SUMMARY
Carbon dioxide (CO2) is the most abundant Greenhouse gas (GHG) in our atmosphere. To combat climate change, we need to reduce the amount of CO2 that we produce. However, we will also need to remove the CO2 that already exists or will imminently exist to reach sustainable levels of GHG. An important avenue for removing CO2 is Direct Air Carbon Capture and Sequestration (DACS). This is a process wherein a machine pulls CO2 from the surrounding air and then permanently stores that CO2, often underground, to prevent it from contributing to our warming planet. We have investigated several DACS projects and recommend purchasing carbon offsets from Climeworks (they call them Carbon Dioxide Removal (CDR) credits), a Switzerland-based company that has built a modular technology for capturing CO2 and then permanently turning it into solid material deep underground.

DACs as a Carbon Offset
Carbon Capture and Sequestration (CCS) can involve pulling CO2 from industrial facilities or from the ambient air, either passively through natural processes like photosynthesis and Enhanced Weathering or actively through machines in a process called Direct Air Capture (DAC).\(^1\) Because of how much CO2 is already in the atmosphere or projected to be released regardless of effort to prevent it, capturing and storing CO2 that already exists in the atmosphere is an important lever in fighting climate change. This paper focuses on Direct Air Capture and Sequestration projects as opposed to other types of CCS such as enhanced weathering, which we will deal with in a separate paper.

DAC projects will typically use the harvested CO2 for commercial purposes or inject it underground with the sole intent of permanently removing it from the atmosphere. While harvesting CO2 for commercial sources may be carbon-negative even if the CO2 is eventually re-emitted, we focus our attention on DAC projects that permanently sequester CO2 (i.e. DACS projects). Some of these projects inject the CO2 under thick layers of rocks to prevent it from leaking out. Others inject it into geological formations that react with the CO2 and turn it into a solid, thereby preventing it from leaking back into the atmosphere (and here).

\(^1\) The technologies that do this work are often called Negative Emissions Technologies (NETs). These include both photosynthetic carbon sinks like forests and plants, as well as projects that manipulate coastline or farmland soil to trap more CO2 (called Enhanced Weathering), Direct Air Capture technologies are also NETs.
OVERVIEW

DACS projects are technically difficult. The process requires capturing CO₂ from the air, which requires advanced technology that is only just beginning to be developed in a scalable fashion. Once CO₂ is captured, it must then be injected deep underground and monitored to ensure that it doesn’t leak back out to the surface. The combined financial cost of developing DACS technology, maintaining the technology, and then sequestering the CO₂ is high. The energy cost of these projects can also be high, as the DACS machines often need to run at a fairly high temperature.

Despite their high costs, DACS projects appear to be one of the most additional and verifiable forms of carbon offsets that exist. Unlike most carbon offset projects that seek to prevent emissions or passively reduce GHG in the atmosphere, DACS projects have the potential to pull CO₂ directly from the air around us and permanently store it underground. The technology is still young, but we believe that these projects represent an important lever in the effort to address climate change.

DAC COMPANIES AND PROJECTS

There are many CCS projects around the world (see this MIT map for an overview of where they are located) but there are only a small number of organizations that we are currently aware of that work on Direct Air Capture. We looked into two of the most well-known:

- Climeworks
- Carbon Engineering

We spoke with Climeworks and Carbon Engineering and investigated both organizations. Below is the summary of our findings on each with a focus on recommending carbon offsets/CDR credits for purchase. Note that these recommendations are preliminary and will be updated as we review further information.

CLIMEWORKS

We recommend buying carbon offsets from Climeworks.

Overview of Company

Climeworks is a Switzerland-based company that does DAC and either sequesters collected CO₂ underground or sells it for commercial purposes including to a Swiss greenhouse and to Coca-Cola Switzerland. Climeworks has a policy against working with fossil fuel production companies, which are a common partner for DAC companies as certain types of fossil fuel extraction can be made

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2 A carbon offset is “additional” if it would not have happened absent the carbon offset market. This means that the reduction in GHG was not mandated by law and would not receive financing from investors without the existence of a carbon offset for purchase.

3 A carbon offset is verifiable if it can be proven that the carbon offset is used to measurably reduce or avoid the emission of GHGs.
more efficient and productive by injecting CO\textsubscript{2} underground in a process called Enhanced Oil Recovery. The climate impact of these projects is debated but we suspect worse than or equal to net-zero GHG impact,\textsuperscript{4} which is why Climeworks’ focus on other types of projects is compelling.

The company uses technology it created to collect CO\textsubscript{2} from the surrounding air. This happens through a two-step process of drawing air into a “collector” using large fans and then using filters to capture CO\textsubscript{2}. After the CO\textsubscript{2} is in the filters, the company heats the filter which releases the CO\textsubscript{2} and enables Climeworks to capture it. The company has two operational facilities, one in Switzerland that uses the CO\textsubscript{2} for commercial purposes and one in Iceland that uses the CO\textsubscript{2} for CDR credits:

**Commercial purposes** - Climeworks’ facility in Switzerland captures CO\textsubscript{2} and provides it to commercial partners for use in their businesses. They have partnered with a Swiss greenhouse that purchases their captured CO\textsubscript{2} for use in agricultural practices. They also sell CO\textsubscript{2} to a Swiss Coca-Cola bottler, where it is used to create the bubbles in soft drinks. They hope to expand their commercial work to more companies that want eco-friendly ways of obtaining CO\textsubscript{2}.

**CDR Credits** - Climeworks also sells CDR credits on the voluntary market through their facility in Iceland. After capturing CO\textsubscript{2}, Climeworks injects the CO\textsubscript{2} deep underground into geological formations where the CO\textsubscript{2} reacts with the minerals around it and forms solid materials. This is considered the safest way to store CO\textsubscript{2} as it is extremely unlikely to leak back into the atmosphere.\textsuperscript{5} When someone purchases a carbon offset from Climeworks, the company puts that money into the operational costs associated with running their CCS project. The Climeworks team claims that the CDR credits that they sell go directly to removing additional tons of CO\textsubscript{2} removed from the atmosphere, as all of the money they receive goes into operational and modular expansion costs (more on this below).

**How are the carbon offset funds actually used?**

Climeworks’ projects require a significant upfront capital investment and ongoing operational costs. The funds from CDR credits purchased from Climeworks are used to cover the ongoing operating costs of offsetting CO\textsubscript{2} at the Iceland facility, which is where Climeworks captures CO\textsubscript{2} and sequesters it underground. There are additional ancillary benefits from each offset purchased, including that they act as a signal of consumer demand for Climeworks’ CDR credits and thus encourage investors to invest in Climeworks. Private sector investment is crucial to Climeworks’ future as it enables R&D and setting up new facilities.

\textsuperscript{4} We plan to do a full investigation of Enhanced Oil Recovery at some point to be able to provide better guidance on how to approach Enhanced Oil Recovery projects.

\textsuperscript{5} https://science.sciencemag.org/content/352/6291/1312
We created the following graphic to explain how the Climeworks team described the importance of carbon offset to Giving Green:

- Purchasing carbon offsets from Climeworks leads to more revenue for Climeworks as shown by the GREEN boxes (which can be used in many ways).
- As shown in the BLUE boxes, the Climeworks team claims to use CDR credits primarily for covering operational expenses related to CCS and to go towards paying back the loans they took to build the CCS facilities (not the main business, but just the loans for the CCS facilities). Selling CDR credits on the market also provides a signal to investors of the market potential of this technology.
- This signal of market potential will hopefully attract additional investors into the market. Additional investment is used for R&D and setting up new projects, which are represented by the ORANGE boxes.

**Additionality**

Climeworks’ operational costs are extremely high, including expensive maintenance on their machines and the cost of injecting the CO\(_2\) underground. CDR credits go towards these operational costs and, according to the company, directly enable more CO\(_2\) to be captured and injected underground by “keeping the lights on.” As such, we are confident that Climeworks’ CDR credits are highly additional.

Beyond the immediate CO\(_2\) removed at the Iceland facility, there three other reasons that buying these CDR credits could help in combating climate change:

- These CDR credits signal to investors that there is a market for DACS technology (point #2 from the previous section), which means that more investors are likely to push money into developing better DACS technology and expanding the company’s projects. We believe that
this will have downstream effects on the amount of CO₂ that can be captured and stored in the long-run.

- **Climeworks has built their technology to be modular**, meaning that they can add small additional units that increase their capacity for CCS. While we do not believe that CDR credits are currently being used to expand the number of units they use (the company is not profitable and they are still using CDR credits to cover operational costs), it is possible that CDR credits will be used for this purpose if enough are purchased.

While Climeworks states that offset income is used to support their carbon sequestration activity, there’s always the possibility that it also supports their commercial side, since money is fungible. We are comfortable with this possibility because we also suspect that the commercial side of Climework’s business is carbon negative relative to the next best alternative, meaning that any benefits from buying CDR credits to the overall business (e.g. expanded investment) will also have climate impact by reducing the climate footprint of the companies that partner with Climeworks. For instance, Climeworks partnered with a bottler for Coca-Cola to provide CO₂. If they had not provided the CO₂, then that bottler would have gotten it from another source, either produced for that purpose or captured from industrial processes. While we have not focused on this part of their business in this investigation, we expect Climeworks CO₂ to be more carbon negative than the average alternative CO₂ that their partners would purchase.

Finally, because of how much energy is required to run DACS machines, there is concern with DACS projects over whether the processes are net carbon negative. With Climeworks, we are confident that their carbon offset project is net carbon negative. Their facility is powered by a geothermal power plant that provides them with renewable energy, meaning that the carbon footprint of their operations is relatively low. They are also able to measurably remove CO₂ from the atmosphere and they track the CO₂ being sequestered underground to ensure that it does not leak to the surface. All of this gives us confidence in the actual net-negative outcome of their work.

Overall, we find Climeworks to be an exciting option for purchasing CDR credits. We believe that their CDR credits are immediately additional and have compelling long-term potential.

Our Concerns with Climeworks

1. **They are expensive**. The current cost of offsetting a ton of carbon is approximately $1,100. This is significantly more expensive than any other CDR credits that we have found.

   **Our take**: there are very few carbon offsets that offer the additionality and certainty of Climeworks. As such, we recommend them even though they are expensive. Additionally, we believe that DACS is likely to be an important part of the overall climate change solution, so
believe it is important to invest in this solution even if it is currently expensive. If Climeworks remains much more expensive than our other high-certainty recommendations, we might reconsider including them but for now we believe them to be one of the most sure-fire ways to reduce CO₂ in the atmosphere, and we conclude that their CDR credits are worth purchasing.

2. **They are not verified by a 3rd party verification organization.** Unlike many carbon offsets that are verified by a 3rd party like Gold Standard or Verra, Climeworks’ carbon CDR credits are not yet verified by a 3rd party. This means that there is less monitoring and validation of their work, as well as less publicly available information on them. Climeworks has informed us that they are currently undergoing the certification process with two external certification groups. They expect the certifications to be completed by mid-2021.

   **Our take:** this is a downside to Climeworks. While it does not negate them from consideration for us - we were able to plug some of the gaps by talking with their team and other associated organizations - the fact that they are not verified meant that we have less certainty in the validity of their CDR credits and less publicly available data to use in making our assessment. We look forward to seeing the third party verifications of their CDR credits in 2021.

3. **They are for-profit.** This means that their CDR credits will eventually be going to repay investors and the founders for their risk. While this can be concerning with some companies, we are not yet worried about this with Climeworks for two reasons:

   a. They are not currently profitable meaning that the concerns mentioned above are not currently problems.

   b. They require a significant upfront capital investment to create their technology and plants. This is unlikely to happen without a profit motive for investors, meaning that a for-profit structure is likely one of the only ways that this technology and these projects could exist.

   **Our take:** we are going to continue monitoring the cost-effectiveness of Climework’s CDR credits compared to the other high-certainty alternatives. If their CDR credits do not remain competitive within the space - suggesting that they are taking home more in profit - we will adjust our recommendations accordingly. We will also continue to monitor their financial situation as possible to help avoid a situation where our recommendations are going towards exorbitant profits. (Some profit is reasonable given capital risk, but large profits likely suggest that other offsets would be more efficient.)

4. **They do not share financial information publicly.** While this is understandable given the competitive nature of their field, we are currently unable to verify their financial claims beyond talking with their team about their financials. We would like for them to share more of their financial information publicly.
Our take: we do not have the full financial picture of Climeworks, which does introduce some risk. That said, we are sufficiently confident in the information their team provided us for us to recommend them even though their publicly available financial information is limited.

CARBON ENGINEERING

While we are excited about the work of Carbon Engineering, they do not currently have carbon offsets for purchase by individuals and thus we do not recommend them.

Carbon Engineering is an industry-leading Canada-based company that works with corporate clients to use the CO₂ they collect for commercial purposes. They have a pilot plant in Squamish, Canada and have several ongoing projects with businesses in the United States, including construction on the world’s largest DAC plant in Texas for the oil and gas company Occidental Petroleum Corporation.

We are excited about Carbon Engineering because they have released projections that their technology could lead to cost-effective DAC, which would be a big step forward. One of the main problems with Climeworks is the high cost. By reducing the cost, Carbon Engineering would make DAC projects even more attractive.

While Carbon Engineering appears to be pushing innovation with DAC, Giving Green does NOT currently recommend Carbon Engineering for three reasons:

1. **Carbon Engineering does not provide offsets that individuals can purchase.** Companies can partner with Carbon Engineering for large-scale projects, but they do not currently have non-bespoke carbon offset offerings.

2. **Carbon Engineering is providing their technology for enhanced oil recovery.** While using CO₂ pulled from the air in enhanced oil recovery is preferable to producing new CO₂ for these purposes, we are worried about the net carbon footprint of enhanced oil recovery and are thus reticent to recommend a company that is making this part of their business at this time. We are open to changing this position if we get more information on the carbon calculation of Carbon Engineering’s work with companies like Occidental Petroleum Corporation.

3. **Carbon Engineering is still piloting their technology and has been slow to market.** Based on our conversation with their team and publicly available information, we are under the impression that Carbon Engineering has been slow in getting their technology to market. Unlike Climeworks that has built a modular technology, Carbon Engineering’s technology requires constructing a large facility. This makes their deployment slower, and to-date they have remained in the prototype phase.

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6 https://on.wsj.com/37pM6PX

7 Climeworks is specifically ruling out this type of work from their business strategy.
OTHER SIMILAR FIRMS

We have also found other DAC projects that work in the commercial space, such as Global Thermostat\(^8\), but none of them appear to sell carbon offsets. As such, we are leaving them out of this analysis.

RECOMMENDATION

We recommend purchasing CDR credits from Climeworks for the following reasons:

1. We are very sure that their project is permanently removing CO\(_2\) from the atmosphere
2. We believe that each dollar invested in their work will additionally remove carbon
3. We are convinced that investments in their work right now are entirely being used to offset carbon as opposed to simply maximizing profit
4. We see long-term potential in their DAC technology

You can purchase CDR credits from Climeworks [at this link](#).

SELECT SOURCES


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\(^8\) Global Thermostat is a commercial-oriented DAC start-up that has also developed technology to pull CO\(_2\) from the air and sell for commercial purposes. Started in 2010, they have opened their first plant in Alabama in 2018 and are marketing their CO\(_2\) across multiple sectors including food and beverages, plastics, greenhouses, biofertilizers, industrial gases, synthetic fuels, water desalination, EOR, and building materials.


