CARBON DIOXIDE REMOVAL

FREQUENTLY ASKED QUESTIONS

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CREATED BY
SUSTAINABLE HUDSON VALLEY
4 CORNERS CARBON COALITION
TREE MEDIA
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WHAT IS CARBON DIOXIDE REMOVAL?

Carbon dioxide removal, or CDR, is the direct removal of carbon dioxide from the atmosphere and transfer into durable products or natural systems, such as rock formations and is contained for the long term (at least 100 years).

WHY IS INCREASED ATTENTION BEING PAID TO REMOVING CARBON DIOXIDE FROM THE ATMOSPHERE?

The climate crisis is having deadly impacts on lives and communities. Heat waves, floods and wildfires are causing enormous suffering as well as staggering economic impacts. While a rapid shift to renewable energy is happening, the IPCC says that in order to keep under 2 degrees we need CDR. The 1.7 trillion tons of carbon dioxide that are already in the atmosphere is continuing to destabilize the climate. That has led to increased consideration of ways to remove carbon, in order to limit warming, rehabilitate the atmosphere and restore planetary health.

Technologies and pathways for this purpose have been developed and demonstrated around the world. The US Department of Energy has also invested in research and development. Carbon removal is gaining interest as a necessary parallel path, alongside renewable energy development. It is required to slow the climate crisis, and eventually stabilize the climate system.

IS CDR THE SAME THING AS CARBON CAPTURE & SEQUESTRATION (CCS), OR CARBON CAPTURE AND UTILIZATION (CCU)?

No. The terminology can be confusing. CCS or “carbon capture and sequestration” refers to capturing CO_2 directly from point-source emissions like cement factories or power plants. CCS is a form of emissions reduction. To be clear: CDR, “carbon dioxide removal” removes CO_2 directly from the atmosphere. While nature also removes and cycles carbon, CDR is additional carbon dioxide removal initiated by humans.

Carbon Capture & Utilization (CCU) describes processes that capture CO_2 either from point sources and deploy it for use in such things like carbonated beverages, CO_2 for greenhouses, chemicals or fuels. When the beverage is consumed, the plants are harvested or the fuel is burned, the CO_2 goes back into the atmosphere. Carbon utilization applications can also source CO_2 from the atmosphere, instead of from industrial point sources. This is called Carbon Removal & Utilization, or CRU. Both CCU and CRU can partially or completely defossilize the production of materials. Some CCU and CRU applications can entail long-term, even permanent storage, such as the use of mineralized CO_2 in concrete curing, or alternate cements and aggregates to name a few.

WHAT DOES THE U.N. INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE (IPCC) HAVE TO SAY ABOUT CDR?

Since 2018, the UN IPCC has been increasingly clear about the inevitable need for large-scale CDR this century, as a critical component of achieving 1.5° C temperature change, the target of the Paris Agreement (2.7° C) temperature change), and global net-zero. Below is a sample of direct quotes from different Assessment Reports in recent years:

"All pathways that limit global warming to 1.5° C with limited or no overshoot project the use of carbon dioxide removal (CDR) on the order of 100–1,000 GtCO2 [billion tons] over the 21st century."
- IPCC (*Global Warming of 1.5° C*, 2018)

"Unless affordable and environmentally and socially acceptable CDR becomes feasible and available at scale well before 2050, pathways to 1.5° C will become difficult to realize."
- IPCC (*Global Warming of 1.5° C*, 2018)

“[CDR] is a necessary element... counter-balancing residual emissions from ‘hard-to-transition’ sectors such as industry, transport and agriculture”
- IPCC (*AR6 Synthesis Report*, 2022)

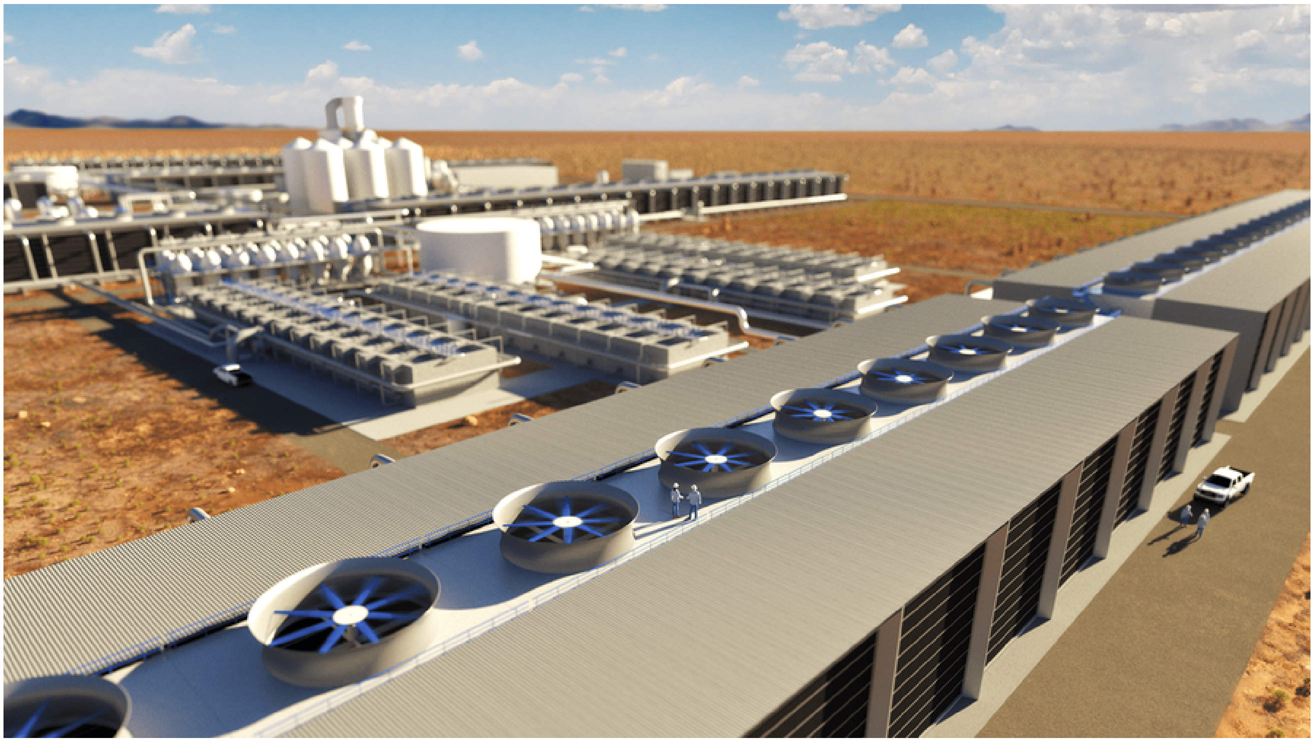
"Carbon dioxide removal (CDR) will be necessary to achieve net-negative CO_2 emissions."
- IPCC (*AR6 Synthesis Report*, 2023)

IS CDR AN ALTERNATIVE TO REDUCING EMISSIONS?

No, absolutely not. There is widespread agreement that our primary task, as we confront the climate crisis, is to decarbonize our economy and reduce greenhouse gas (GHG) emissions as quickly as possible. We are fortunate in New York that this prioritization is established in the form of the state’s landmark Climate Leadership and Community Protection Act (CLCPA) which mandates net-zero by 2050 – the vast majority of which (85%) is to be achieved via aggressive targets to reduce GHG emissions from the energy sector, transport, and the built environment. While this decarbonization reduces future emissions, carbon removal addresses the greenhouse gases already in the atmosphere as well as mitigating against the hard to address emissions that are destabilizing the climate right now.

WE KNOW WE CAN AND MUST REMOVE CO_2 THROUGH FORESTS, SOILS, "BLUE CARBON," AND OTHER NATURAL SYSTEMS. ISN'T THAT ENOUGH?

Unfortunately, no. It is absolutely essential to protect, maintain, and extend our forests – which in addition to the carbon they store, deliver critical ecosystem services and community benefits. Blue carbon enhances coastal resiliency, deacidifies the ocean, and serves as a nursery for our fisheries. Building soil carbon and other regenerative agriculture practices can increase field productivity and offer a foundation for more sustainable and resilient food systems. However, there is physically not enough land for these natural "sinks" to deliver the scale of CDR we need. In addition, the carbon storage in natural systems is reversible (for example, when forests burn). We absolutely need strong policies to incentivize the scaling of forests, regenerative agriculture, and blue carbon alongside durable CDR that will address longterm carbon storage.



Carbon Engineering is planning the world's largest direct air capture plant, in Texas, USA (Credit: Carbon Engineering, BBC)

SO HOW DO WE ACTUALLY DRAW CARBON OUT OF THE ATMOSPHERE? HOW DO THE TECHNOLOGIES WORK?

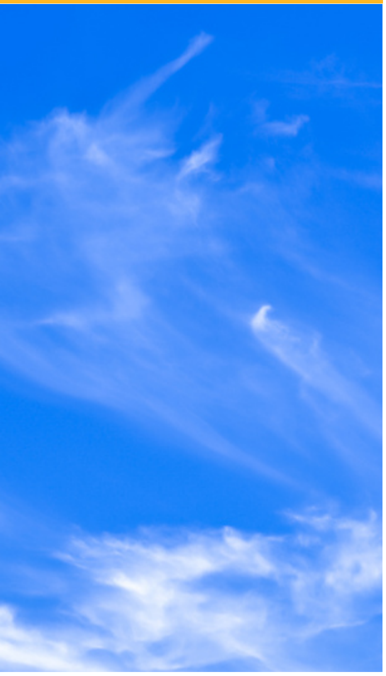
Virtually every CDR pathway uses human invention to accelerate and scale a component process from the earth's natural carbon cycle. A wide variety of approaches and many types of systems are in play, from naturally occurring to highly engineered. Primary CDR methods being developed include:

- Durable bio-storage – such as in soils using biochar produced by anaerobic heating of organic materials, or enhanced rock weathering using rock dust to bond with CO_2 in soil (accelerating a natural process by increasing the rock surface area greatly)
- Mineralization – reaction with alkaline minerals to form solid, stable carbonate compounds
- Increased ocean alkalinity to allow for greater storage of CO_2, generally by dissolving minerals or electrochemistry
- Direct air capture through chemical separation of CO_2 in the air with a liquid solvent or solid sorbent

Just like the manufacture of solar panels, electric vehicles, heat pumps and batteries, some of these approaches are industrial processes that must be permitted and managed carefully. Others involve low temperature, low risk processes with commonly used ingredients.

New York is fortunate to have extensive geologic, agricultural, and oceanic resources that can be used; exceptional academic institutions where durable CDR pathways are being researched and developed; and a world-leading commercial sector for deployment. CDR via enhanced rock weathering is being researched at Cornell, and Columbia leads the world in exploring mineralization-based CDR. New York is a hotbed of biochar research and innovation, and Long Island's extensive coastline offers tremendous opportunity for ocean-based CDR. On the more engineered front, one of the world's pioneer direct air capture companies is based in NYC, and DAC researchers in the state have received a number of U.S. Department of Energy (DOE) grants in recent years.

WHAT IS THE CARBON FOOTPRINT OF THE PROCESSES THEMSELVES? HOW DO WE KNOW WE ARE REMOVING MORE CARBON THAN THEY ARE USING TO DO SO?



This question is on the minds of technology adopters, investors and climate activists alike. In fact, the life-cycle economics and carbon balance of these technologies varies widely; tech companies aiming for credibility and innovation are pushing themselves to document the performance of their technology and its associated emissions in order to qualify for carbon credits under systems that are increasingly rigorous.

One key aspect of the lifecycle performance of CDR technologies is the energy available to power them. As renewable options for powering industrial processes become more widely available, carbon dioxide removal will become more impactful with fewer inputs from carbon-based energy sources. To be eligible for carbon credits, anyone deploying CDR technology needs to show net carbon sequestration after the carbon footprint of fueling the process is subtracted.

HOW MUCH CDR WOULD IT TAKE TO REMOVE THE EXCESS CO_2 THAT'S NOW IN THE ATMOSPHERE?

Estimates vary as to how much CDR will be required, ranging from 1.5-3.1 Gigatons to 10+Gt per year globally by 2050. Whichever scenario proves correct, we need to start responsibly scaling CDR now. A Gt is a billion tons; the most promising CDR pathways are currently operating at kiloton (Kt or thousand-ton) scale. To reach Gt-scale by mid-century we must gear up now.

WHAT IS THE STATE OF MATURITY OF THESE TECHNOLOGIES, AND OUR ABILITY TO MEASURE THEIR PERFORMANCE?

CDR technologies are rapidly evolving and diverse, with 32 distinct types of technology identified by RMI in 2023. As a result, they have highly varied footprints in terms of land use, water needs, energy consumption and byproducts. Systems and protocols for independent monitoring, reporting and verification (MRV) of CDR performance are rapidly being developed by industry associations, consultancies, investor groups, government agencies and others.

To achieve economic viability and be able to scale, CDR technologies must stand up to scrutiny in the measurement of the inputs of materials and energy they require, the amount of sequestered carbon that results and any byproducts that must be dealt with. MRV methods must keep up with the diversity and complexity of the technologies

Two of the most relevant technologies for the Hudson Valley, biochar and enhanced rock weathering, are considered to be in the “advanced demonstration” stage; their methods of production and ability to sequester carbon are proven, but there are not yet consistent standards for evaluating their impacts. Increasingly rigorous demonstrations of these technologies are coming online, as the case study below illustrates.

CASE STUDY

Bioforcetech demonstrates the production of biochar through advanced pyrolysis in Redwood City, California. It is the first advanced pyrolysis project approved by the U.S. Environmental Protection Agency for management of biosolids in the U.S., though use of these units is well established in Europe. Fundamentally different from incineration, pyrolysis is a highly controlled, anaerobic process for high-temperature processing of materials. (See Here and Here)

In addition to EPA approval, the project also cleared requirements from the Bay Area Air Quality Management District, considered one of the most stringent permitting authorities in the country.

The project combines advanced pyrolysis units with engineered biodryers which utilize the heat released by the pyrolysis units to prepare the next material for processing.

The advanced pyrolysis units also:

- Use little energy for the initial start and are autonomous once started
- Recycle their gasses and burn exhaust at high temperatures

The energy neutral process results in ~ 800,000 tons of carbon dioxide equivalent per year, per unit, sequestered as biochar. Over 300 truck trips per year are also eliminated by the operation, for an additional emissions benefit. The process has been shown to destroy many contaminants of emerging concern in feedstocks, including PFAS and PFOAs

Overall, the best way to set these projects up for success is to:

- Rely on renewable energy and/or highly efficient processes;
- Use local carbon sources and storage locations to minimize the project’s transportation footprint and ensure that the communities that benefit from the project are involved at the outset in approving it;
- Organize decentralized business models that allow many small operations to aggregate benefits.

SHOULDN'T WE DEVOTE ALL POSSIBLE FUNDING TO DECARBONIZATION NOW, AND SHIFT OUR FOCUS TO CDR LATER IN THE CENTURY?

Bringing innovation to commercial scale takes time - sometimes years and usually decades. If we want CDR to be ready - i.e. affordable, proven and safe - to meet the eventual need, we have to accelerate research, development, monitoring and verification now. Renewable energy technologies have been proven; these industries have put in decades of work to develop their business case and win policy support. They are rapidly scaling now. They deserve the majority of public and private capital investment and political focus. CDR is at an earlier stage of development. The CDR industry can prepare to scale with modest public financing, mainly support for R & D and technology commercialization.

SO MANY TECHNOLOGIES HAVE BEEN DEPLOYED WITH LIMITED PUBLIC INVOLVEMENT OR ACCOUNTABILITY – ARTIFICIAL INTELLIGENCE AS AN OBVIOUS EXAMPLE. HOW CAN THE ADOPTION OF CDR BE MANAGED FOR TRANSPARENCY AND ACCOUNTABILITY?

Social accountability in the development of CDR is a core concern of the industry. The Carbon Business Council, Carbon 180, Carbon Future and many other organizations are actively working with the CDR industry to factor environmental justice and community participation into decisions about who pays for CDR projects, who owns the assets, who gets the jobs and how communities can benefit. Under the Climate Law, New York's government and community based organizations have done important work to identify "disadvantaged" communities that require funding programs. This sets the stage for a transparent demonstration of community-engaged planning to launch a new industry in a way that centers on community benefits. As we build an entirely new industry from scratch, we have the opportunity to ensure a fair and just distribution of the benefits, particularly to frontline communities that have been negatively impacted by the fossil economy.

The Four Corners Carbon Coalition, led by four local governments in the southwestern US, provides one model for establishing CDR demonstrations with community inputs and transparent performance monitoring. With a technical advisory panel and active stakeholder engagement, the project raised funding to support a cluster of demonstration projects using low-carbon concrete, including an affordable housing initiative in partnership with Habitat for Humanity. A similar model could be used in the Hudson Valley with a focus on the resources and opportunities that are most abundant, such as soil enhancements that could open up access to carbon markets with benefits to our farms.

HOW CAN COMMUNITIES BE ENGAGED IN THIS WORK?

Each CDR pathway needs specific inputs, and these inputs should be found ideally within a 50-mile radius. Communities around the world can and should engage in the creation and management of CDR projects. Additionally, in order to achieve the impacts that are needed to remove legacy carbon in meaningful quantities, some CDR installations will need to be large. Similar to manufacturing of renewable energy, battery storage and electric vehicles, larger CDR locations must be located in appropriate areas and developed with concerted, serious engagement of local communities.

DOES CDR OFFER BENEFITS BEYOND CLIMATE?

CDR is forecast to be a multi-trillion-dollar global industry by mid-century. Through NYSERDA, New York has made significant investments in carbontech innovation and R&D, and the CLCPA bolsters those investments by providing market support to scale the deployment of durable CDR in the state. The jobs and industrial development potential from CDR are enormous, and widely distributed across the state, from Long Island to the North Country to Western New York. In addition to the economic opportunity, many CDR pathways, such as biochar and enhanced rock weathering, offer significant ecosystem and agricultural co-benefits in the form of increased soil productivity and health.

Additional Resources:

Carbon180, “Fact Sheets” (2022). https://carbon180.org/fact-sheets

Carbon180, “Deep Dives” (2022). https://carbon180.org/deep-dives

Corpora, Isabella, “Monitoring, Reporting & Verification: Issue Brief” (2023). https://www.carbonbusinesscouncil.org/news/mrv

Open Air Collective, “This is CDR” (webinar series, weekly via Zoom and archived) (2023). http://www.openaircollective.cc/shows/

Rocky Mountain Institute, “Applied Innovation Road Map for CDR: An Independent Perspective to Guide CDR RD&D Funding” (2023). https://rmi.org/insight/the-applied-innovation-roadmap-for-cdr/

Smith et al., “State of Carbon Dioxide Removal - 1st Edition” (2023). https://osf.io/w3b4z/ or https://www.stateofcdr.org

Wilcox, Jennifer, Ben Kolosz and Jeremy Freeman, “CDR Primer” (2021). https://cdrprimer.org/

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