[CarStorCon® Technologies GmbH]

Carbon Dioxide Removal Purchase Application

Fall 2022

General Application - Prepurchase

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

Company or organization name

CarStorCon® Technologies GmbH

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

Marienhafe, Germany

Name(s) of primary point(s) of contact for this application

Axel Preuß

Brief company or organization description

We are a climate tech startup working on decarbonizing the construction industry with biochar based solutions.

1. Project Overview[1]

a. Describe how the proposed technology removes CO_2 from the atmosphere, including as many details as possible. Discuss location(s) and scale. Please include figures and system schematics. Tell us why your system is best-in-class, and how you're differentiated from any other organization working on a similar technology.

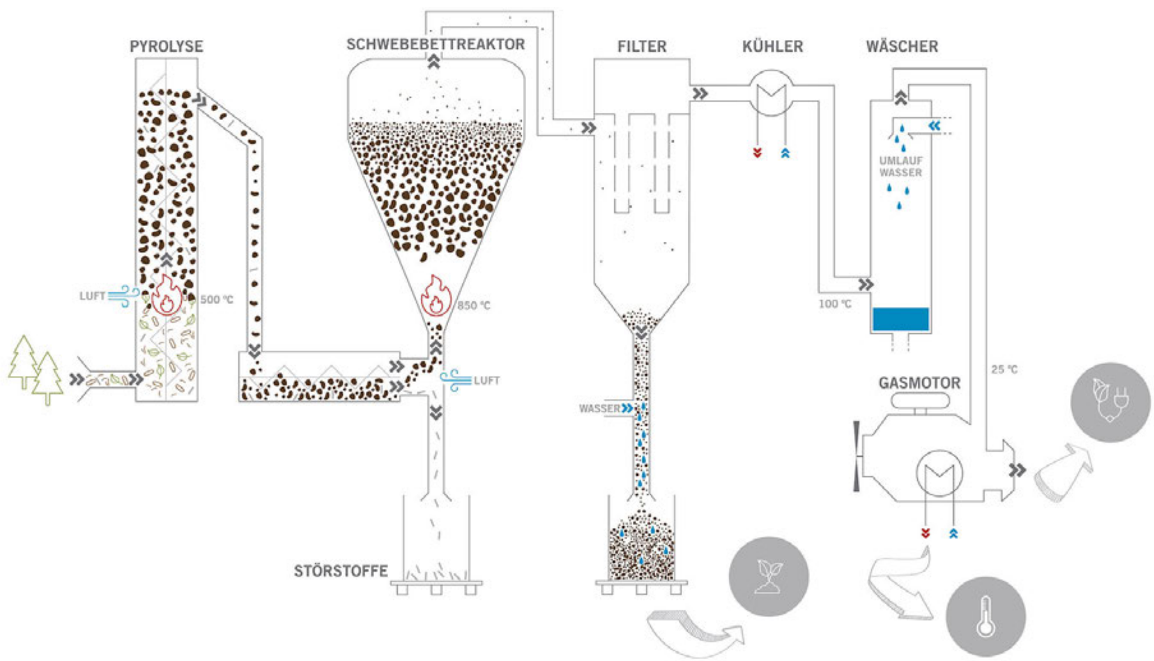
We are providing customized solutions on how to use biochar in innovative products and existing material cycles with the aim to decarbonize construction materials and turn them into long-term carbon sinks. 1 t of our biochar can store up to 2.98 t of CO_2. This capacity is certified by 3rd party audit.

[1] We use "project" throughout this template, but note that term is not intended to denote a single facility. The "project" being proposed to Frontier could include multiple facilities/locations or potentially all the CDR activities of your company.

OUR TECHNOLOGY

Our technology is based on biochar, pyrolysed biogenic material from sustainable biomass.
Plants convert atmospheric CO_2 into biomass through photosynthesis. This biomass in the form of wood is used on a large scale in urban contexts which, at the end of life, is often disposed of in open pits or incinerated. Furthermore, a large amount of forestry waste and low-quality wood is never used for commercial purposes. As a result, the temporarily sequestered CO_2 re-enters the atmosphere through weathering or combustion. If the biomass is instead pyrolysed, a porous solid called biochar is produced, in which carbon is bound and thus removed from the carbon cycle. Pyrolysis is a thermochemical process under low oxygen conditions.

We extend this process with a specialized treatment to optimize the implementation of the biochar as additive in construction materials. The CO_2 remains safely stored and can be (re)activated unlimitedly.



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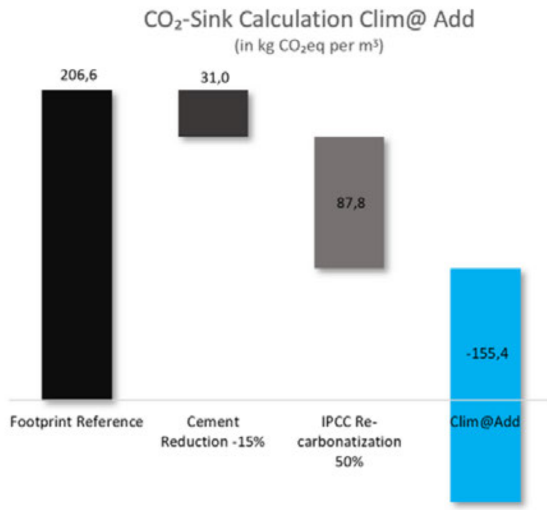
Our technology is based on SynCraft® pyrolysis plants. The process is not only self-energized but also produces a large amount of heat and electricity along with the specialized biochar. The biochar is then treated further to match the properties that are necessary for its application in concrete and other construction materials.
The surplus energy that is produced is considered climate neutral in comparison to conventional gas and can be processed as heat or electricity. The biochar obtained, forms the basis of our additive Clim@Add®, which, when used in cementitious materials, permanently locks the carbon. The CO_2 gets chemically bound and remains over the building´s lifetime, securely stored and retains its properties even when recycled. If, at the end-of-life point, the concrete is mechanically crushed and reused in roads - the carbon will remain locked.

Our main USP is a functional enhancement of the final material. Our additive not only reduces the carbon footprint but also enhances the performance of concrete. Our product improves the concrete's compressive and flexural strength by 23% and 15%, making it technically valuable and economically viable. The Clim@Add® itself is sold as a high-performing concrete additive. Therefore, less cement is necessary for the mixture. This in turn avoids additional emissions and land-use change for its production. The full CO_2 sink potential is calculated by the cement reduction plus the sequestered carbon.

To calculate the footprint of the resulting concrete, also the recarbonization potential can be accounted for.



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CIRCULAR ECONOMY

Our process utilizes low value organic residues as input material for the production of biochar. At the moment we collaborate with different plant owners and local waste disposers in the DACH region, Benelux, FR and IT. Our supply chains operate locally, minimizing transport ways of waste streams and biochar. We aim to create local circular economies.

The carbon obtained is considered harmless, and, when in the form of biochar, chemically stable, and can be reintegrated into new material cycles. In our case, a permanent and secure sequestering is then ensured by mixing the biochar into building materials like concrete.

Thus, our solution not only contributes to the circular economy, but also has the potential to have a positive effect on resource scarcity and carbon savings from lesser use of resources.

We further plan to verify and validate the carbon capture and storage potential of our biochar by conducting a thorough cradle-to-grave life cycle assessment, which would then be reviewed and validated by an external reviewer as per the ISO 14040/44 standards.

Earlier this year, together with partners, we were selected top 60 in the XPRIZE Carbon Removal Competition.

SCALABILITY

In terms of carbon capture and storage potential, an enormous CO_2-extracting effect can be expected upon up-scaling.

Take for example the German cement industry: In 2018, 33.7 million tons of cement were produced in Germany, corresponding to 20 million tons of CO_2 emission. If 2% of cement by weight can be substituted with the biochar based additive, 1.6 million tons of CO_2 will be removed from the atmosphere and cement production emissions will additionally be reduced by 0.4 million tons – every year. This amount, in turn, corresponds to 10% of the German cement industry's emissions. If scaled up, over 200 million tons of CO_2 could be removed annually from the atmosphere worldwide, considering only a minor cement substitution. At present we are assuming a maximum substitution of 15% by weight of cement, which implies an exponentially higher carbon removal potential. Moreover, the use of biochar is not limited to above-ground construction, but may also be used in large-scale public technical infrastructure projects (e.g. roads, piazzas, sewer tunnels). Therefore, the public sector could take a pioneering role in mitigating climate change and contribute to further removal on scale-up. With further advancement in the technology leading to a higher replacement rate, as well as possible scale up across Europe and other countries globally, we expect the volume of CO_2 capture to consequently increase. We also expect the costs to be competitive once we attain large scale demand and manufacture.

The technology is ready and with all stakeholders on board we are ready to scale up. Clim@Add® allows the storage of up to 72 kg of CO_2 per m3 of concrete. Expected capacity of CO_2 storage potential for 2023 is 1000 tons.

At the moment we do operate with trusted 3rd party plant owners. To scale further, we are in negotiations for an owned plant set-up. Not only to ensure larger regional availability but also to facilitate research for new waste streams and ways of application.

COMPETITIVE LANDSCAPE

The field of biochar application in construction material is growing and has received a lot of attention from investors recently. However we are not aware of competitors that proved and deployed enhanced material functionalities. Within the construction industry we see approaches such as recycling and new recipes that we welcome as collaborators and partners. The additionality of our technology allows us to combine efforts and join forces to transform the construction industry together.

b. What is the current technology readiness level (TRL)? Please include performance and stability data that you've already generated (including at what scale) to substantiate the status of your tech.

The pyrolysis-plant technology to produce the basic material for our Clim@Add® is on TRL 9, with several years of successfully running in multiple plants. We optimized this technology in existing plants for the needs of the construction industry. Their operational readiness is demonstrated on an industrial production scale.

The modification and the use of the modified biochar within the concrete is on TRL 6, with several existing demonstrators (buildings) that are built right now that have the modified biochar in them. The functionality has been shown in lab scale before and ist constantly monitored.

NB: The TRL 7 indicated in round 1, resulted from a median composed of the underlying technology, that is already TRL 9 and our research and work on biochar application in construction material that we consider to be TRL 6 atm.

c. What are the key performance parameters that differentiate your technology (e.g. energy intensity, reaction kinetics, cycle time, volume per X, quality of Y output)? What is your current measured value and what value are you assuming in your nth-of-a-kind (NOAK) TEA?

Key performance parameter	Current observed value (units)	Value assumed in NOAK TEA (units)	Why is it feasible to reach the NOAK value?
Biomass used	6-8,8 bcm	We expect values	Due to ongoing research and

(bcm biomass) to 1 t CO2 captured		at the upper scale for NOAK	promising lab results
Surplus energy produced (kWh electricity)	3.750.000 kWh Electricity produced per module of a plant	Depending on the plant size, the input material and capacity factor	The plant technology is stable and will most probably have even greater efficiency improvements
Surplus energy produced (kWh electricityMW)	5.550.000 kWh	Depending on the plant size, the input material and capacity factor	The plant technology is stable and will most probably have even greater efficiency improvements
CO_2 captured (in tonnes)	160t as of today	5000	Scaling with 3rd party plants and own plant from 2023 will allow this increase
Carbon Content biochar	76-93%	We expect values at the upper scale for NOAK	Depends on biomass and processing technology
Additive rate to the concrete	7- 35%	We expect values at the upper scale for NOAK	Due to ongoing research and promising lab results
Improved material functionality	Ex. 38,7 N/mm^2 / 56 days	We expect slightly improved values at NOAK	Due to ongoing research and promising lab results

d. Who are the key people at your company who will be working on this? What experience do they have with relevant technology and project development? What skills do you not yet have on the team today that you are most urgently looking to recruit?

With our partners we develop biochar solutions since 2020. We saw the huge potential of biochar as negative-emission technology and founded CarStorCon® Technologies GmbH together with a plant manufacturer that builds unique, patented power plants that produce biochar as a byproduct (beside renewable energy). As a plant constructor, SynCraft Engineering GmbH guarantees the optimal plant set-up, they hold five patents and extensive IP out of 15 years of plant development, are specialized in biochar production and have already licensed out successfully. We also cooperate with various plant operators.

Founder Axel Preuß has a proven track record of innovating and implementing engineering solutions in the construction industry. His strong network, his sales competencies and forward thinking company development are complementing his skills. Besides its own technical expertise, the team holds close connection and research agreements with R&D facilities and research institutions. Project Management, Finances and Marketing are in experienced hands.

With the scale up of the solution the team will need to expand regionally to ensure the creation and support of local economies. Midterm own R&D and technical teams within the company will be set up.

e. Are there other organizations you're partnering with on this project (or need to partner with in order to be successful)? If so, list who they are, what their role in the project is, and their level of commitment (e.g., confirmed project partner, discussing potential collaboration, yet to be approached, etc.).

Partner	Role in the Project	Level of Commitment
SynCraft	Co owner	High
EnergieWerk Ilg	Co owner / delivery of raw material for a key region	High
Pyrolysis Plant owner	Main contractors	High
Concrete plants	Applicants of the Clim@Add	Medium - high depending on the ownership of the project
Concrete producers	Concrete manufacturer, with whom we have been in a trusting cooperation for 1.5 years.	Medium - high depending on the project stage
CDR market places	Our current partner to market the CO_2 certificates is Carbonfuture GmbH.	High
Research institutes & universities	There are ongoing contracts with two research institutes to address the various challenges of incorporation into the building material.	High

f. What is the total timeline of your proposal from start of development to end of CDR delivery? If you're building a facility that will be decommissioned, when will that happen?

We are already operating with 3rd party plants since this year.
We will start scaling our own facility in 2023.
We are happy to share more details confidentially.

g. When will CDR occur (start and end dates)? If CDR does not occur uniformly over that time period, describe the distribution of CDR over time. Please include the academic publications, field trial data, or other materials you use to substantiate this distribution.

CDR occurs already and will exponentially grow with the amount of plants / projects. We do expect uniform CDR removal by ton of biochar but higher application rates in the application. As this is due to ongoing research and development we do count with:

- each ton biochar results in *2 kg CO_2 removed (according to the LCA assessment) and
- each ton added to concrete / construction material will store the respective amount of CO_2

permanently

h. Please estimate your gross CDR capacity over the coming years (your total capacity, not just for this proposal).

Year	Estimated gross CDR capacity (tonnes)
2023	900 sold to customers in construction industry / 100 t/a for Frontier = 1000 t/a total capacity
2024	1800 sold to customers in construction industry / 200 t/a for Frontier = 2000 t/a total capacity
2025	1800 sold to customers in construction industry / 200 t/a for Frontier = 2000 t/a total capacity
2026	4750 sold to customers in construction industry/ 250 t/a for Frontier =5000 t/a total capacity
2027	4750 sold to customers in construction industry/ 250 t/ a for Frontier = 5000 t/a total capacity
2028	4750 sold to customers in construction industry/ 250 t/ a for Frontier = 5000 t/a total capacity
2029	4750 sold to customers in construction industry/ 250 t/ a for Frontier = 5000 t/a total capacity

i. List and describe at least three key milestones for this project (including prior to when CDR starts), that are needed to achieve the amount of CDR over the proposed timeline.

	Milestone description	Target completion date (eg Q4 2024)
1	Scale with existing plant corporations, secure open contracts and scale application amounts	Q4 2022
2	Secure own plant production	H1 2023
3	Secure long term biomass contracts for own plants, biochar contracts with 3rd party plant owners	H1 2023
4	Research results on application methods	H2 2023
5	Scale own plant production	2024

j. What is your IP strategy? Please link to relevant patents, pending or granted, that are available publicly (if applicable).

We are currently in the patenting process for our treatment process.
Expected time to patenting Q2 2023

k. How are you going to finance this project?

At the moment we are project, research grant and self financed. We are in discussions with investors and plant commissioners.

Currently the major part of our certificates are sold to our customers to enable them to intake their unavoidable remaining emissions. We want to sell the remaining certificates to Frontier to enable us to scale independently.
As we operate with 3rd party plant owners we are currently bound to their production capacity.
While we do not see any limiting shortages working with 3rd party plant owners, we do push our plans for our own plant set up to scale and to enable continuous non-project bound research on new biomass inputs and scalable application methods of biochar in construction material.

l. Do you have other CDR buyers for this project? If so, please describe the anticipated purchase volume and level of commitment (e.g., contract signed, in active discussions, to be approached, etc.).

We do sell carbon credits to our customers directly, in addition we do involve Carbonfuture as our CDR buyer. www.carbonfuture.earth

Level of commitment is high as customers use their certificates to inset their remaining unavoidable emissions.

m. What other revenue streams are you expecting from this project (if applicable)? Include the source of revenue and anticipated amount. Examples could include tax credits and co-products.

The Clim@Add® itself will be sold as a high-performing concrete admixture, improving e.g. the compressive strength. Therefore, less cement is necessary for the mixture, avoiding additional emission and land-use change for its production. Prices vary depending on the customized product.

Next to the carbon in the form of Clim@Add® , energy in the form of electricity and heat can be sold. The surplus energy that is produced is considered climate neutral in comparison to conventional gas.
Energy produced could be sold at 0,22$ / kWh with expected surplus energy of 3,75 Mio kWh per plant.
Heat produced could be sold at 0,4$ / kWh with an expected surplus heat of 5,5 Mio kWh per plant.

Depending on the project and contract, the CO_2 certificates can be sold as a stable, secure storage possibility is created.

Further, an additional revenue stream for wood residues is created that are difficult to use today, which were e.g. already used in one use cycle and cannot be re-used in their form and cause in some cases disposal costs.

n. Identify risks for this project and how you will mitigate them. Include technical, project execution, ecosystem, financial, and any other risks.

Risk	Mitigation Strategy
Rising demand of biomass	With the current rising demand for wood biomass as an energy provider, we are covered by strong nature protection laws in DE and AU. European laws are in the process of being implemented. Pyrolysis counts as a higher usage scenario than burning wood or letting it decompose. Our additional offer to create effective carbon sinks and thus generate additional revenue streams gives us another strategic advantage. Today mostly woody biomass is used for biochar production, but this limits the efficiency and sustainability in a global application. To further exploit the potential, it is planned to adapt the plant and Clim@Add® production system so that it is able to use locally available residual lignin-containing biomass streams. With different feedstock, a well-developed and closely monitored QM System will be necessary to ensure the quality of the concrete additive.
Not enough new plants build	We do not see any shortage for the next year, operating with existing plants. With our own plant in planning and close cooperation with SynCraft® we do not see plant capacity issues to reach our indicated CDR goals. Scaling up of the production capacities will be navigated by partnering up with two of the globally active cement manufacturers to directly produce the Clim@Add® onsite and by decreasing costs and delivery time of the modules significantly.
Workforce development	The technology on which we base the carbon storage concept does offer long lasting job opportunities because it's based on future technologies. Most importantly power and heat production based on renewables, residual biomass. Also, for the building and construction industry where the need for change is addressed, our concept offers big opportunities. There's a need for improvements in this sector, it needs to decarbonize. But on the other hand we'll see a further increasing demand in concrete consumption for infrastructure. Thus enabling the industry offering carbon negative concrete will give it a future.

2. Durability

a. Describe how your approach results in permanent CDR (> 1,000 years). Include citations to scientific/technical literature supporting your argument. What are the upper and lower bounds on your durability estimate?

The permanent, secure sequestration of carbon is ensured by mixing our technical carbon based

additive (Clim@Add®) into building materials, such as concrete. When used in concrete mixtures, the technical carbon becomes part of the matrix, is stably anchored in the product and thus remains bound even after several recycling cycles. The material can be used again and again with repeated addition of Clim@Add®. Biochar that is bound in a mineral matrix has the capability of storing carbon for longer than 1000 years.

Testing performed on our EBC certified biochar samples shows a Oxygen - Carbon ratio of less than 0.01 resulting in a half-life of more than 1000 years. When stored in concrete applications the functional groups are well bound. This allows for several use cycles of the product while ensuring the carbon capture of more than 1000 years.

Detailed life cycle analysis and Environmental Product declaration (EPD) will be conducted to confirm the carbon storage potential of more than 1000 years.

b. 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 risk of a partial or complete re-emission is low because the biochar is chemically bound in the cementitious matrix. A re-emission can take place if the concrete is broken down and milled and then heated over 3 minutes over 350 degrees. Those conditions can only happen if the fine fraction is put through a certain type of recycling process after the breaking down of a building. The recycling rates with this type of recycling process are currently very low.
Tests, whether a re-emission of the carbon can happen due to a house fire, are still in progress. Biochar is not qualified as flammable substances according to UN standards. It is expected that the biochar will increase the fire resistance of the building material.

A very small fraction can be re-emitted if the concrete surface shows erosion. Then a small percentage of the chemically bound carbon could erode from that erosive material as well. The quantity of the carbon that is transformed back into CO_2 is a fraction of that and can be neglected.

3. Gross Removal & Life Cycle Analysis (LCA)

a. How much GROSS CDR will occur over this project's timeline? All tonnage should be described in **metric tonnes** of CO_2 here and throughout the application. Tell us how you calculated this value (i.e., show your work). If you have uncertainties in the amount of gross CDR, tell us where they come from.

Gross tonnes of CDR over project lifetime	25.000t
Describe how you calculated that value	The CDR potential is calculated based on the t of Clim@Add® used to be permanently stored in concrete (or another cementitious matrix). Clim@Add® storage potential can be quantified by the amount of the

	carbon it contains and the emissions caused during its production and handling. Each ton of pure carbon binds the equivalent of 3.6t of CO2. The calculation of the Clim@Add® itself contains: estimate of the footprint from the biomass used (woody biomass), the transport of the biomass to the plant, the pre-treatment of the biomass (e.g. drying) the calculation of the charing process (the surplus climate-neutral energy produced is not taken into the calculation of our "raw product" biochar and the required process heat can be generated from the biomass) and our treatment process. Transport emissions for the biochar transport to the concrete facility are not included yet. We did not calculate a further markdown for release over the lifetime, since the carbon is bound within the concrete matrix and even when being recycled after dismounting a building will stay fixated in the material.

b. How many tonnes of CO_2 have you captured and stored to date? If relevant to your technology (e.g., DAC), please list captured and stored tons separately.

To date we have captured and stored 160t. The capacity is much higher. We started with a conservative estimate taking into consideration the near term sales pipeline and the outstanding quantity agreements. Without those agreements there is still competition from other biochar application fields. Hence our focus on expanding through a self operated and owned plant.

c. If applicable, list any avoided emissions that result from your project. For carbon mineralization in concrete production, for example, removal would be the CO_2 utilized in concrete production and avoided emissions would be the emissions reductions associated with traditional concrete production. Do <u>not</u> include this number in your gross or net CDR calculations; it's just to help us understand potential co-benefits of your approach.

We are avoiding the emissions for the cement production, since we can partially replace the cement and ensure the same performance when Clim@Add® is added. This ranges from 6-20 kg cement per cubic meter of concrete that can be replaced.

The pyrolysis process also produces biogas, which can be included in the impact if it is used to generate heat or electricity. This energy is with all our partner plants used in the industry or to supply households. Hereby a CO_2 saving can be calculated compared to the conventional energy mix.

With the usage of residual biomass, rotting or incineration processes are avoided, resulting in lower methane and particulate matter emission. Further, a use scenario for wood residues is created that are difficult to use today, which were e.g. already used in one use cycle (e.g as construction wood) and cannot be re-used in their form.

The following flow chart and numbers are calculated for a small scale projects with 500t/a biochar

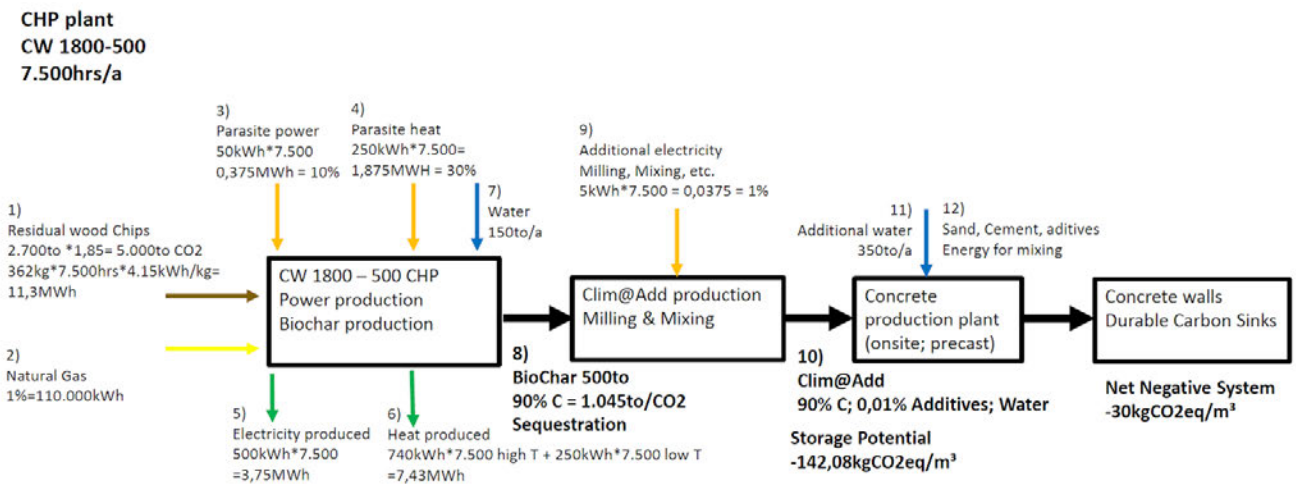
production.

d. How many GROSS EMISSIONS will occur over the project lifetime? Divide that value by the gross CDR to get the emissions / removal ratio. Subtract it from the gross CDR to get the net CDR for this project.

Gross project emissions over the project timeline *(should correspond to the boundary conditions described below this table)*	22 t of CO_2 released
Emissions / removal ratio *(gross project emissions / gross CDR–must be less than one for net-negative CDR systems)*	2%
Net CDR over the project timeline *(gross CDR - gross project emissions)*	We will remove 25.000 t over the 7 years. The amount will consist of biochar that we purchased (e.g. from the plant that we referenced in “current project” to show a current cost estimation), treat and then sell to the construction industry and the CDR we generate with our own planned plant (referred to in FOAK).

e. Provide a process flow diagram (PFD) for your CDR solution, visualizing the project emissions numbers above. This diagram provides the basis for your life cycle analysis (LCA). Some notes:

- The LCA scope should be cradle-to-grave
- For each step in the PFD, include all Scope 1-3 greenhouse gas emissions on a CO_2 equivalent basis
- Do not include CDR claimed by another entity (no double counting)
- For assistance, please:
    - Review the diagram below from the CDR Primer, Charm’s application from 2020 for a simple example, or CarbonCure’s for a more complex example
    - See University of Michigan’s Global CO_2 Initiative resource guide
- If you’ve had a third-party LCA performed, please link to it.



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

Raw material procurement, transportation, operation of gasifier, post processing and application have been included in the system boundaries. Expected life of our product is similar to regular concrete and we are exploring end of life scenarios, for that reason it is excluded from our current system. This flow does not account for the emissions resulting from land use change. We work with plant owners and biomass producers to get hold of that information We didn't calculate transportation to the end customer as well as biomass to the production plant (gate to gate calculation) since we are building up local supply chains with small production facilities. A 3rd party verified LCA is currently carried out.

g. Please justify all numbers used to assign emissions to each process step depicted 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.

Process Step	**CO_2(eq) emissions over the project lifetime (metric tonnes)**	**Describe how you calculated that number. Include references where appropriate.**
Biomass extraction and preprocessing	1,582,500 kg CO_2 eq (caution: the processing (chipping) CO_2 emissions are higher than in a optimized plant)	Project duration is 7 years (with our own plant production starting next year with a maintenance cycle of 7 years) Over this time period approximately 7500 tons of

		biochar with a CDR potential in the range of 25.000 tons will be produced. For the data obtained from the pyrolysis plant approximately 23 tons of wood ships are required for the production of 1 ton of biochar along with 21.04 MWh of electricity. Life cycle study conducted shows 1 kilo of fuel/wood has an emission factor of 0.0211 kg CO_2 eq. Over the described period 7500 tons of biochar will require 75,000 tons of wood with CO_2 emission eq of approximately 1,582,500 kg CO_2 eq. The emission factor of wood highly depends on the wood source (waste wood, certified fresh wood or non-certified fresh wood). https://www.syncraft.at/files/pdf/PO_HEBA_CEBC2020_Poster_LCA_Gasification_Kaeppler_final.pdf
Operation of gasifier	- 8,207,963kg CO_2 eq	Operation of a gasifier in absence of air does not allow the biomass to combust. Carbon is therefore stored in the form of biochar. Data obtained from the plant shows 72.08 tons of biochar was accompanied by 1517 MWh (1517*1000 kWh) of electricity and for each kWh of electricity 52 g of CO_2 is stored in the form of biochar. 7500 tons of biochar will be accompanied with 157,845,449 kWh of electricity and will have an approximate CO_2 storage of 8,207,963 kg CO_2 eq. (https://www.syncraft.at/files/pdf/PO_HEBA_CEBC2020_Poster_LCA_Gasification_Kaeppler_final.pdf)
Application of biochar in concrete (CarStorCon®)	- 4,425,000 kg CO_2 eq	Clim@Add® can be used to replace cement in the concrete mix. Therefore, a subsequent amount of cement is saved when it allows us to save carbon which reduces the carbon footprint of concrete. 7500 tons of biochar reduces the same amount of cement. One kilogram of cement has a carbon footprint of 0.59 kg CO_2 eq and therefore by not using 7500 tons of cement we will be able to save upto 4,425,000 kg CO_2 eq. https://www.mdpi.com/2673-3994/3/2/21/pdf#:~:text=Due%20to%20its%20high%20energy,emitted%20on%20average%20%5B2%5D.

4. Measurement, Reporting, and Verification (MRV)

Section 3 above captures a project's lifecycle emissions, which is one of a number of MRV considerations. In this section, we are looking for additional details on your MRV approach, with a particular focus on the ongoing quantification of carbon removal outcomes and associated uncertainties.

a. Describe your ongoing approach to quantifying the CDR of your project, including methodology, what data is measured vs modeled, monitoring frequency, and key assumptions. If you plan to use an existing protocol, please link to it. Please see Charm's bio-oil sequestration protocol for reference, though note we do not expect proposals to have a protocol at this depth at the prepurchase stage.

> EBC-Certificate for biochar in raw material form does not exist until its application where the carbon is stored.
> Following the EBC C-Sink, the biochar must be tracked by a system that assesses and registers all carbon expenditures and greenhouse gas emissions that occur on its pathway (i.e. production, transporting, milling, processing). A service that an accredited trader can ensure next to our own batch tracking records. As soon as the biochar is mixed into concrete, the C-sink potential is converted into C-sink certificates. Potentially, a digital monitoring process can be implemented according to EBC-Sink methodology.
>
> Currently, each plant is tracking their biochar production with a sensor- and protocol based system (feeding into excel) that is onsite. The after-treatment process always runs similarly, therefore it can be seen as a constant and we can track the carbon quantity according to the production parameters from the plants. We can currently rely on the EBC-certification processes and the SynCraft® -internal yearly plant audits to ensure the compliance to the emission and emission values.
>
> An auditing process for the biochar-production plants will be set up in the future.

b. How will you quantify the durability of the carbon sequestered by your project discussed in 2(b)? 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.)*

> The risk of a partial or complete re-emission is low because the biochar is chemically bound in the cementitious matrix. A re-emission can take place if the concrete is broken down and milled and then heated over 3 minutes over 350 degrees. Those conditions can only happen if the fine fraction is put through a certain type of recycling process after the breaking down of a building. The recycling rates with this type of recycling process are currently very low.
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> Tests, whether a re-emission of the carbon can happen due to a house fire, are still in progress. Biochar is not qualified as flammable substances according to UN standards. It is expected that the biochar will increase the fire resistance of the building material.
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c. This tool diagrams components that we anticipate should be measured or modeled to quantify CDR and durability outcomes, along with high-level characterizations of the uncertainty type and magnitude for each element. We are asking the net CDR volume to be discounted in order to account for uncertainty and reflect the actual net CDR as accurately as possible. Please complete the table below. Some notes:

- In the first column, list the quantification components from the Quantification Tool relevant to your project (e.g., risk of secondary mineral formation for enhanced weathering, uncertainty in the mass of kelp grown, variability in air-sea gas exchange efficiency for ocean alkalinity enhancement, etc.).
- In the second column, please discuss the magnitude of this uncertainty related to your project and what percentage of the net CDR should be discounted to appropriately reflect these uncertainties. Your estimates should be based on field measurements, modeling, or scientific literature. The magnitude for some of these factors relies on your operational choices (i.e., methodology, deployment site), while others stem from broader field questions, and in some cases, may not be well constrained. We are not looking for precise figures at this stage, but rather to understand how your project is thinking about these questions.
- See this post for details on Frontier's MRV approach and a sample uncertainty discount calculation and this Supplier Measurement & Verification Q&A document for additional guidance.

Quantification component Include each component from the Quantification Tool relevant to your project	**Discuss the uncertainty impact related to your project** Estimate the impact of this component as a percentage of net CDR. Include assumptions and scientific references if possible.
Storage leakage (Re-emission from cement-bound matrix (concrete)	Based on chemistry principles and composition of cementitious-bound matrices: Very low risk of erosion or re-emission
Storage monitoring and maintenance	At the moment no tracking mechanisms are in place for end of life of buildings. In the future a central database is going to serve this purpose. With BIM, a central database is being established.
Material embodied emissions	A small emission is coming from the treatment chemicals, since those are biobased we can neglect them in the calculation.
Indirect land use change emissions	The land use for the plants is comparably small. No additional land is used to obtain input raw materials since mainly green waste, unused low-quality wood, and wood waste from forestry are used as feedstock. Again strong nature protection laws prevent the land use to be exploited.

d. Based on your responses to 4(c), what percentage of the net CDR do you think should be discounted for each of these factors above and in aggregate to appropriately reflect these uncertainties?

none

e. Will this project help advance quantification approaches or reduce uncertainty for this CDR pathway? If yes, describe what new tools, models or approaches you are developing, what new data will be generated, etc.?

> We are on the way to improve the Carbon sequestration potential monitoring. The project will give us the freedom to run subsequent tests on durability and improve our internal measurement.

f. Describe your intended plan and partners for verifying delivery and registering credits, if known. If a protocol doesn't yet exist for your technology, who will develop it? Will there be a third party auditor to verify delivery against that protocol or the protocol discussed in 4(a)?

> We are planning to work with Carbonfuture as an external verifier for the credits. We are still looking for a way to verify the carbon credits that will be purchased directly from our customers in the construction sector.
> We can in general reference to the EBC protocol to quantify the carbon sink potential of the char used. In the construction industry, currently no standard is valid yet to measure explicitly CDR solutions.

5. Cost

We are open to purchasing high-cost CDR today with the expectation the cost per tonne will rapidly decline over time. The questions below are meant to capture some of the key numbers and assumptions that you are entering into the separate techno-economic analysis (TEA) spreadsheet (see step 4 in Applicant Instructions). There are no right or wrong answers, but we would prefer high and conservative estimates to low and optimistic. If we select you for purchase, we'll work with you to understand your milestones and their verification in more depth.

a. What is the levelized price per net metric tonne of CO_2 removed for the project you're proposing Frontier purchase from? This does not need to exactly match the cost calculated for "This Project" in the TEA spreadsheet (e.g., it's expected to include a margin), but we will be using the data in that spreadsheet to consider your offer. Please specify whether the price per tonne below includes the uncertainty discount in the net removal volume proposed in response to question 4(d).

> 500 $/tonne CO_2

b. Please break out the components of this levelized price per metric tonne.

Component	**Levelized price of net CDR for this project ($/tonne)**
Capex	370 Euro
Opex (excluding measurement)	85 Euro
Quantification of net removal (field	~10 Euro for EBC certification

measurements, modeling, etc.)[2]	
Third party verification and registry fees (if applicable)	~35 Euro
Total	(should match 5(a))

c. Describe the parameters that have the greatest sensitivity to cost (e.g., manufacturing efficiencies, material cost, material lifetime, etc.). For each parameter you identify, tell us what the current value is, and what value you are assuming for your NOAK commercial-scale TEA. If this includes parameters you already identified in 1(c), please repeat them here (if applicable). Broadly, what would need to be true for your approach to achieve a cost of $100/tonne?

Parameter with high impact on cost	Current value (units)	Value assumed in NOAK TEA (units)	Why is it feasible to reach the NOAK value?
Woody biomass incl. Transport to site	140 € /bcm	140 € /bcm	Market prices
Energy price (kWh) produced electricity	0,22 cent	0,22 cent	Market prices - if the value increases, cost pressure is taken off the biochar as a product, if the energy price decreases, the char needs to carry more of the capex and opex from the current process
Energy price (kWh) Excess heat	0,04 cent	0,04 cent	Market prices - if the value increases, cost pressure is taken off the biochar as a product, if the energy price decreases, the char needs to carry more of the capex and opex from the current process

d. What aspects of your cost analysis are you least confident in?

The reduction of the CAPEX for a scaled plant is yet to be proven

e. How do the CDR costs calculated in the TEA spreadsheet compare with your own models? If there are large differences, please describe why that might be (e.g., you're assuming different learning rates, different multipliers to get from Bare Erected Cost to Total Overnight Cost, favorable contract terms, etc.).

Our technology is based on biochar as a feedstock. The biochar production produces surplus energy that can be fed into the grid. The costs of the plant can be distributed to the energy, the CO_2

[2] This and the following line item is not included in the TEA spreadsheet because we want to consider MRV and registry costs separately from traditional capex and opex.

certificates and the char produced. Unfortunately, we cannot insert additional revenue streams anywhere, therefore we see a discrepancy in the automatically calculated costs and the real costs that we inserted into the text based section of the application.

f. What is one thing that doesn't exist today that would make it easier for you to commercialize your technology? (e.g., improved sensing technologies, increased access to X, etc.)

Decreasing the red tape for the application in the construction industry, increased access to biomass.

6. Public Engagement

In alignment with Frontier's Safety & Legality criteria, Frontier requires projects to consider and address potential social, political, and ecosystem risks associated with their deployments. Projects with effective public engagement tend to:

- Identify key stakeholders in the area they'll be deploying
- Have mechanisms in place to engage and gather opinions from those stakeholders, take those opinions seriously, and develop active partnerships, iterating the project as necessary

The following questions help us gain an understanding of your public engagement strategy and how your project is working to follow best practices for responsible CDR project development. We recognize that, for early projects, this work may be quite nascent, but we are looking to understand your early approach.

a. Who have you identified as relevant external stakeholders, where are they located, and what process did you use to identify them? Please include discussion of the communities potentially engaging in or impacted by your project's deployment.

1. Municipalities and local governmental structures
    - need innovative and cost effective recycling systems
    - need to comply with cascading wood waste use regulations
    - need green concepts for infrastructure and building development

We work with municipalities and local structures as consultants and connect builders and manufactures to create local networks.

2. Concrete and construction material producers
    - need green strategies for customers, investors and employee retainment, depending on size also are faced with legal implications for emission mitigation strategies
    - need offtake strategies for unavoidable emissions

As we develop customized solutions and atm on a project base we have very close relationships with our customers, integrating their needs in our work across the entire value chain.

3. Builders and project developers
    - need to respond to customers requirements for greener products and investment strategies

Together with the producers, these are our main customers, their influence on the market is key for us and we target project developers with dedicated marketing and acquisition.

4. Energy Providers
- need to complete their renewable energy mix with biomass based systems
- aim to create local green energy provision

We work with energy providers in consultancy mandates.

5. EBI - we are early member of the European Biochar Industry (EBI) - to help develop industry standards on biochar-based carbon sinks and ultimately grow the biochar market.

We identified stakeholders by needs analysis and in direct dialogue while developing our pilot projects

b. If applicable, how have you engaged with these stakeholders and communities? Has this work been performed in-house, with external consultants, or with independent advisors? If you do have any reports on public engagement that your team has prepared, please provide. *See Project Vesta's community engagement and governance approach as an example and Arnestein's Ladder of Citizen Participation for a framework on community input.*

We engage with stakeholders mainly through our projects and initiatives. We do work with PR outlets and are currently in the process of relaunching our website and social media. We do visit and exhibit at fairs and engage with our stakeholders in workshops and conferences.

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?

Our solution is highly customizable and adaptable with existing infrastructure. The compatibility of our technology has shown as a door opener for new projects.

d. Going forward, do you have changes to your processes for (a) and (b) planned that you have not yet implemented? How do you envision your public engagement strategy at the megaton or gigaton scale?

We are working on case studies and external validation to have greater showcase momentum.

7. Environmental Justice[3]

As a part of Frontier's Safety & Legality criteria, Frontier seeks projects that proactively integrate environmental and social justice considerations into their deployment strategy and decision-making on an ongoing basis.

a. What are the potential environmental justice considerations, if any, that you have identified associated with your project? Who are the key stakeholders? Consider supply chain impacts, worker compensation and safety, plant siting, distribution of impacts, restorative justice/activities, job creation in marginalized communities, etc.

[3] For helpful content regarding environmental justice and CDR, please see these resources: C180 and XPRIZE's Environmental Justice Reading Materials, AirMiners Environmental and Social Justice Resource Repository, and the Foundation for Climate Restoration's Resource Database

We create local circular supply chains by connecting local waste distributors and energy providers. As local energy networks can be created we benefit local communities.
The Pyrolysis technology can be seamlessly integrated in existing infrastructure and hence don't require massive land use.
The implications to the workforce and the social implications are yet to be researched.

b. How do you intend to address any identified environmental justice concerns and / or take advantage of opportunities for positive impact?

On top of the above we encourage municipal engagement and collaboration for optimal use of waste streams, to ensure cascade usage of the woody waste streams and an optimal connection to local heat and energy systems.

The technology discussed and explained here for demonstration projects does not affect the aspect of environmental justice. When disseminated in countries with respective laws the commissioning will fully comply with these. The land use for the plants is comparably small. The needed feedstock being residual wood is sufficiently available according to research and statistics. The conversion of biomass into heat, power and biochar can be seen as a perfect symbiosis for energy transition, closing the carbon circle, whilst not harming endangered communities.

8. Legal and Regulatory Compliance

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

Woody biomass needs to be qualified as a sustainable waste stream / non hazardous waste stream.

b. What permits or other forms of formal permission do you require, if any, to engage in the research or deployment of your project? What else might be required in the future as you scale? 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.

At the moment the correct labeling of the biomass is the only permission needed. We are working on a certification for our additive for an easier application and broader listing within the construction material production. At the moment we work with 1-1 permissions and individual monitoring and permission for each project. Hence the broader certification is key for our scale up plan.

c. Is your solution potentially subject to regulation under any international legal regimes? If yes, please specify. Have you engaged with these regimes to date?

At the moment we do not plan international expansion apart from Europe, where we comply with the legal regimes and do not see any regulatory constraints.

d. 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.

see above

e. Do you intend to receive any tax credits during the proposed delivery window for Frontier's purchase? If so, please explain how you will avoid double counting.

no

9. Offer to Frontier

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

Proposed CDR over the project lifetime (tonnes) *(should be net volume after taking into account the uncertainty discount proposed in 4(c))*	1000 t over the lifetime of the project
Delivery window *(at what point should Frontier consider your contract complete? Should match 1(f))*	End of 2027
Levelized Price (\$/metric tonne CO_2) *(This is the price per tonne of your offer to us for the tonnage described above)*	500 \$ / t

Application Supplement: Biomass

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

Feedstock and Physical Footprint

1. What type(s) of biomass does your project rely on?

> We use woody biomasses, locally sourced, mainly from certified sustainable forestry and green residues and in accordance with the cascading use of biomass for an optimal utilization of forest and acreage. This biomass in the form of wood is used on a large scale in urban contexts which at the end of life is often disposed of in open pits or incinerated. Furthermore, a large amount of forestry waste and low-quality wood is never used for commercial purposes. We offer a higher value usage and an effective carbon sink.

2. How is the biomass grown (e.g., kelp) or sourced (e.g., waste corn stover)? Do you have supply agreements established?

> The major biomass used is woody biomass. The forest sector produced around 33 million tons of dry matter of woody biomass residues only in Germany in 2015.
>
> The resources of residual wood out of forests and manufacturing or wood waste collection are sufficiently supplying the biochar production. Additionally we are currently investigating long term contracts with biomass and biochar providers.
>
> At the moment we do operate with trusted 3rd party plant owners. To scale further we are in negotiations for an owned plant setup. Not only to ensure larger regional availability but also to facilitate research for new waste streams and ways of application.

3. Describe the logistics of collecting your waste biomass, including transport. How much carbon emissions are associated with these logistics, and how much does it cost? How do you envision this to evolve with scale?

> We are using forest waste wood which is taken from regional forests around 20km in distance from the processing (pyrolysis) facility. CO_2 emissions of approximately 0.774 kg CO_2/ ton of biomass are produced while transportation over a distance of 20km. We aim to reduce the emissions further by reducing distance and using green transport systems.

4. Please fill out the table below regarding your feedstock's physical footprint. If you don't know (e.g. you procure your biomass from a seller who doesn't communicate their land use), indicate that in the table.

	Area of land or sea (km^2) in 2022	Competing/existing project area use (if applicable)
Feedstock cultivation	The land use for the plants is comparably small. No additional land is used to obtain input raw materials since mainly green waste, unused low-quality wood, and wood waste from forestry are used as feedstock. Again strong nature protection laws prevent the land use to be exploited.	N/A
Processing	The land used will be mainly built on already developed land and industrial areas of cement and concrete manufacturers as well as companies and municipalities handling forestry and green waste. The SynCraft pyrolysis facility we operate with, is well-designed, compact, and modern, taking only 0.4 hectares of land including storing facilities and logistics area.0.4 hectares of land including storing facilities and logistics area.	N/A
Long-term Storage	The long term storage is happening in the construction material. No additional land use is required.	N/A

Capacity

5. How much CDR is feasible globally per year using the biomass you identified in question 1 above? Please include a reference to support this potential capacity.

Production is coupled with climate-smart technology which processes biomass to ensure permanence. The major energy source used is woody biomass. The pyrogenic carbon capture and storage potential sequestration capacity depend on assumptions about the availability of biomass and its allocation for the production of biochar. While some publications show a worldwide potential of at least 3 - 6 Gt CO2e/a others consider the achievable potential to be rather in the order of one Gt CO_2. The forest sector produced around 33 million tons of dry matter of woody biomass residues only in Germany in 2015. On another scale, China's tree residue reached 511.63 Mt in 2015. Also, EPA reported in 2014 that

in the US, approximately 70 million tons of "urban" biomass waste was collected, and only 30% was recycled.

Additionality and Ecosystem Impacts

6. What are applications/sectors your biomass feedstock could be used for other than CDR? (i.e., what is the counterfactual fate of the biomass feedstock)

Besides other CDR application options, the biomass is mainly used in wood power plants and the woody streams are simply burned. As a result, all the CO_2 bound by photosynthesis is released back into the atmosphere. And the solid combustion residues must be disposed of in landfills.

7. There are many potential uses for waste biomass, including avoiding emissions and various other approaches to CDR. What are the merits and advantages of your proposed approach in comparison to the alternatives?

Our technology makes maximum use of the residual wood, produces climate-neutral energy and heat in addition to the biochar. Despite the release of CO_2 into the environment (during the utilization of the energy sources), the system remains climate positive due to the carbon sink.

With our technology a large part of the carbon remains bound and the formation of CO_2 is prevented. The resulting carbon becomes usable in its further processed form as technical carbon, as valuable raw material and enables us, for example, to turn buildings into carbon sinks.

8. We recognize that both biomass production (i.e., growing kelp) and biomass storage (i.e., sinking in the ocean) can have complex interactions with ecological, social, and economic systems. What are the specific, potential negative impacts (or important unknowns) you have identified, and what are your specific plans for mitigating those impacts (or resolving the unknowns)?

We do not see negative impacts resulting from production or storage of our biomass.
Especially in the DACH region but also across Europe, use of wooden biomass is governed by restrictive legislation to prevent the use of timber into combustion or prevent a shift of timber in the biomass sector. The cascading law allows energetic use only after material use.

This September the EU parliament adopted the Renewable Energy Directive (REDIII) and recognized primary woody biomass as a sustainable source.

Application Supplement: CO_2 Utilization

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

CO_2 Feedstock

1. How do you source your CO_2, and from whom? If your approach includes CO_2 capture and it's described above (e.g., general application and one of the supplements), simply respond N/A here.

N/A

2. What are alternate uses for this CO_2 stream?

The traditional use of biochar was in agriculture, as a feed or soil additive. This is a very sensitive area of the food industry and therefore prone to strict regulations. Use of biochar in construction material not only offers the possibility to allow a broader set of feedstocks but most notably a permanent CO_2 storage, whereas in agriculture use the sequestration can not be considered as permanent.
The demonstration of biochar used as Clim@Add® being a valuable additive in mineral construction materials will open new market segments and enabling the creation of high-quality type 5 carbon sinks through a permanent bonding of the carbon in the building material – in comparison to the current less permanent type 4 (soil carbon) classification of biochar.

Utilization Methods

3. How does your solution use and permanently 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).*

Our pyrolysis process stores CO_2 in the form of biochar. The treated biochar is then put into concrete (or other cementitious bound matrices). In the process carbon in biochar is chemically reacted in the concrete and bound permanently. This chemical reaction not only allows permanent binding of CO_2 but also at the same time improves the quality of concrete. This method of usage allows us to achieve 100% utilization rate

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

The biochar based additive becomes part of the product matrix and can therefore be recycled again (and again) even after the product has reached the end of its life. This means that for each new building, a significantly CO_2-reduced or even climate-positive building material can be produced again using the recyclate and a further admixture.

5. 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 CDR benefits and how could an independent auditor validate no double counting?)*

As we oversee the entire process and act as intermediary between the plant owner and the material producer we know where the certificates will be claimed. For most of our projects we do sell the certificates with the treated biochar to our customers. As explained above we will offer the remaining amount (from customers that do prefer a lower price than the certificate or do not need a certificate as they don't have unavoidable emissions to compensate) to Frontier.