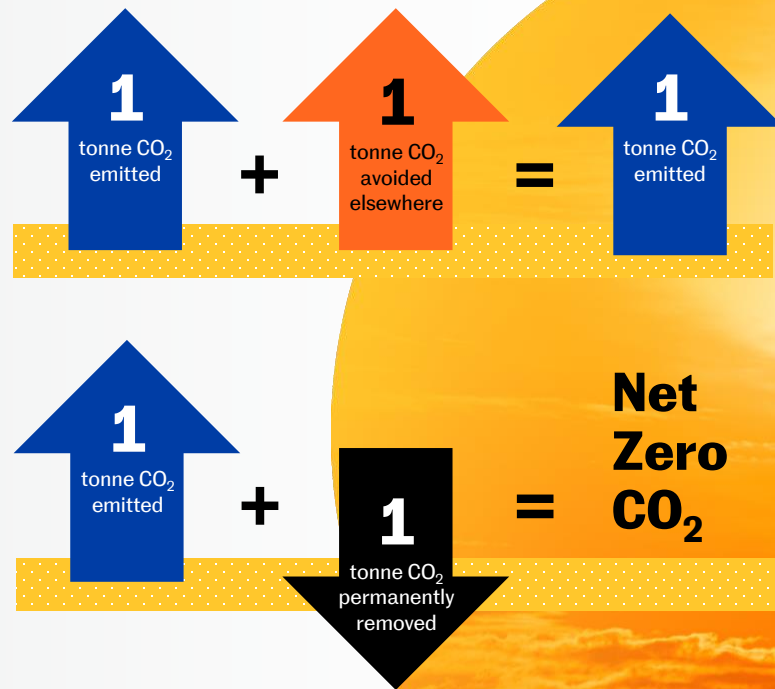


Figure 1: CDR can be used to neutralize residual emissions for no net change to greenhouse gas concentrations in the atmosphere.

Addressing residual and legacy emissions

Why is CDR important?

Major assessments on how to avoid the worst impacts of climate change — including those from the IPCC and the National Academy of Sciences — agree that deployment of CDR solutions, alongside far-reaching emission reduction efforts, is critical if we are to limit global warming to 1.5 °C. CDR is poised to play a key role in global decarbonization, especially in two main areas: addressing hard-to-abate emissions and, in the future, addressing legacy emissions, should we overshoot the world's carbon budget.

The amount of CDR needed to limit warming to 1.5°C is dependent on the rate and amount that we reduce anthropogenic greenhouse gas (GHG) emissions. [The CDR Primer](#) found that scenarios that limit warming to 1.5°C include “CDR deployment by 2050 ranging from 1.3 to 29 GtCO₂/yr., with most falling between 5 and 15 GtCO₂/yr.”

For organizations that have made net zero commitments, CDR provides a mechanism to address residual emissions — those that cannot be directly reduced or eliminated.



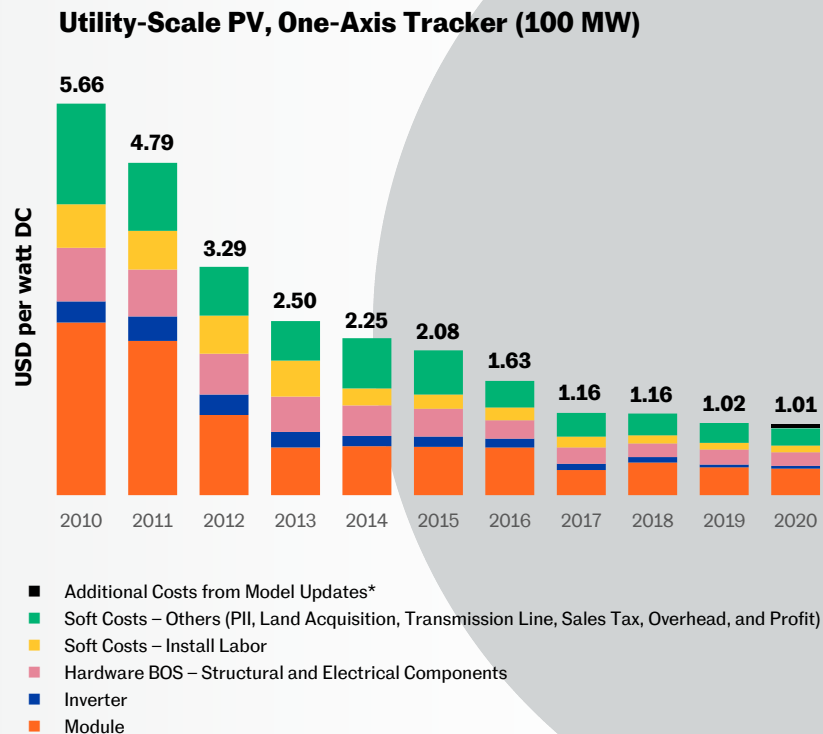
Why now?

- Carbon dioxide removal (CDR) solutions can be an effective tool to tackle the impacts of climate change; however, costs reductions are important to support needed widespread deployment with some technologies not being commercially viable in large volumes today.
- It's believed that only approximately a few tens of thousands of tonnes of carbon dioxide removal occur annually per year today. Meaning, an up to 1 million times increase in scale could be required to get to the 5-15 Gt/year by 2050.¹
- Building that capacity will take time and starting now allows the technology to improve and costs to lower for when it's needed in much larger quantities.
- The cost reductions seen for wind and solar (see Figure 2) are an appropriate analogy for the CDR industry. Many technology providers are forecasting costs for permanent carbon removal at ~\$100/tonne but like solar and wind, investment and deployments are required to move down the cost curve.

1. If 10,000 tonnes occurs today and 10Gt is needed by 2050. The calculations were originally from Swiss Re's [The insurance rationale for carbon removal solutions](#)

2. NREL U.S. Solar PV System and Energy Storage Cost Benchmark: Q1 2020 [nrel.gov/docs/fy21osti/77324.pdf](https://www.nrel.gov/docs/fy21osti/77324.pdf)

Figure 2: Tracking solar PV energy costs from 2010-2020. Investment in the decade brought significant cost reductions ²



What's in it for your organization?

Meet your climate goals – If your organization has a net zero goal, it's likely that you will need CDR to remove unabatable emissions that cannot be reduced, in order to achieve it.

Add value for your customers – businesses like Stripe and Shopify are using CDR to add to their value offering by incorporating it as an option for their customers.

Build a foundation for the future – others have recognized the potential of the CDR industry for their own business and publicly expressed¹ what their industry could do to support CDR, build their understanding of the market and later benefit.

Leadership recognition – consistent recognition of frontier-like leadership has been a reward for the handful of businesses leading the charge to support the CDR industry.

Risk Management – by starting now, organizations can test their strategies and build competencies at low volumes before much larger quantities are needed.

Save costs in decarbonization – CDR must be deployed in concert with rapid emissions reductions and can be used to neutralize the types of emissions which are expensive and difficult to abate, therefore lowering the costs of decarbonization.

1. Swiss Re, Special feature: Locking it up – carbon removal and insurance [swissre.com/institute/research/sonar/sonar2020/sonar2020-carbon-removal-insurance.html](https://www.swissre.com/institute/research/sonar/sonar2020/sonar2020-carbon-removal-insurance.html)



The future of CDR

- Climate experts have told us CDR is going to be needed at scale to meet our 1.5 °C goals. This is creating a fast growing and ESG aligned industry that the market is waking up to.
- Recently, we've seen the emergence of corporate leaders make bold commitments to help scale CDR technologies such as the launch of the \$1 billion Frontier Fund led by Stripe, Shopify, Meta and others, Airbus' 400,000 tonne purchase of DAC carbon removal from 1PointFive using Carbon Engineering's technology.
- We're also seeing increased investment into the space with the closing of LowerCarbon Capital's \$350 million CDR-exclusive venture fund.
- These examples provide evidence that the world is seeing the importance of scaling CDR technologies and getting high quality credits to market.
- In addition to CO₂ sequestration, captured atmospheric carbon dioxide also has use cases in products that create CDR such as, concrete, plastics and carbon fibre and other forms of utilization for emissions reductions including low-carbon intensity e-fuels.
- There are still a lot of challenges to overcome on both the supply and demand sides as the work is just beginning and organizations can play different roles to support that development. That includes:
 - Advocating for the inclusion of carbon removal in decarbonization strategies and policies
 - Purchasing carbon removal to create an early market; supporting project deployments, financing and employment
 - Working as a technology developer to optimize CDR solutions
 - Facilitating the development of the market through providing services to industry participants



Image credit: Carbon Engineering Ltd.

How can an organization support CDR?

Every organization's need and ambitions differs and there are different ways for businesses to purchase CDR today:

Do the work internally – Some businesses are purchasing carbon removal through their sustainability teams or groups responsible for decarbonization. This may be the best strategy for businesses with larger budgets and ambitions to lead in the market.

Work with a buyers group – [Frontier Climate](#) is an excellent example of what could be coming to the CDR industry with a \$925M commitment for CDR by 2030. If successful, a buyers group can perform the administrative work on behalf of the parties, saving time and resources.

Work with an aggregator – Some organizations are in the business of sourcing carbon removal from many projects and buying them in larger quantities to get wholesale pricing. This can help businesses purchase carbon removal from many projects who may not have the resources to source and sign multiple purchase agreements and do not require unique arrangements with their suppliers.

Advocacy – There's also work to be done to ensure CDR is properly supported in regulations and more voices are needed to support that effort. Advocacy ideas could include, supporting equal treatment between permanent CDR and an abated emission as fungible activities when the proper governance structure is applied and direct government procurement of CDR. Examples include the eligibility of DACS in California and BC's Low Carbon Fuel Standards (LCFS), CDR Procurement Act in the United States which calls for procuring engineered CDR beginning in 2024 and the EU committing to procuring 5Mt/y of engineered CDR by 2030.

Portfolio thinking – Given the amount of CO₂ the world needs to pull from the atmosphere to keep global temperatures below 1.5 °C warming, it won't be one single solution that gets us there. We'll need a combination of technologies and solutions. Therefore, like stock portfolios, CDR portfolios are a common practice that support many types of technologies and projects.

Educate your network – Great resources on carbon dioxide removal include [CDR Primer](#), [The Oxford Principles for Net Zero Aligned Carbon Offsetting](#), [Shopify's How to Kick Start the Carbon Removal Market Playbook](#).

FAQ

Doesn't carbon removal just give companies the ability to continue to emit GHGs?

Carbon removal and rapid emissions reductions are not mutually exclusive activities. Leading climate institutions have reported that we need both if we want to keep temperatures to 1.5 °C.

Further, using permanent or durable carbon removal is more affordable on a levelized cost of carbon abatement basis than eliminating the hardest-to-abate emissions but less affordable than other emissions sources such as power production. Therefore, neutralizing emissions with permanent CDR still creates an economic incentive for extensive value chain emissions reductions.

I already purchase carbon credits that offset my emissions. Why do I need to purchase carbon removal?

Offsets and removals are different decarbonization tools. With offsets, you pay someone else to not emit however, your emissions still exist. Removals pull CO₂ back out of the atmosphere which means that your emissions are neutralized.

Leading institutions like the SBTi and Oxford University have shared that net-zero aligned offsetting should shift to a focus on durable carbon removal over time. See [The Oxford Principles for Net Zero Aligned Carbon Offsetting](#) -Figure 1 for visual explanations.

Why support tech when we have trees?

Trees and nature are vital in our fight against climate change and also bring a variety of other advantages such as supporting biodiversity. But trees alone won't be able to solve the climate change problem. Many other forms of CDR have more durable forms of storage. When paired with secure geologic sequestration, CDR can put the CO₂ back where it came from, under the Earth's surface to treat emissions on a "like-for-like" basis.¹ Drawing down emissions and securely storing them back where they came from will be critical in restoring balance to atmospheric CO₂.

1. Professor Myles Allen, Oxford Martin School, Introducing a Carbon Takeback Policy, [youtube.com/watch?v=SkiAvl2G5Tg](https://www.youtube.com/watch?v=SkiAvl2G5Tg)

FAQ

How much does it cost?

The costs vary depending on the technology, size of project and technical maturity. Many technology developers have \$100/tonne targets in the long-term. Regarding the costs today, Stripe is one of the leading companies purchasing CDR and they have made their purchases transparent, including pricing. In a recent Atlantic article, Nan Ransohoff of Stripe stated the price per tonne for the CDR Stripe has purchased has ranged from \$75 to \$2,052.¹ Shopify has paid an average of over \$600 per tonne for long-term carbon removal to date, with some solutions costing as much as \$2,000 per tonne.

Why pay for more now when I can pay less later?

It's believed there's a need for gigatonne scale carbon removal in the coming decades and today's estimates for supply are only in the tens of thousands of tonnes removed per year.

Therefore, there's an incentive to develop the technology and market with smaller purchases today, lowering the costs of the technologies for when larger quantities are needed.

Why pre-pay?

Prepaying creates revenue certainty for the projects, often nascent in nature and this helps with financing, hiring and other activities to get the project operational.

Why not wait until later?

Waiting to purchase CDR prevents important demand signals from reaching developers, making the build out of projects today more challenging. Market development must happen over time as we can't just switch on 10Gt of removals in 2050. Waiting on deployments is waiting to grow the capturing capacity, build the market and reduce our costs from technological improvements.

Swiss Re has estimated that the required compounding annual growth rate (CAGR) of CDR from 2021 to 2050 is 59%. Waiting until 2030 would result in a needed 100% CAGR for the same capacity to be met.²

1. theatlantic.com/science/archive/2022/04/big-tech-investment-carbon-removal/629545

2. swissre.com/institute/research/topics-and-risk-dialogues/climate-and-natural-catastrophe-risk/expertise-publication-carbon-removal-technologies.html

About Mission from MaRS

This guide was developed as part of Mission from MaRS: Climate Impact Challenge with the support of Carbon Engineering, a Mission from MaRS Climate Champion, as well as various industry stakeholders that supported the program.

Mission from MaRS: Climate Impact Challenge is an ambitious technology adoption program that tackles society's greatest challenges by rapidly accelerating the widespread deployment of Canada's most effective innovations to address them. The Climate Impact Challenge, aims to identify, implement, and scale Canadian climate-tech solutions with the highest potential to reduce GHG emissions while economically meeting industry needs, at scale.

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Thank you

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