General Application

(The General Application applies to everyone, all applicants should complete this)

Company or organization name

neustark

Company or organization location (we welcome applicants from anywhere in the world)

Berne, Switzerland

Name of person filling out this application

Valentin Gutknecht

Email address of person filling out this application

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Brief company or organization description

Mineralisation of atmospheric CO_2 in demolished concrete

1. Overall CDR solution (All criteria)

a. Provide a technical explanation of the proposed project, including as much specificity regarding location(s), scale, timeline, and participants as possible. Feel free to include figures.

neustark removes CO_2 from the atmosphere and permanently stores it in construction & demolition waste. We are as of today operating a full CDR value chain that covers all steps from atmospheric CO_2 capture through waste biomass to mineralization in recycled concrete aggregate. The following figure depicts the end-to-end and cross-industry CDR process we are currently orchestrating in Switzerland and which we want to scale globally.

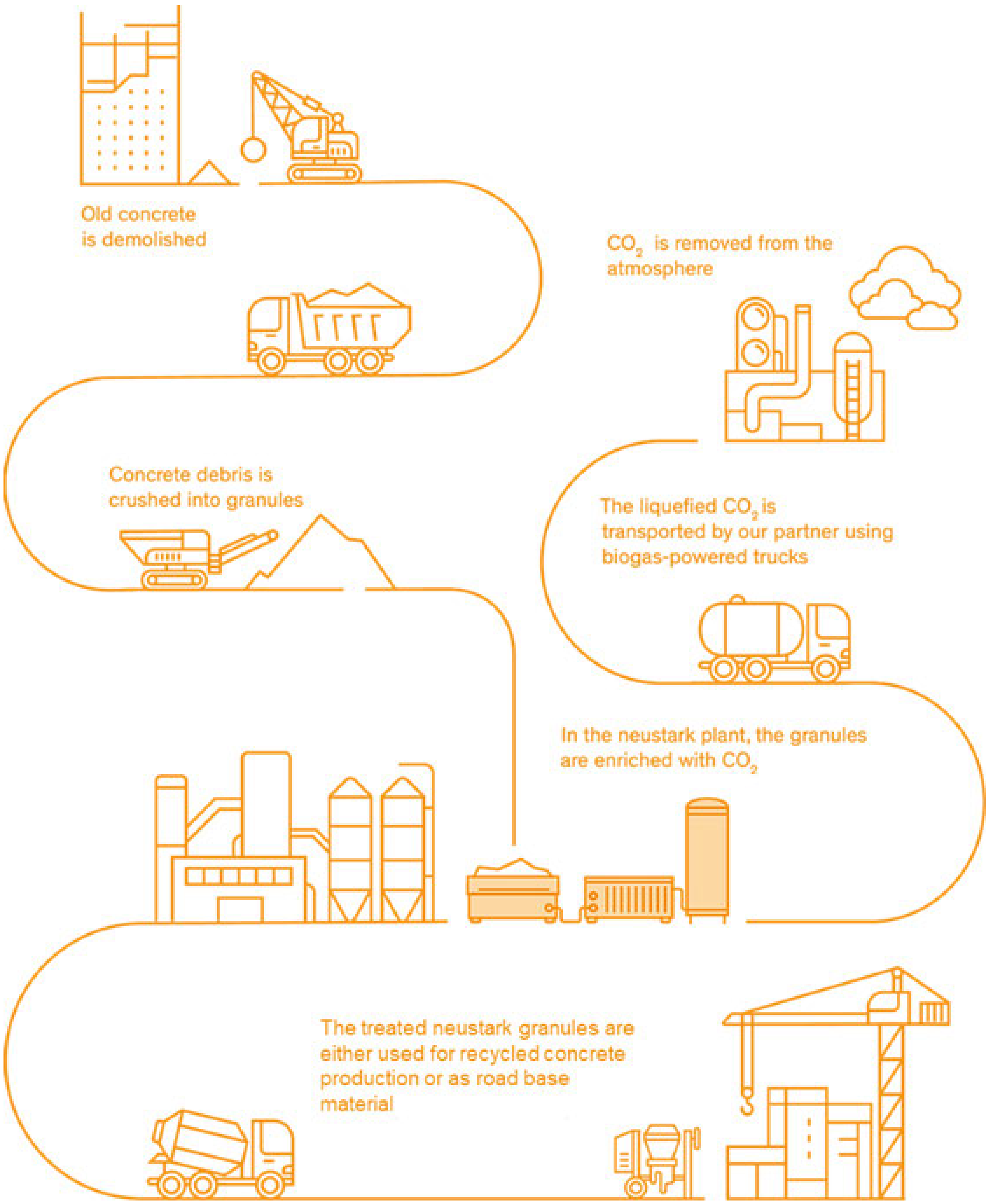


Figure 1: Illustration of neustark's cross-industry value chain

Mineralization process

In our reactors, concrete aggregate obtained from the demolition of buildings is mixed with CO_2.

Figure 2: Mobile neustark plant deployed at the Kästli concrete recycling and production plant in Rubigen, Switzerland

Through so-called mineralization, the carbon dioxide is permanently bound. The $Ca(OH)_2$ of the cement phases of the old concrete together with CO_2 transform into the thermodynamically stable form $CaCO_3$ in an exothermic reaction. This phenomenon essentially reverses the geogenic CO_2 release taking place during cement production. In the construction industry, this process is well researched and known as natural mineralization or carbonation. neustark accelerates the mineralization process from over 1000 years to just a few hours, thereby quintupling the average CO_2 uptake.

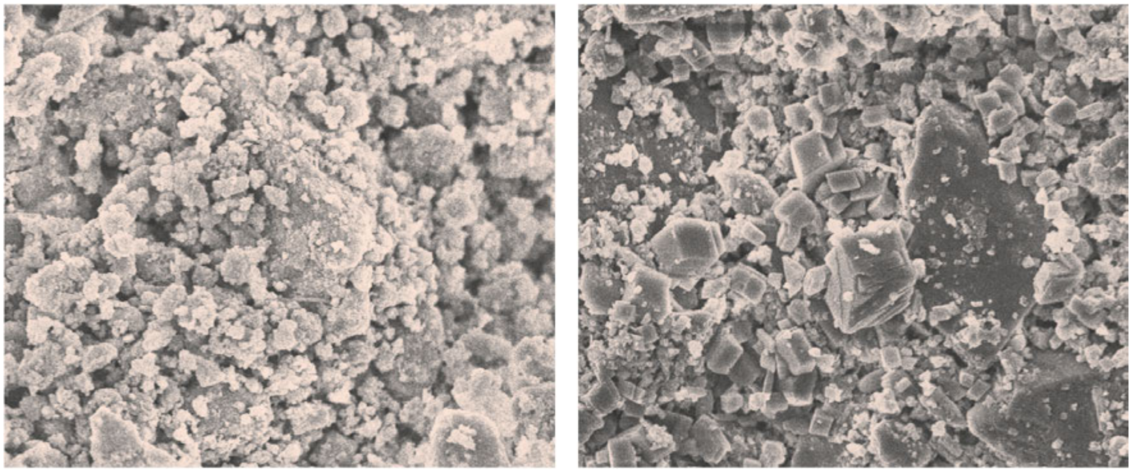


Figure 3: SEM microscopy image of the surface of RCA before (left) and after (right) the neustark process with a clearly visible formation of calcite ($CaCO_3$) crystals.

The CO_2 uptake per ton of RCA is mostly dependent on the particle grain size. Throughout the last 7 months our mobile plant carbonated about 7'000 tons of RCA with a particle diameter of 0-16mm, which is a common size fraction in industry. During this operation we were able to store 7.2 kg CO_2 per ton of RCA on average.

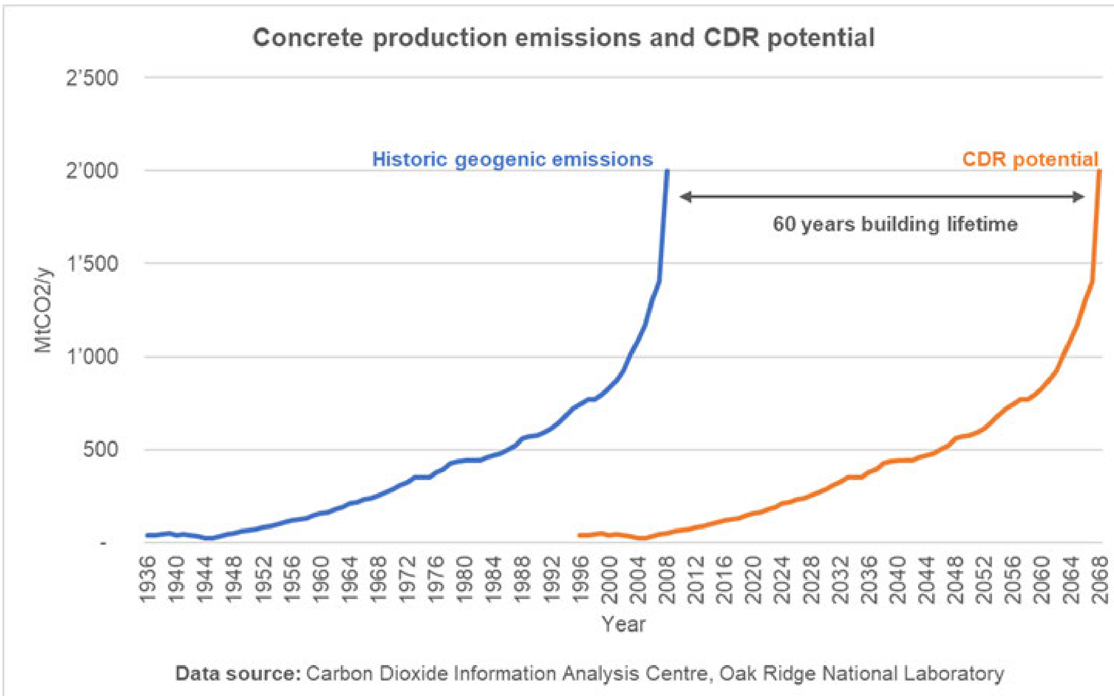
Figure 4: Storage pile of about 800 tons of recycled concrete aggregate (RCA) of size fraction 0-16mm

We systematically analyzed the CO_2 uptake potential of different particle size fractions in the lab. The results clearly show that the finer the material, the more CO_2 is taken up.

Figure 5: CO_2 uptake per ton of RCA of different size fractions

In current industry recycling processes, concrete debris is typically crushed to a maximum grain size of 60, 22 or 16mm. As of today the grain size of the crushed concrete is typically not affected by the neustark technology. Through a combination of a finer crushing of the material and further developments of the neustark technology, there is a potential to store up to 60kg of CO_2 per ton of demolished concrete which means that the geogenic CO_2 emissions of the cement originally used to produce the demolished concrete would be completely reversed.

Based on historic global geogenic cement production emissions and a medium building lifetime of 60 years, we therefore expect the global CDR potential of demolished concrete to double decade after decade and reach 500 $MtCO_2$ by 2050.



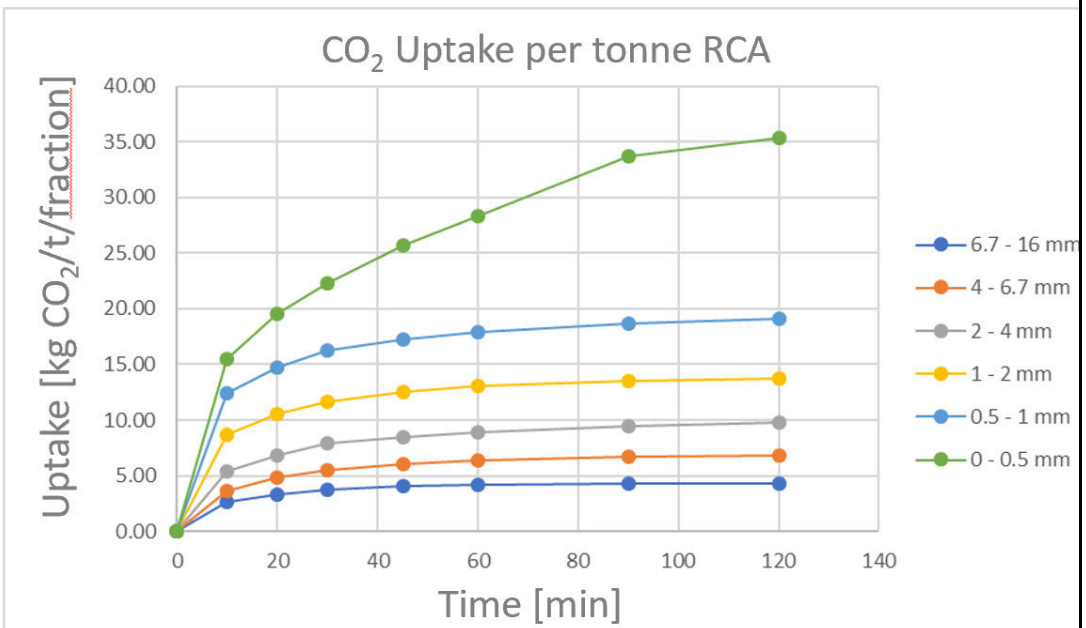


Figure 6: Historic concrete production emissions and future CDR potential.

The total global CO_2 uptake potential of neustark's approach can be further enlarged by applying the technology to other alkaline waste streams (e.g. slags) or even alkaline natural mineral formations (e.g. olivine or basalt). It is our ambition to permanently store 1 $GtCO_2$ per year by 2050.

Additionality

Our process takes place after the end of life of a concrete structure and after the recycling process, right before reuse of the recycled concrete. CO_2 storage induced, measured and claimed by neustark therefore happens on top of any natural carbonation of the material. Independently of neustark, recycled concrete aggregate (RCA) is mostly used as road base material or for production of lean concrete. A small fraction (<5%) is used for the production of structural concrete. In any case the material will be isolated from atmospheric CO_2 supply during its re-use phase, which means that with or without neustark, no further natural carbonation takes place.

Atmospheric CO_2 capture

We source the CO_2 from the biogas upgrader which is located at Ara Region Bern . Ara Region Bern is a waste water treatment plant. The sludge, which is discharged from their waste water treatment processes goes through digesters and is transformed to biogas (about 60% methane, 40% CO_2). The CO_2 is separated from the biogas to comply with the natural gas standards and to be able to feed it to the natural gas grid.

Figure 7: neustark CO_2 truck in front of the Ara Region Bern biogas upgrader (absorption column in the background on the right)

Up until now, the removed biogenic CO_2 stream of about 5'000 tCO_2 has been released to the atmosphere. In april 2021 neustark will start to capture, liquefy and transport this biogenic CO_2 for utilization and negative emissions in its mineralization plants.

Figure 8: neustark CO_2 liquefaction unit during factory acceptance test

The situation at Ara Region Bern is representative of many larger scale sewage treatment and biogas plants with biomethane production around the globe and thus can be replicated. For neustark, biomethane production is the ideal CO_2 source because first, the CO_2 off gas is typically already available at a purity of around 99% and just needs to be liquefied and transported. Second, biomethane is just as concrete recycling a decentralized process with often a very good match of capacities. This means that we can deploy many local CDR networks mostly in metropolitan areas around the globe where one biomethane production facility can typically supply several mineralization plants located at concrete recyclers in a diameter of up to a few hundred kilometers. The IEA estimates global biomethane production to account for 75 to 200 Mtoe by 2040 which would translate into a CO_2 supply potential of 100 to 300 $MtCO_2$ per year. Beyond biomethane production, the 33 to 50% biogenic share of CO_2 from waste incineration as well as DAC (e.g. Climeworks) are well suited CO_2 sources for our process whereas none of them requires any additional biomass cultivation.

Who we are and status
Research on our technology started in 2017. The company was founded in 2019 by Johannes Tiefenthaler and Valentin Gutknecht as a Spinn-off of ETH Zürich. In the same year, we were able to close our first financing round and secure public grants from the EU (Climate-KIC), Switzerland (Swiss Federal Office for the Environment and Swiss Innovation Agency) and the private sector (Swiss Climate Foundation). With this support in place we were then able to recruit our core team and commission our first mobile plant in commercial scale (Figure 2) by July 2020. The mobile unit triggered significant interest in the Swiss and even European construction market and its performance exceeded our expectation. As a result, we were able to sell the first units and neustark concrete and aggregate is now available across Switzerland at a total of 18 branches of the building material companies Kästli and KIBAG. Test series with Holcim Switzerland and other international building material companies are currently going on. We are a gold-winner of the 2020 MASSCHALLENGE and holder of the Seal of Excellence of the European Innovation Council. As of spring 2021 we are a growing team of 9 people with diverse backgrounds in chemical engineering, environmental sciences and economics.

b. What is your role in this project, and who are the other actors that make this a full carbon removal solution? *(E.g. I am a broker. I sell carbon removal that is generated from a partnership between DAC Company and Injection Company. DAC Company owns the plant and produces compressed CO_2. DAC Company pays Injection Company for storage and long-term monitoring.)*

Our mineralisation plants are owned and operated by our partnering concrete recyclers. We capture and liquefy CO_2 from biomethane production with our infrastructure and transport it to the mineralization plants through partners. We monitor and market CDR certificates and share the revenue with biomethane producers and concrete recyclers.

c. What are the three most important risks your project faces?

We are aware of the following three key risks that could delay the scaleup of our solution. All of them can be mitigated through the right CDR takeoff agreements:

Slow investment decisions
Even with an appealing business case it takes time to make it into the investment budgets of concrete recyclers. This is amongst others due to the perceived risk of betting on the concept of a relatively young startup company. Being able to prove a solid long term CDR offtake from established customers speeds up this process.

Individualization
Engineering a specific mineralization technology for single concrete recyclers might in some cases optimize project-specific economics but significantly slows down the overall roll-out of our technology. A CDR offtake that allows for a flexible geographic deployment mitigates this risk because it allows us in a first stage to pick the most compatible recyclers on an international level.

Matching supply and demand
One key scaleup challenge form neustark is continuously matching supply and demand of CDR certificates, demolished concrete and CO_2 whereas the latter two have to match on multiple regional levels in parallel. A solid upfront CDR uptake allowing for deployment flexibility in terms of time and geography significantly facilitates this balancing act.

d. If any, please link to your patents, pending or granted, that are available publicly.

Not applicable for now, first patents are registered but not published yet.

2. Timeline and Durability (Criteria #4 and Criteria #5)

a. Please fill out the table below.

	Timeline for Offer to Stripe
Project duration *Over what duration will you be actively running your DAC plant, spreading olivine, growing and sinking kelp, etc. to deliver on your offer to Stripe? E.g. Jun 2021 - Jun 2022. The end of this duration determines when Stripe will consider renewing our contract with you based on performance.*	July 2021 - July 2023
When does carbon removal occur? *We recognize that some solutions deliver carbon removal during the project duration (e.g. DAC + injection), while others deliver carbon removal gradually after the project duration (e.g. spreading olivine for long-term mineralization). Over what timeframe will carbon removal occur?* *E.g. Jun 2021 - Jun 2022 OR 500 years.*	July 2021 - July 2023
Distribution of that carbon removal over time *For the time frame described above, please detail how you anticipate your carbon removal*	Evenly distributed over the whole time frame

capacity will be distributed. E.g. "50% in year one, 25% each year thereafter" or "Evenly distributed over the whole time frame". We're asking here specifically about the physical carbon removal process here, NOT the "Project duration". Indicate any uncertainties, eg "We anticipate a steady decline in annualized carbon removal from year one into the out-years, but this depends on unknowns re our mineralization kinetics".	
Durability *Over what duration you can assure durable carbon storage for this offer (e.g, these rocks, this kelp, this injection site)? E.g. 1000 years.*	>1'000 years in the form of calcium carbonate

b. What are the upper and lower bounds on your durability claimed above in table 2(a)?

1'000 - millions of years

c. Have you measured this durability directly, if so, how? Otherwise, if you're relying on the literature, please cite data that justifies your claim. *(E.g. We rely on findings from Paper_1 and Paper_2 to estimate permanence of mineralization, and here are the reasons why these findings apply to our system. OR We have evidence from this pilot project we ran that biomass sinks to D ocean depth. If biomass reaches these depths, here's what we assume happens based on Paper_1 and Paper_2.)*

Since July 2020 we directly measure the conversion of CO_2 into calcium carbonate by both mass uptake of the demolished concrete and mass flows of CO_2 in and out of our reactors. Figure 9 shows how those two independent measurements provide almost identical results.

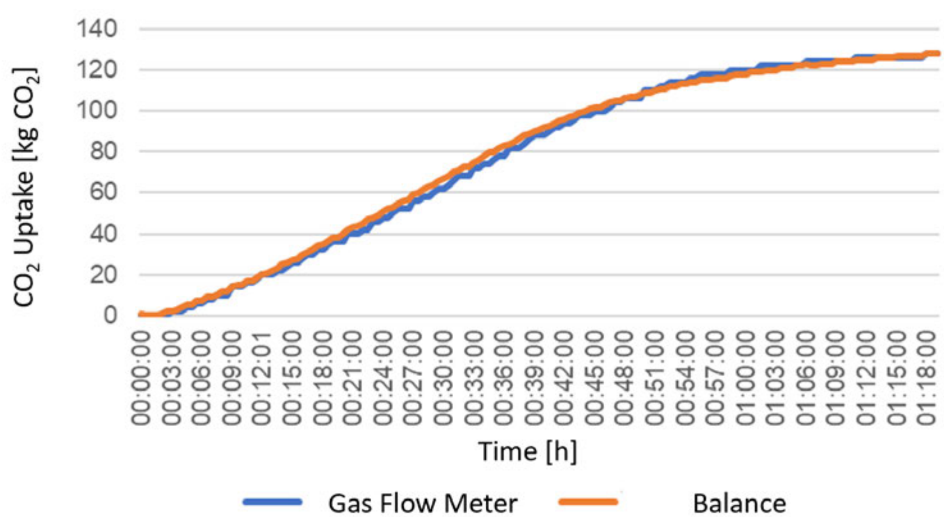


Figure 9: Measurement of the CO_2 uptake through a balance and gas mass flow meters

The results of our industrial scale continuous measurement systems were furthermore validated through thermogravimetry. At ETH Zurich, demolished concrete sand was separated in two samples whereas one was treated with CO_2 by neustark. Figure 10 shows on the left how the sample loses mass while being heated to 1’000 °C. Below temperatures of 530 °C mostly water is released whereas above this temperature point, calcium carbonate is decomposed into CaO and CO_2. It’s clearly visible that about 25% more CO_2 is bound in the form of calcium carbonate in the treated sample compared to the untreated one.

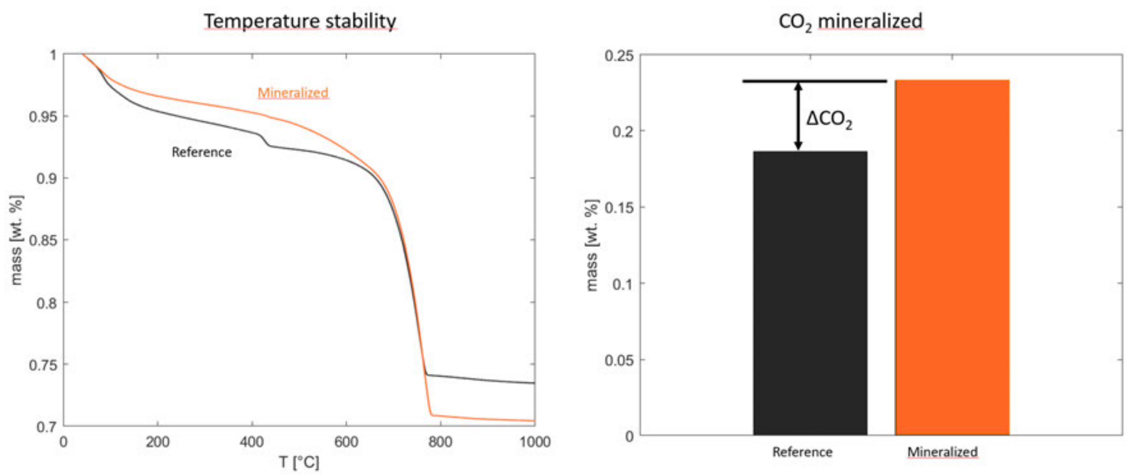


Figure 10: Thermogravimetry measurement supporting that calcium carbonate if formed from CO_2 in the neustark process

d. What durability risks does your project face? Are there physical risks (e.g. leakage, decomposition and decay, damage, etc.)? Are there socioeconomic risks (e.g. mismanagement of storage, decision to consume or combust derived products, etc.)? What fundamental uncertainties exist about the underlying technological or biological process?

The treated material is mostly used as a road base material or as an aggregate for the production of recycled concrete. In any case, a re-release of the transformed CO_2 is highly unlikely - even in case of deconstruction of the recycled road base or concrete element. CO_2 can only be released from $CaCO_3$ at temperatures above 530 °C or in contact with strong acids. The only event in which this is imaginable would be a strong building fire. In that case, loss of CO_2 would be marginal as only the CO_2 stored in one specific burned down building might be re-released. The permanence of CO_2 stored in the form of $CaCO_3$ is also underlined by the Royal Society who says “carbonate minerals are stable and represent perhaps the most secure CO_2 storage option”. The permanence is furthermore also reflected by the EU Commission implementing Regulation 2018/2066 on the EU emissions trading scheme according to which CO_2 chemically bound in the form of calcium carbonate is recognised as not released into the atmosphere.

e. How will you quantify the actual permanence/durability of the carbon sequestered by your project? If direct measurement is difficult or impossible, how will you rely on models or assumptions, and how will you validate those assumptions? *(E.g. monitoring of injection sites, tracking biomass state and location, estimating decay rates, etc.)*

Through online measurement of gas mass flows. For the last seven months and 7’000 tons of RCA the CO_2 uptake was determined through a measurement of both mass increase and gas mass flows (Figure 9). As the two methods continuously delivered almost identical results we plan to continuously reduce the amount of mass measurements.

3. Gross Capacity (Criteria #2)

a. Please fill out the table below. **All tonnage should be described in metric tonnes here and throughout the application.**

	Offer to Stripe (metric tonnes CO_2) over the timeline detailed in the table in 2(a)
Gross carbon removal Do not subtract for embodied/lifecycle emissions or permanence, we will ask you to subtract this later	750tCO_2
If applicable, additional avoided emissions e.g. for carbon mineralization in concrete production, removal would be the CO_2 utilized in concrete production and avoided emissions would be the emissions reductions associated with traditional concrete production	Zero tCO_2 if all of the treated RCA is sold as unbound road base aggregate or for production of recycled lean concrete and up to about 5’000 tCO_2 if all of the treated RCA is used as an aggregate for production of recycled structural concrete where our process can enable cement reductions.

b. Show your work for 2(a). How did you calculate these numbers? If you have significant uncertainties in your capacity, what drives those? *(E.g. This specific species sequesters X tCO_2/t biomass. Each deployment of our solution grows on average Y t biomass. We assume Z% of the biomass is sequestered permanently. We are offering two deployments to Stripe. X*Y*Z*2 = 350 tCO_2 = Gross removal. OR Each tower of our mineralization reactor captures between X and Y tons CO_2/yr, all of which we have the capacity to inject. However, the range between X and Y is large, because we have significant uncertainty in how our reactors will perform under various environmental conditions)*

Stripe removal is expected to happen mostly through a new stationary deployment with a concrete recycler processing 100’000 tons of concrete debris per year into an RCA with a maximum particle size of 16mm and thus an average CO_2 uptake of about 7.2 kg per ton.

In case of an unexpected delay or technical problem with the new stationary deployment we could also achieve the offered removal until July 2023 by operating our existing mobile plant with fine RCA particles (see point c).

c. What is your total overall capacity to sequester carbon at this time, e.g. gross tonnes / year / (deployment / plant / acre / etc.)? Here we are talking about your project / technology as a whole, so this number may be larger than the specific capacity offered to Stripe and described above in 3(b). We ask this to understand where your technology currently stands, and to give context for the values you provided in 3(b).

In a 8 hours per day one shift operation, our current mobile mineralization plant has an annual capacity to mineralize about 215 tons of CO_2 per year in about 30’000 tons of demolished concrete crushed to a maximum particle size of 16mm. The CO_2 removal capacity of the existing mobile mineralization plant can be increased to >400 tCO_2 per year if finer RCA with particle sizes of 0-2 or 0-4mm is treated.

d. We are curious about the foundational assumptions or models you use to make projections about your solution’s capacity. Please explain how you make these estimates, and whether you have ground-truthed your methods with direct measurement of a real system (e.g. a proof of concept experiment, pilot project, prior deployment, etc.). We welcome citations, numbers, and links to real data! *(E.g. We assume our sorbent has X absorption rate and Y desorption rate. This aligns with [Sorbent_Paper_Citation]. Our pilot plant performance over [Time_Range] confirmed this assumption achieving Z tCO_2 capture with T tons of sorbent.)*

Our commercial operation so far looked the following:

1. 6 Containers could be filled with on average 20 t of 0-16 mm concrete aggregate per day
2. Each container showed a CO_2 uptake of 144 kg within 2 hours (average CO_2 uptake measured over 7’000 t of RCA is 7.2 $kgCO_2$ per tonne of RCA)
3. Minimum of 250 days of operation a year and 30’000 tonnes RCA gives the annual storage capacity per plant with the existing technology.
4. In case, the containers are filled with 20t of 0-4 mm material, the CO_2 uptake per container increases by factor 2 to 3.

e. Documentation: If you have them, please provide links to any other information that may help us understand your project in detail. This could include a project website, third-party documentation, project specific research, data sets, etc.

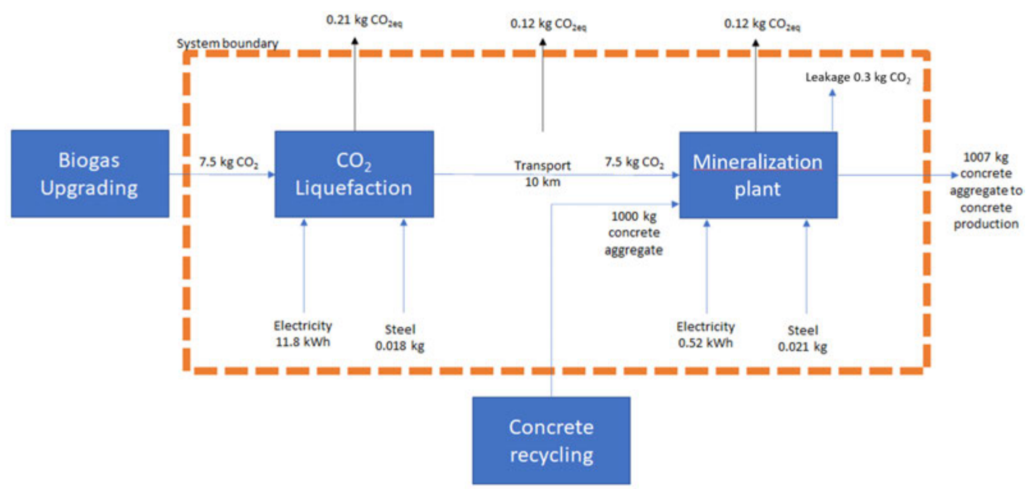
- www.youtube.com/watch?v=QZQvbjKYVBc
- www.neustark.com

4. Net Capacity / Life Cycle Analysis (Criteria #6 and Criteria #8)

a. Please fill out the table below to help us understand your system's efficiency, and how much your lifecycle deducts from your gross carbon removal capacity.

	Offer to Stripe (metric tonnes CO_2)
Gross carbon removal	750 tCO_2
Gross project emissions	46.2 tCO_2
Emissions / removal ratio	0.0616
Net carbon removal	703.8 tCO_2

b. Provide a carbon balance or "process flow" diagram for your carbon removal solution, visualizing the numbers above in table 4(a). Please include all carbon flows and sources of energy, feedstocks, and emissions, with numbers wherever possible *(E.g. see the generic diagram below from the [CDR Primer](), [Charm's application]() from last year for a simple example, or [CarbonCure's]() for a more complex example).* If you've had a third-party LCA performed, please link to it.



c. Please articulate and justify the boundary conditions you assumed above: why do your calculations and diagram include or exclude different components of your system?

System boundaries
We made a differential analysis: (Concrete recycling + CDR technology) - (Concrete recycling). The boundaries correspond to the additional positive and negative emissions associated with the CDR value chain. Since for concrete recycling, upstream and downstream processes do not change, the only additional steps are the CO_2 supply chain and the mineralization plant. The biogas upgrading plant (= CO_2 source) is also outside of the system boundary, since this process is today performed to produce biomethane and CO_2 corresponds to the waste stream which is usually discharged to the atmosphere.

Data Source
Ecoinvent v3.6, making use of the IPCC 2013 GWP 100a V1.03 method

d. Please justify all numbers used in your diagram above. Are they solely modeled or have you measured them directly? Have they been independently measured? Your answers can include references to peer-reviewed publications, e.g. Climeworks LCA paper.

CO_2 Storage capacity
The 7.2 kg CO_2 per ton of RCA were measured in commercial operation throughout the last 7 months - carbonating about 7'000 t of concrete aggregate with a particle size of 0-16mm. However, the effective CO_2 uptake is measured online for every batch.

Liquefaction of CO_2
The required energy and steel for the CO_2 liquefaction is based on what technology suppliers for liquefactions provide in their data sheets.

Transport
Every urban area has concrete recycling plants - but also wastewater treatment plants - with an average distance of 10 km. The roundtrip emissions for a EURO 6 Diesel truck were considered.

Carbonation plant
Requires electricity for the CO_2 reboiler and the process control. An atmospheric reboiler is used to evaporate the CO_2 and keep the energy demand small. Throughout the operation, we measured a CO_2 storage efficiency of 95% - 5% of the gas was leaking to the atmosphere (measured at 80 batches of material). Since the CO_2 is of biogenic nature, the leakage itself is considered to be carbon neutral - however it increases the energy demand of upstream processes, which is taken into consideration. The CO_2 leakage is measured online for every batch.

Work in progress
1. Swiss Environmental Product Declaration for carbonated RCA, 3rd party verified (available mid 2021)
2. Peer-reviewed LCA paper (collaboration of ETH Zurich and PSI) (available mid 2021)

e. If you can't provide sufficient detail above in 4(d), please point us to a third-party independent verification, or tell us what an independent verifier would measure about your process to validate the numbers you've provided. (We may request such an audit be performed.)

5. Learning Curve and Costs (Backward-looking) (Criteria #2 and #3)

We are interested in understanding the learning curve of different carbon removal technologies (i.e. the relationship between accumulated experience producing or deploying a technology, and technology costs). To this end, we are curious to know how much additional deployment Stripe's procurement of your solution would result in. (There are no right or wrong answers here. If your project is selected we may ask for more information related to this topic so we can better evaluate your progress.)

a. Please define and explain your unit of deployment. *(E.g. # of plants, # of modules) (50 words)*

Our unit of deployment is the number of mineralization plants whereas there is typically one plant in operation per concrete recycler.

b. How many units have you deployed from the origin of your project up until today? Please fill out the table below, adding rows as needed. Ranges are acceptable if necessary.

Year	Units deployed (#)	Unit cost ($/unit)	Unit gross capacity (tCO_2/unit)	Notes
2020	1	500'000	215tCO_2/y	Mobile commercial plant currently in operation with 2x15m^3 reactor volume
2019	1	150'000	10tCO_2/y	First reactor deployed at concrete plant with 5m^3 reactor volume
2018	1	<100'000	<1tCO_2/y	Laboratory deployment

c. Qualitatively, how and why have your deployment costs changed thus far? *(E.g. Our costs have been stable because we're still in the first cycle of deployment, our costs have increased due to an unexpected engineering challenge, our costs are falling because we're innovating next stage designs, or our costs are falling because with larger scale deployment the procurement cost of third party equipment is declining.)*

The cost per ton of CO_2 removed from the atmosphere has been falling significantly as we could reduce the capital expenditure per ton of CO_2 removed by deployments of plants with larger throughputs.

d. How many additional units would be deployed if Stripe bought your offer? The two numbers below should multiply to equal the first row in table 3(a).

# of units	Unit gross capacity (tCO_2/unit)
1	720 tCO_2/y

6. Cost and Milestones (Forward-looking) (Criteria #2 and #3)

We ask these questions to get a better understanding of your growth trajectory and inflection points, there are no right or wrong answers. If we select you for purchase, we'll expect to work with you to understand your milestones and their verification in more depth.

a. What is your cost per ton CO_2 today?

700 $/tCO_2$

b. Help us understand, in broad strokes, what's included vs excluded in the cost in 6(a) above. We don't need a breakdown of each, but rather an understanding of what's "in" versus "out."

The cost is calculated on a net carbon removal basis and includes capital, energy and operational expenditure for capture, liquefaction, transportation, intermediate storage and reboiling of biogenic CO_2, mineralization at the concrete recycling site including additional handling of RCA. The collection and the crushing of demolished concrete is excluded as those costs occur independently of the neustark process. The neustark process can in some cases lead to cement savings when being used as an aggregate for production of recycled structural concrete. We did not deduct any cost savings due to this effect as overall, this path of re-use is insignificant. Switzerland is amongst the countries in which recycled concrete is most established and widespread and even here only about 5% of recycled construction aggregates flow into structural concrete applications. The remaining 95% recycled construction aggregates are being used for either lean concrete production or road base construction where carbon mineralization does not generate any economic co-benefit.

c. List and describe **up to three** key upcoming milestones, with the latest no further than Q2 2023, that you'll need to achieve in order to scale up the capacity of your approach.

Milestone #	Milestone description	Why is this milestone important to your ability to scale? (200 words)	Target for achievement (eg Q4 2021)	How could we verify that you've achieved this milestone?
1	Deployment with medium size recycler (100'000 tRCA/y, 720 tCO_2/y) where CO_2 injection will be performed in a stationary construction aggregate silo in Switzerland. This milestone will be enabled by	Through stationary deployments the operational cost for the handling of our current mobile version of more than 250$/tCO_2$ is completely eliminated. Furthermore, the capital cost per tCO_2 is decreased by around 50%.	Q4 2021	Remote or physical inspection of the plant including inspection and validation of key measurement data.

	Stripe's CDR purchase.			
2	Emissions Reduction Programme/Methodology under the new Swiss CO_2 law approved by the Swiss Federal Office for the Environment.	The new Swiss CO_2 law will allow CDR in a compliance market for >2'000'000 tCO_2 reductions per year in a price range in which neustark can be competitive.	Q1 2022	Inspection of our verified methodology which will be in the public domain.
3	Deployment with large size european recycler (300'000 tRCA/y, 2'000 tCO_2/y) where CO_2 injection will be performed in a stationary construction aggregate silo outside of Switzerland, most probably in Germany or the Netherlands.	By doubling the capacity of a single system, the capital cost per tCO_2 can be further decreased by over 50%. Furthermore the international expansion allows for a saving of at least 30% as CO_2 transportation costs are especially high in Switzerland due to high labour cost and taxes.	Q2 2023	Remote or physical inspection of the plant including inspection and validation of key measurement data.

i. How do these milestones impact the total gross capacity of your system, if at all?

Milestone #	Anticipated total gross capacity prior to achieving milestone (ranges are acceptable)	Anticipated total gross capacity after achieving milestone (ranges are acceptable)	If those numbers are different, why? (100 words)
1	215 tCO_2/y	>935 tCO_2/y	Milestone 1 consists of the deployment of an additional system with a capacity of 720 tCO_2/y.
2	>935 tCO_2/y	>935 tCO_2/y	
3	3'000 tCO_2/y	5'000 tCO_2/y	Milestone 3 consists of the deployment of an additional system with a capacity of 2'000 tCO_2/y.

d. How do these milestones impact your costs, if at all?

Milestone #	Anticipated cost/ton prior to achieving milestone (ranges are acceptable)	Anticipated cost/ton after achieving milestone (ranges are acceptable)	If those numbers are different, why? (100 words)
1	$700	$300	Through stationary deployments the operational cost for the handling of our current mobile version is completely eliminated. Furthermore, the capital cost per tCO_2 is decreased by around 50%.
2	$300	$300	
3	$300	$200	By doubling the capacity of a single system, the capital cost per tCO_2 can be decreased by over 50%. Furthermore the international expansion allows for a CO_2 cost reduction of at least 30% as CO_2 transportation costs are especially high in Switzerland due to high labour cost and taxes.

e. If you could ask one person in the world to do one thing to most enable your project to achieve its ultimate potential, who would you ask and what would you ask them to do?

Any concrete recycler in the world processing more than 100'000 tons of concrete debris per year should get in touch with us under hello@neustark.com

f. Other than purchasing, what could Stripe do to help your project?

Spreading the word about neustark to any other company who is currently or in the future running a RFP for CDR purchases.

7. Public Engagement and Environmental Justice (Criteria #7)

In alignment with Criteria 7, Stripe requires projects to consider and address potential social, political, and ecosystem risks associated with their deployments. Projects with effective public engagement tend to do the following:

- Identify key stakeholders in the area they'll be deploying

- Have some mechanism to engage and gather opinions from those stakeholders and take those opinions seriously, iterating the project as necessary.

The following questions are for us to help us gain an understanding of your public engagement strategy. There are no right or wrong answers, and we recognize that, for early projects, this work may not yet exist or may be quite nascent.

a. Who are your external stakeholders, where are they, and how did you identify them?

Stakeholders identified so far are: concrete recyclers, concrete producers, cement producers, biomethane producers, public and private builders, architects, civil engineers, climate policy makers and timber construction companies and organizations. We have identified those stakeholders mostly by starting to publicly communicate about our project in summer 2020 through media and then observing and registering carefully the kind of people and organisations approaching us with public or private comments and messages.

b. If applicable, how have you engaged with these stakeholders? Has this work been performed in-house, with external consultants, or with independent advisors?

To the extent possible with our still quite small team we try to be approachable and engage in public dialogues. The most critical comments usually come from the timber industry pointing out that timber stores significantly more CO_2 than our RCA and thus is the superior solution. In response to this critique we generally try to illustrate the scale of the CDR challenge making it obvious that many solutions absolutely need to co-exist. So far we did most of this engagement in-house with the exception of one product launch campaign for which we partnered with an external communications agency.

c. If applicable, what have you learned from these engagements? What modifications have you already made to your project based on this feedback, if any?

We have learned that almost all conflicts with the identified stakeholders trace back to a lacking understanding of the field of carbon dioxide removal and that we thus continuously need to improve our communication in this field. So far we took two specific actions which are not necessarily ordinary for the relatively young stage of our company. First, we prioritized work on a peer reviewed LCA paper on our process which will be published by mid 2021 and second, we systematically worked with the media (e.g. Neue Zürcher Zeitung) to produce several in-depth background media articles.

d. Going forward, do you have changes planned that you have not yet implemented? How do you anticipate that your processes for (a) and (b) will change as you execute on the work described in this application?

With a growing team we plan to transition to a more systematic dialogue with our stakeholders through measures such as webinars, newsletters, social media and events.

e. What environmental justice concerns apply to your project, if any? How do you intend to consider or address them?

In less developed countries, demolished concrete is as of today more likely to be landfilled than recycled. The situation in more developed countries is the opposite. As soon our technology is established in our western european entry markets, we will adapt our technology and business model so that those less developed countries have a similar chance of benefiting from our solution. We see carbon removal as both a climate necessity and major economic opportunity of the 21st century which ideally brings additional economic welfare to those who need it most.

11. Legal and Regulatory Compliance (Criteria #7)

a. What legal opinions, if any, have you received regarding deployment of your solution?

We provided our carbon credit methodology draft to both the Swiss Federal Office for the Environment and the Gold Standard Foundation and received a generally positive feedback with some constructive criticism to consider during the currently ongoing development of the full methodology. Furthermore we conducted a freedom to operate research with external patent attorneys.

b. What permits or other forms of formal permission do you require, if any? Please clearly differentiate between what you have already obtained, what you are currently in the process of obtaining, and what you know you'll need to obtain in the future but have not yet begun the process to do so.

In order to significantly scale up the offtake of CDR certificates we need approved methodologies on both the voluntary- and compliance carbon markets. We are currently developing methodologies under the standards of the Gold Standard Foundation (international voluntary market) and the Swiss Federal Office for the Environment (Swiss compliance market). There is a need to get accredited by additional local/national compliance markets (e.g. California Low Carbon Fuel Standard). In terms of engineering we need to get CE marking for the scaleup in Europe for which a first conformity analysis was performed by an external consultant. For the market entry on other continents we still have to get a better understanding of the locally relevant engineering standards.

c. In what areas are you uncertain about the legal or regulatory frameworks you'll need to comply with? This could include anything from local governance to international treaties. For some types of projects, we recognize that clear regulatory guidance may not yet exist.

We are uncertain on how a cross border operation of our value chain would qualify for compliance certificate markets. By cross border operation we mean that CO_2 capture would happen in another country than the CO_2 mineralization.

12. Offer to Stripe

This table constitutes your offer to Stripe, and will form the basis of our expectations for contract discussions if you are selected for purchase.

	Offer to Stripe
Net carbon removal (metric tonnes CO_2)	703.8 tCO_2
Delivery window (at what point should Stripe consider your contract complete?)	July 2021 - July 2023
Price ($/metric tonne CO_2) ***Note on currencies:*** *while we welcome applicants from anywhere in the world, our purchases will be executed exclusively in USD ($). If your prices are typically denominated in another currency, please convert that to USD and let us know here.*	400$/$tCO_2$ After completion of milestone 1 we expect a cost of about 300$/$tCO_2$. The price of 400$/CO_2 reflects that some of the removal will happen before the completion of milestone 1 where the cost are still higher at 700$/$tCO_2$.

Application Supplement: CO_2 Utilization

(Only fill out this supplement if it applies to you)

Feedstock (Criteria #6 and #8)

1. How do you source your CO_2, and from whom?

We source the CO_2 from the biogas upgrader which is located at Ara Region Bern. Ara Region Bern is a wastewater treatment plant. The sludge, which is discharged from their wastewater treatment processes goes through digesters and is transformed to biogas (about 60% methane, 40% CO_2). To comply with the natural gas standards and to be able to feed to the natural gas grid, a pure biomethane is produced by removing the CO_2. Up until now, the removed biogenic CO_2 stream of about 5'000 tCO_2 has been released to the atmosphere. In April 2021 neustark will start to capture, liquefy and transport this biogenic CO_2 for utilization and negative emissions in its mineralization plants.

2. What are alternate uses for this CO_2 stream?

Ara Region Bern is the first biogas plant in Switzerland, where the CO_2 off-gas is liquefied. Today, smaller amounts of this CO_2 (few %) are used onsite to neutralize water. The remaining CO_2 is discharged to the atmosphere. In Switzerland, there is a small demand for CO_2 by green houses, beverage companies and operations for neutralizing water. This demand is met by fossil CO_2 captured in Switzerland and surrounding Europe.

3. Do you have a pathway towards sourcing atmospheric CO_2 so as to achieve carbon removal? *(e.g. Future coupling of process to direct air capture)*

We already do so today by using biogenic CO_2 from biogas upgrading and thus achieve carbon dioxide removal. Until 2030, there is going to be a sufficient amount of biogenic CO_2 from biogas upgrading available to mineralize all Swiss demolition concrete.
Alternative to that, there is:

- Flue gas from waste incineration, which is 33 to 50% biogenic
- CO_2 from DAC (e.g. Climeworks)

In the process of scaling, we will first exploit CO_2 from biogas upgraders, later from waste incineration and DAC.

Utilization Methods (Criteria #4 and #5)

4. How does your solution use and store CO_2? What is the gross CO_2 utilization rate? *(E.g. CO_2 is mineralized in Material at a rate of X tCO_2 (gross) / t storage material).*

We store CO_2 by cabonating, cement - thus as calcium carbonate. According to a judgement of the european court, CO_2 as calcium carbonate is considered as permanent (Judgment of the court in case C-460/15)

1 t of concrete aggregate with a particle size of 0-16 mm can store roughly 7.2 kg of CO_2 within 2h. Thus the gross mineralisation ratio is 0.72%. However, the effective value depends on many factors, e.g. the particle size, pore water saturation of the material and the processing time. Thus, this value can vary between 0.5 and 3%.

5. What happens to the storage material (e.g. concrete), and how does that impact its embodied carbon storage over time? How do you know?

The treated RCA is either used as road base material or for production of concrete. In any case, a re-release of the transformed CO_2 is highly unlikely - even in case of deconstruction of the recycled road base or concrete element. CO_2 can only be released from $CaCO_3$ at temperatures above 530 °C or in contact with strong acids. The only event in which this is imaginable would be a strong building fire. In that case, loss of CO_2 would be marginal as only the CO_2 stored in one specific burned down building might be re-released. No matter if the RCA is used as a road base or for concrete production it will be isolated from atmospheric CO_2 supply during its re-use phase, which means that with or without neustark, no further natural carbonation takes place.

6. How do you ensure that the carbon benefits you are claiming through a CO_2 utilization process are not double counted? *(E.g. If sourcing CO_2 from a DAC system, or selling your product to a user interested in reducing their carbon footprint, who claims the carbon removal benefits and how could an independent auditor validate no double counting?)*

Through our contracts with CO_2 sources and concrete recyclers, the rights of the negative emissions remain with neustark. This is important, since neustark takes care of the CO_2 supply and the emission monitoring and the trading of negative emission allowances.

Thus, there are two cases:
Case 1: The concrete customer is not interested in a more sustainable concrete. They purchase the concrete and the negative emission allowance is sold to a 3rd party (e.g. Stripe)

Case 2: The concrete customer wants to purchase more sustainable concrete. They purchase the concrete, and approach neustark to purchase in addition the corresponding number of negative emission allowances.