Climeworks

APPLICATION FOR STRIPE 2020 NEGATIVE EMISSIONS PURCHASE

Section 1: Project Info and Core Approach

1. Project name

Climeworks Carbon Dioxide Removal

2. Project description. ***Max 10 words***

Climeworks captures CO_2 with direct air capture technology and permanently removes it from the atmosphere.

3. Please describe your negative emissions solution in detail, making sure to cover the following points:
   a) Provide a technical explanation of the project, including demonstrations of success so far (preferably including data), and future development plans. Try to be as specific as possible: all relevant site locations (e.g. geographic regions), scale, timeline, etc. Feel free to include figures/diagrams if helpful. Be sure to discuss your key assumptions and constraints.
   b) If your primary role is to enable other underlying project(s) (e.g. you are a project coordinator or monitoring service), describe both the core underlying technology/approach with project-specific details (site locations, scale, timeline, etc.), and describe the function provided by your company/organization with respect to the underlying technology/approach.
   c) Please include or link to supplemental data and relevant references.

Max 1,500 words *(feel free to include figures)*

Climeworks captures CO_2 from ambient air with the world's first commercial Carbon Dioxide Removal technology. The Climeworks Direct Air Capture plants capture CO_2 with a patented filter and are powered by either waste or renewable energy.

Climeworks offers Carbon Dioxide Removal, enabling customers to realize their climate goals by safely and permanently storing air-captured CO_2 underground, and thereby ultimately stopping climate change from reaching dangerous levels.

The current Climeworks Carbon Dioxide Removal technology is applied in Iceland. Here, CO_2 is captured from air by Climeworks and turned into stone by CarbFix, using renewable energy from ON Power.

Acknowledgement: The project CarbFix2 has received funding from the European Union's Horizon 2020 research and innovation programme and is led by Iceland's multi-utility company Reykjavik Energy. It is based on the

original CarbFix project, initiated in 2007. Further partners to CarbFix2 are The University of Iceland, CNRS (Toulouse, France) and Amphos 21 (Barcelona, Spain). This group of partners is referred to as the "CarbFix consortium".

The Carbon Dioxide Removal process is as follows: the Climeworks Direct Air Capture technology captures CO_2 from air. Thanks to the CarbFix process, the CO_2 is then mixed with water from the Hellisheiði Geothermal Power Plant and pumped deep underground for geological mineralization. Advantageous is the porous basaltic rock, which serves as a perfect basis for CO_2 storage. Through natural processes, the CO_2 reacts with the basaltic rock to become solid carbonates (another form of rock) within just two years. Mineralized in the pores of the basalt several hundred meters below ground, the CO_2 is removed from the atmosphere permanently and safely. Iceland is one of several locations around the world that provide the ideal conditions for this pioneering process.

The basaltic conditions at existing geothermal power plants such as Hellisheiði make Iceland a very good place to start the permanent storage of CO_2. There are, however, many places worldwide that have similar conditions. The Icelandic Rift System, for example, has a capacity of 50 million tons of CO_2 per year. On a global scale, studies have estimated an overall capacity of 30 trillion tons of CO_2. Other suitable locations include North America, the Middle East, China, regions in Africa and oceanic ridges.

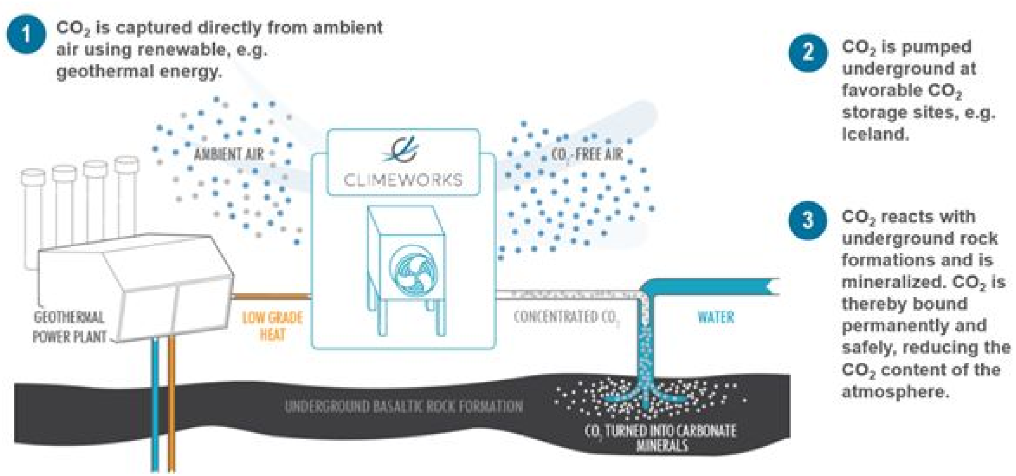
Together with the CarbFix consortium, we currently remove around 50 tons of CO_2 per year from the atmosphere in Iceland. Following the successful completion of this pilot phase, Climeworks and its partner CarbFix are now amidst the project-planning phase for expanding its Carbon Dioxide Removal capacity in Iceland.[LC1] Namely within the next 12 months, we plan to commission a scaled-up plant on the premises of the Hellisheiði Geothermal Power Plant in Iceland with capture capacity of several thousand tons of CO_2 per year. Our development roadmap forecasts future Climeworks Carbon Dioxide Removal capacities, at a range of locations worldwide, of over 50 million tons of CO_2 per year as of 2030, with specific milestones to be reached about every two years.

As mentioned above, storage capacities are widely available globally. One challenge for Climeworks will be securing the required access to renewable energy to power the plants.

For an interesting paper regarding the CarbFix geological mineralization process in Iceland, please see: https://www.nature.com/articles/s43017-019-0011-8

[LC1]As per http://www.climeworks.com/wp-content/uploads/2018/10/CDR-1.5-goal-Climeworks-press-release.pdf

Image depicting the current process:



Section 2: 2020 Net-Negative Sequestration Volume

See Stripe Purchase Criteria 1: The project has volume available for purchase in 2020.

4. Based on the above, please estimate the **total net-negative sequestration volume** of your project (and/or the underlying technology) in 2020, in tons of CO2. (Note: We're looking for the net negative amount sequestered here, net lifecycle emissions. In Section 3; you'll discuss your lifecycle and why this number is what it is).

50 tons of CO2

5. Please estimate how many of those tons are still available for purchase in 2020 (i.e. how many tons not yet committed). This may or may not be the same as the number above.

1

6. (Optional) Provide any other detail or explanation on the above numbers if it'd be helpful. ***Max 100 words.***

These numbers come from our pilot plant commissioned in October 2017 at the Hellisheiði Geothermal Power Plant, which has a yearly Carbon Dioxide Removal capacity of 50 tons. The 2020 capacity has been sold and attributed to customers already, however we would be able to redirect 1 ton of CDR to Stripe (CO2 captured and stored in 2020), as a symbolic amount to open the doors for future collaborations.

As we are currently developing our CO2 removal capacities, we are offering customers to buy, today, CO2 removal, which we will deliver in the next 4 years.

The first milestone of our scale up is the commissioning of the next plant in Iceland, which will have a capacity of capturing several thousand tons of CO2 per year. When including these capacities, our available capacities for sale in 2020 are higher.

Section 3: Life Cycle Analysis

See Stripe Purchase Criteria 2: The project has a carbon negative complete lifecycle (including energy use, etc).

7. Provide a life cycle analysis of your negative emissions solution demonstrating its carbon negativity, as complete as possible given limited space, and making sure to cover the following points:

a) Include a flow sheet diagram of direct ingoing and outgoing flows (GHG, energy, materials, etc) that bear on the LCA.
b) Please be explicit about the boundary conditions of your LCA, and implications of those boundaries on your life cycle. Let us know why the conditions you've set are appropriate to analyze your project.
c) Make sure to identify assumptions, limitations, constraints, or factors that relate to ingoing and outgoing flows, citing values and sources (for example: land and resource scarcity, limitations on a required chemical, energy requirements). Also identify key sources of uncertainty in determining these values.
d) If your solution results in non-CO2 GHG emissions, please be sure to separately specify that (e.g. in units of GWP 20 or 100 years, ideally both).
e) For solutions that rely on modular components (for example: incoming energy flows or outgoing CO2 streams), feel free to cite values associated with those interfaces instead of fully explaining those components. For these values, please identify the upstream and downstream life cycle emissions of the component.
f) Explain how you would approach a more comprehensive LCA by citing references and underlying data needed for the analysis.

***Max 1,000 words** (feel free to include figures or link to an external PDF)*

The main motivation of capturing CO_2 from the atmosphere is the reduction of the climate impact.

The cradle-to-grave environmental impacts for Climeworks' captured and sequestrated CO_2 is continuously assessed and reviewed through external independent partners. The cradle-to-grave system boundaries include all processes associated with the supply of the product captured CO_2, i.e. the construction, auxiliaries, energy supply and adsorbent for the DAC plant, recycling and disposal after lifetime, as well as with geological storage (i.e. carbon dioxide removal).

Our assessments focus on the environmental impact 'climate change'. However, other environmental impacts are associated with our system and 15 further environmental impact categories have been assessed to determine potential environmental trade-offs and to detect potential burden shifting (incl. ozone depletion, particulate matter, acidification, eutrophication freshwater).

The function of direct air capture systems is to capture CO_2 from ambient air and subsequently permanently remove it. Hence, we define "1 kg CO_2 sequestrated" as a functional unit.

The results provided below are derived from the independent study performed by researchers at the University of Aachen, Germany, based on Climeworks Life Cycle Inventory for the 3000tCO_2[MT1] /y, being commissioned in 2020.

The main sources of GWP are the sorbent material, the energy used in the process and construction.

- Climeworks CO_2 capture and sequestration process requires a mix of electricity and heat.
    - Electricity is used during operation of the plant, to pull air through the adsorbent, as well as for sequestration, where CO2 is compressed and injected into an underground geological formation.

- Thermal energy is needed to heat up the adsorbent in the collector to initiate the desorption of CO_2

- The total GWP contribution from the sorbent material depends on its manufacturing and disposal, as well as the lifetime of this material in our DAC plant.
- Recycling of the metal parts of the plant at the end of life is considered when assessing the impact of the construction of the plant.

Taking into consideration a detailed analysis of these different inputs, we expect our DAC plants to reach a carbon removal efficiency (cradle-to-grave) of > 90%, if the energy is provided from a renewable source, such as for example geothermal energy. A top level overview of the contributions to this number is provided Figure 1.

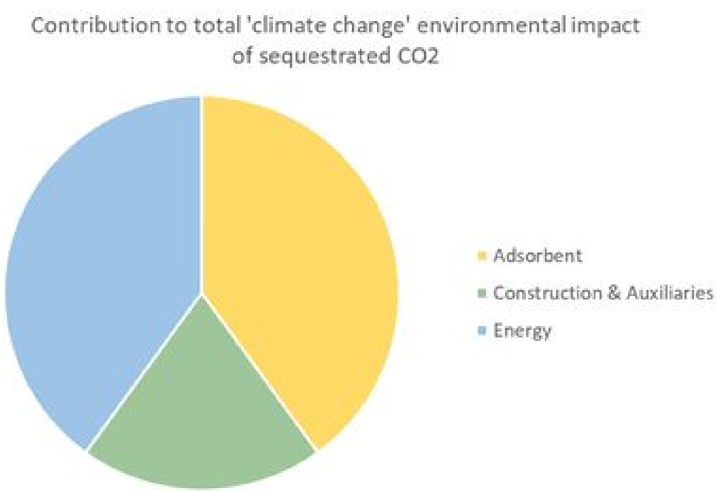


Figure 1: 'Climate change' environmental impact contributions

Future work:

The LCA of our entire product lifecycle is a critical aspect of Climeworks's activities. This is why we have, for many years already, partnered up with researchers, universities and independent experts to support us in making independent reliable assessments of our products. We already provide our inventory to researchers and welcome critical assessment of our products. Future avenues to explore would include more detailed analyses of our supply chain, which we have already started by having some of our key suppliers' environmental footprint independently assessed.

8. Based on the above, for your project, what is the ratio of emissions produced as any part of your project life cycle to CO2 removal from the atmosphere? For true negative emissions solutions, we'd expect this ratio to be less than 1.

0.1

Section 4: Permanence and Durability

stripe

See Stripe Purchase Criteria 3: The project provides durable, long-term storage of carbon.

9. Provide an upper and lower bound on the likely durability / permanence of sequestered carbon provided by your project, in years:

The likely durability is absolute permanence (i.e. millions of years).

10. Please provide a justification for your estimates, and describe sources of uncertainty related to: the form of storage, effects of environmental or climatic variability, difficulty in monitoring or quantification, etc. Specifically, discuss the risks to permanence for your project, the estimated severity/frequency of those risks (e.g. 10% of the acres of forest in this forest type are burned by fire over a 100 year period), and the time-horizon of permanence given those risks.

Max 500 words

The Climeworks DAC technology and the CarbFix method for geological storage guarantee permanent and safe Carbon Dioxide Removal.

From the perspective of an expert risk assessment, the risk of leakage and perceptible induced seismicity are small for conventional CO_2 storage, as both the probability and consequence of such happenings are minimal. In the specific case of the CarbFix method for geological CO_2 storage, the risks are again significantly decreased or even excluded.

Contrary to the conventional method of injecting pure CO_2 at supercritical conditions, CarbFix dissolves the CO_2 in water prior to injection. The resulting solution of carbonic acid has a higher density than the saline formation water present in the reservoir, such that the dissolved CO_2 is negatively buoyant. Hence, the risk of upward leakage through the cap rock is physically excluded. Furthermore, the highly reactive nature of the basaltic rock formations prevailing at the storage site enables spectacularly rapid mineralization of the CO_2, i.e. the dissolved CO_2 reacts with rock minerals to form solid carbonates, such as $CaCO_3$ (calcite). CarbFix has demonstrated the mineralization of 95% of the injected CO_2 within two years. In conventional CO_2 storage, dissolution and mineralization of the CO_2 require centuries to millennia. Thermodynamically, carbonates represent the lowest-possible energy level a carbon atom can attain and consequently, carbonate rocks are hardly reactive and environmentally benign. Leakage of CO_2 back into the atmosphere requires unusual conditions – e.g. direct contact with magma during the birth of a new volcano – and is highly unlikely to occur. Should it happen against all odds, the release of CO_2 would remain small as only a fraction of the mineralized CO_2 would be directly in contact with magma.

The risks concerning induced seismicity are put in perspective by the fact that the maximum CO_2 fraction in the injected water is approximately 3%-wt. Consequently, the co-injection of such small fractions of CO_2 do not alter the seismic risks significantly. The consequences of water injection and production at the Hellisheiđi geothermal power plant in Iceland are expertly understood after more than a decade of geothermal operations and the monitoring system on site has validated that there is no increase of seismicity that could lead to large earthquakes or rock failure.

The characterization and monitoring of the storage reservoir goes beyond the high standards typically applied for CO_2 storage, primarily due to the fact that the CO_2 is stored directly in the geothermal reservoir. The geothermal operation motivated and funded the drilling of tens of boreholes for injection, production and monitoring. Each of these boreholes provides invaluable information about the subsurface and the extraction of the geothermal brine allows for the monitoring of the fate of the CO_2 in the reservoir with high accuracy. As an additional and redundant monitoring technique, the CO_2 flux from the top soil is measured continuously and compared to historical background data, in order to detect any unusual appearance of CO2.

Climatic variability does not affect the CO_2 in the geothermal reservoir, which is at about 1,700 m depth.

Section 5: Verification and Accounting

See Stripe Purchase Criteria 4: The project uses scientifically rigorous and transparent methods to verify that they're storing the carbon that they claim, over the period of time they claim to.

11. Provide detailed plans for how you will measure, report, and verify the negative emissions you are offering. Describe key sources of uncertainty associated with your monitoring, and how you plan to overcome them.
Max 500 words

An inherent advantage of Climeworks CDR is its nature as a transparent, metered, and permanent carbon removal technology. With the help of flow meters, we can measure exactly how much CO_2 is captured from the atmosphere and how much is injected into the storage formation, i.e. the geothermal reservoir. Climeworks has experience in measuring the CO_2 flow generated in its DAC plants, including in commercial settings where a customer is billed based on the measured amount.

Monitoring of the permanence of the geological CO_2 mineralisation is described in Section 4. In summary, CO_2 leakage from the reservoir is unlikely from the perspective of the physico-chemical processes involved, due to 100% complete dissolution trapping and ultra-rapid mineral trapping. In addition, the fate of the CO_2 is monitored by sampling the formation water and by analyzing its geochemistry. The dissolution and mineralization of CO_2 in the reservoir can directly be retraced through such chemical analysis. Furthermore, CO_2 surface flux measurements monitor a large area above the storage reservoir as a redundant tool that ensures the detection of any potential leakage – irrespective of how improbable it is.

In summary, the concept behind verifying the negative emissions and their permanence is to know exactly how much CO_2 has been removed and to guarantee 100% permanent storage.

12. Explain your precise claim to ownership of the negative emissions that you are offering. In particular, explain your ownership claim: 1) in cases in which your solution indirectly enables the direct negative emissions technology and 2) when, based on the LCA above, your solution relies on an additional upstream or downstream activity before resulting in negative emissions. Please address the notion of "double counting" if applicable to your project, and how you'll prevent it.
Max 200 words

Climeworks CDR enables negative emissions directly. The only upstream activity that affects the life cycle emissions is the provision of energy to the DAC plant. As described above, the energy is provided by the geothermal power plant in the form of low-grade heat and electricity. Geothermal power has an exceptionally low carbon intensity, particularly in Iceland, where the natural conditions of the geology are ideal with geothermal gradients of >100°C/km.

Section 6: Potential Risks

This section aims to capture Stripe Purchase Criteria 5: The project is globally responsible, considering possible risks and negative externalities.

13. Describe any risks or externalities, any uncertainties associated with them, and how you plan to mitigate them. Consider economic externalities, regulatory constraints, environmental risk, social and political risk. For example: does your project rely on a banned or regulated chemical/process/product? What's the social attitude towards your project in the region(s) it's deployed, and what's the risk of negative public opinion or regulatory reaction?
Max 300 words

Regulatory constraints are not in sight for the existing, as well as for the planned project. The planned facilities are going to be built in an existing industrial park and the responsible municipality is eager to attract companies to the park. Injection permits are already in place for the operation of the geothermal plant and the political environment is in favor of climate change mitigation projects with value creation in Iceland.

The public perception of onshore CO_2 storage is negative to neutral in Europe, outside of Iceland and Norway. In general, new projects tend to explore offshore CO_2 storage, which is more widely accepted.
The negative perception of geological CO_2 storage is often intensified by a limited understanding of underground activities. Wrong mental models of empty cavities that would be filled with highly pressurized CO_2 or the perception of CO_2 as an explosive gas are a consequence of this lack of understanding. Hence, there is a need for knowledge transfer about geological CO_2 storage and the physico-chemical working principles behind it. In addition, there is a specific need for education about the differences between point source CO_2 capture and DAC and between conventional CO_2 storage and the CarbFix method for geological CO_2 mineralization.

In Iceland, people are generally very familiar with geothermal energy operations, and hence, with the underground. Being situated in the cold climate zone of the arctic with its particularly fragile natural environment, Icelanders are particularly aware of and worried about climate change. The CDR operations in Hellisheiði are therefore perceived very positively, in general.

Nevertheless, Climeworks will continue to communicate transparently and pro-actively about the project and strive to further improve climate change awareness and the knowledge about geological CO_2 storage and in particular about geological CO_2 mineralization via the CarbFix method.

Section 7: Potential to Scale

This section aims to capture Stripe Purchase Criteria 6: The project has the potential to scale to high net-negative volume and low cost (subject to the other criteria).

14. Help us understand how the cost and net-negative volume of your solution will change over time. Note that we aren't looking for perfect estimates. Instead, we're trying to understand what the long-term potential is and what the general cost curve to get there looks like. (Note: by "cost" here we mean the amount Stripe or any other customer would pay for your solution):

	Today	In ~5 years	In ~20 years
Est. Cost per net-negative ton (in $)	735-800 (sales price >1'000 in our webshop)	250-350	100

Est. Net-negative volume (in tons of CO2)	50	1’100’000	100’000’000

15. What are the drivers of cost? Which aspects of your costs could come down over the next 5 years, and by how much? Do you think your eventual scale potential is limited by cost or by volume? Why? Refer to any relevant constraints from question #7, like land or materials scarcity, and specify the boundary conditions for which you consider those constraints.

Max 300 words

The main cost drivers are OPEX which include operational and maintenance costs and CAPEX. We will benefit from economies of scale on various aspects: the cost of developing our technology will lower, we will scale our production which will lower the fixed costs per ton and we will be able to manage operational costs on a bigger scale and more automatized way, which will as well drive costs down.

Section 8: Only for projects with significant land usage

See Stripe’s Purchase Criteria 2: The project has a net cooling effect on the climate (e.g. carbon negative complete life cycle, albedo impact, etc.) ***This section is only for projects with significant land usage requirements: Forest, Soil, and BECCS/Biochar/Biomass sequestration projects.***

16. Location: Please provide baseline information about the geographic location(s) of your project; and link shapefile(s) of project area(s).
Max 100 words

na

17. Land ownership: Please describe the current (and historical as relevant) land ownership and management for the area(s) provided in (16). If your project is not the landowner, describe your relationship to the landowner.
Max 150 words

na

18. Land use: For forest projects, please provide details on forest composition as well as forest age and basal crop area/density. For soil projects, please provide details on land use and crop type (if agricultural), soil organic

carbon baselines, and regenerative methodology. For BECCS, biochar, or wooden building materials projects, please provide details on biomass crop type and methodology as applicable.
Max 500 words

na

19. Net effect on climate: Please discuss the non-CO2 impacts of your project that may not be covered in your LCA, such as your impact on albedo.
Max 150 words

na

Section 9: Other

20. What one thing would allow you to supercharge your project's progress? This could be anything (offtakes/guaranteed annual demand, policy, press, etc.).
Max 100 words

On the commercial side we need pioneering clients to embark on the Climeworks Carbon Dioxide Removal journey with us. They will serve as references to prove the business case of large scale Carbon Dioxide Removal and help us drive education, credibility and knowledge of the technology. On the policy side, we need governments to agree on a global price of carbon.

21. (Optional) Is there anything else we should know about your project?
Max 500 words

Climeworks currently has 14 pilot plants across Europe, we use low grade heat and work only with renewable energy. This enables us to have a very low carbon footprint and thus a real impact on the density of CO_2 in the atmosphere.

Section 10: Submission details

*This section **will not** be made public.*

22. Please insert below the name and title of the person submitting this application on behalf of your company (or, if you are submitting this application on your own behalf, your own details). By submitting this application, you confirm that you have read and accept the Project Overview (available HERE), as well as the further conditions set out below. As a reminder, all submitted applications will be made public upon Stripe's announcement. *Once you've read and completed this section, submit your application by March 20th by clicking the blue "Share" button in the upper right, and share the document with **nets-review-2020@stripe.com**.*

Name of company or person submitting this application

[redacted]

Name and title of person submitting this application (may be same as above)

[redacted]

Date on which application is submitted

[redacted]

We intend to make the selection process as informal as possible. However, we do expect that (a) the content of your application is, to the best of your knowledge, complete and correct; (b) you do not include any content in your application that breaches any third party's rights, or discloses any third party's confidential information; (c) you understand that we will publicly publish your application, in full, at the conclusion of the selection process. You also understand that Stripe is not obliged to explain how it decided to fund the projects that are ultimately funded, and - although extremely unlikely - it is possible that Stripe may decide to not proceed, or only partially proceed, with the negative emissions purchase project. Finally, if you are selected as a recipient for funding, Stripe will not be under any obligation to provide you with funding until such time as you and Stripe sign a formal written agreement containing the funding commitment.