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Charm Industrial

APPLICATION FOR STRIPE 2020 NEGATIVE EMISSIONS PURCHASE

Section 1: Project Info and Core Approach

1. Project name

Charm Industrial Bio-oil Sequestration

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

Geological sequestration of bio-oil

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

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

Biomass is a well-known source of atmospheric carbon. Typical biomass carbon sequestration projects convert biomass to a sequesterable solid (e.g. biochar on fields) or a sequesterable gas (CO_2 in underground geological formations). The permanence of biochar is hotly debated and CO_2 geological storage is generally used controversially for enhanced oil recovery and is expensive due to high energy associated with gas separation, compression, and transportation. Instead, we plan to convert biomass to a liquid (bio-oil) via a well-known process called fast pyrolysis, which is generally self-heated. Bio-oil is similar to crude oil removed from geological formations after many millions of years, but bio-oil is heavily oxygenated (making it less valuable as a fuel/chemical, but just as carbon-rich for sequestration). We plan to pump the bio-oil into an EPA Underground Injection Class I Industrial and Municipal Waste Disposal Well for extremely long-term geological storage. We will effectively be refilling deep underground porous rock formations with a partially oxygenated crude oil lookalike extracted from the atmosphere.

Both key technologies—fast pyrolysis to bio-oil & underground waste injection—are well-researched and even commercially available. See 20+ years of fast pyrolysis and bio-oil research documented by IEA Task Force 34 and the EPA's Class I Well website (even cheese whey is commonly injected down these wells). However, to our knowledge, the two technologies have only been conceptually connected as a potential carbon sequestration pathway twice before (Schmidt 2018 and Werner 2018). We do not believe an actual injection of bio-oil has ever been attempted.

This project seeks to (1) demonstrate geological sequestration of bio-oil for the first time and establish a baseline cost, (2) allay key practical risks in geological sequestration of bio-oil with our patent pending methodology (which covers, among other things, processes for preventing blockages due to bio-oil particulate & corrosivity, safety with respect to bio-oil vapor flash point, storage duration and polymerization impact on bio-oil viscosity, etc. for different deep injection well types.)

For this project we have arranged bio-oil supply including transport from existing commercial bio-oil producers, and underground injection well capacity from existing injection wells, both in North America and in Europe. We expect to be able to begin sequestration activities within a few months.

Section 2: 2020 Net-Negative Sequestration Volume

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

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

10,000

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

10,000

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

We are currently limited by bio-oil production capacity.

Section 3: Life Cycle Analysis

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

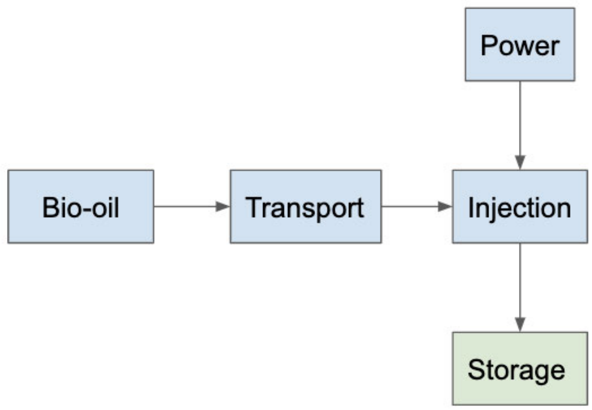
7. Provide a life cycle analysis of your negative emissions solution demonstrating its carbon negativity, as complete as possible given limited space, and making sure to cover the following points:
   a) Include a flow sheet diagram of direct ingoing and outgoing flows (GHG, energy, materials, etc) that bear on the LCA.
   b) Please be explicit about the boundary conditions of your LCA, and implications of those boundaries on your life cycle. Let us know why the conditions you've set are appropriate to analyze your project.
   c) Make sure to identify assumptions, limitations, constraints, or factors that relate to ingoing and outgoing flows, citing values and sources (for example: land and resource scarcity, limitations on a required chemical, energy requirements). Also identify key sources of uncertainty in determining these values.
   d) If your solution results in non-CO2 GHG emissions, please be sure to separately specify that (e.g. in units of GWP 20 or 100 years, ideally both).

e) For solutions that rely on modular components (for example: incoming energy flows or outgoing CO2 streams), feel free to cite values associated with those interfaces instead of fully explaining those components. For these values, please identify the upstream and downstream life cycle emissions of the component.
f) Explain how you would approach a more comprehensive LCA by citing references and underlying data needed for the analysis.

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

Every 1 tonne of bio-oil we procure contains 1.55 tonnes of CO_2e. In the process we emit 0.36 tonnes of CO_2e from transport and power usage, for a net sequestration of 1.19 tonnes CO_2e per ton of bio-oil.

This diagram shows the overall process, beginning with bio-oil and ending with geological storage:



We plan to complete a comprehensive LCA as soon as possible with an outside consultant, but this LCA is our best estimate and model as of today:

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Carbon Intensity Calculations					
			GREET		
Production Step	**Use Rate**	**Unit**	**LCI Data**	**Unit**	**Emissions (t CO2e/t bio-oil)**
Bio-oil					
Bio-oil Production	1.00	tonne bio-oil/tonne bio-oil	0.296	tonne CO2e/tonne	0.296
Transport to Well					
Fuel Efficiency	436	tonne-miles/gal			
Transport Distance	2000	miles			
Fuel Consumption	4.6	gal/tonne	10.16	kg CO2e/gal	0.047
Injection					
Electric Power	35	MJ/tonne bio-oil	102.5	g CO2e/MJ	0.004
Storage					
Bio-oil Water Content	24%	tonne water/tonne bio-oil			
Bio-oil Carbon Content	55%	tonne C/tonne bio-oil dry			
Bio-oil Carbon Content	42%	tonne C/tonne bio-oil			
Molar Mass CO2	44.12	g/mol			
Molar Mass Carbon	12.01	g/mol			
Stored CO2e		tonne CO2e/tonne bio-oil			-1.53
Total					
Net CO2e Emissions					-1.19

For this project's LCA, a few notes:

1. "Bio-oil Production" carbon intensity is based on averages of public information about our bio-oil suppliers, including GREET LCA analyses approved by CARB.
2. "Transport to Well" carbon intensity is based on average rail fuel efficiency and the real transport distance from one of our bio-oil suppliers to one of our injection wells.
3. "Injection" carbon intensity is based on a maximum estimate of injection pumping power. Some wells are gravity-fed and require no power.
4. "Storage" carbon content is based on averages of public information about the typical bio-oil water and carbon content from our suppliers.
5. We've validated that (a) the bio-oil procured for this project is excess capacity, so we are not getting bio-oil that would have otherwise replaced fossil fuel burning, (b) the bio-oil procured for this project is produced from biomass that would otherwise have rotted, so we are not getting bio-oil produced from biomass that would have otherwise replaced fossil fuel burning.

For future scaleup we anticipate localizing the bio-oil supply chain, leading to a different life cycle analysis boundary that would begin with the waste biomass. Additionally, future projects will validate that the waste biomass entering the process does not have a legitimate alternative use that would displace fossil fuel burning.

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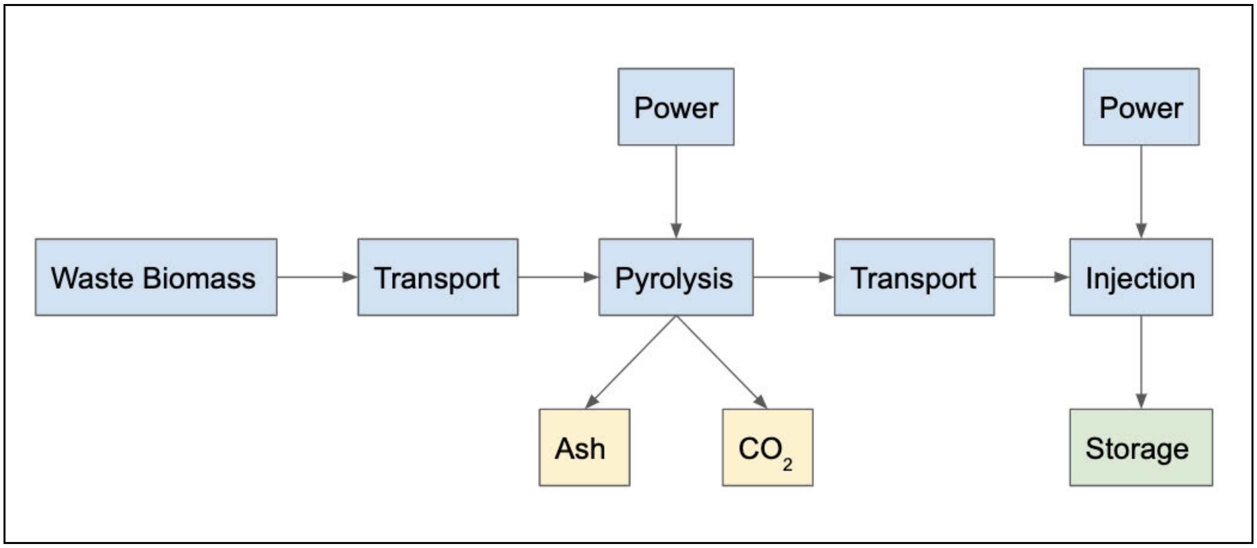

8. Based on the above, for your project, what is the ratio of emissions produced as any part of your project life cycle to CO2 removal from the atmosphere? For true negative emissions solutions, we'd expect this ratio to be less than 1.

0.28

Section 4: Permanence and Durability

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

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

300,000,000

10. Please provide a justification for your estimates, and describe sources of uncertainty related to: the form of storage, effects of environmental or climatic variability, difficulty in monitoring or quantification, etc. Specifically, discuss the risks to permanence for your project, the estimated severity/frequency of those risks (e.g. 10% of the acres of forest in this forest type are burned by fire over a 100 year period), and the time-horizon of permanence given those risks.
Max 500 words

We are injecting an oxygenated crude-oil lookalike into a geological formation whose existing crude oil has been trapped there for 300,000,000 years: https://en.wikipedia.org/wiki/Permian_Basin_(North_America)#Depositional_history

Section 5: Verification and Accounting

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

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

We can provide:
1. Carbon intensity/lifecycle analysis from our bio-oil suppliers and injection partners.
2. Verification of receipt/transport of the bio-oil to our injection site from our bio-oil suppliers.
3. Verification of injection from our injection partners.
4. Lot-sampled bio-oil composition analysis to confirm carbon content.

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

Bio-oil suppliers sell their product assuming that it will be burned, re-emitting CO_2 previously removed from the atmosphere. As the consumer of the bio-oil, it's entirely under our control what we do with the bio-oil and the negative emissions credit lies clearly with us, not with any other party.

Section 6: Potential Risks

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

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

We face risks associated with injecting bio-oil into an injection well for the first time. Specifically, particulate content, acidity, polymerization and vapor flash point are examples of potential risks that we intend to mitigate through the course of the project.

COVID-19 represents a challenge to our supply chain's ability to operate in a timely manner. One bio-oil supplier continues to operate, while another bio-oil supplier has had to pause operations until a partial re-opening allows them to fully staff their production facility. Note that the amount of bio-oil required for this project is less than two days of production capacity, so we feel the likelihood of COVID-19 preventing execution of the project is unlikely over the remainder of 2020.

Section 7: Potential to Scale

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

14. Help us understand how the cost and net-negative volume of your solution will change over time. Note that we aren't looking for perfect estimates. Instead, we're trying to understand what the long-term potential is and

what the general cost curve to get there looks like. (Note: by "cost" here we mean the amount Stripe or any other customer would pay for your solution):

	Today	In ~5 years	In ~20 years
Est. Cost per net-negative ton (in $)	$600	$175	$55
Est. Net-negative volume (in tons of CO2)	10,000/year	1 Mt/year	7 Gt/year

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

Max 300 words

Cost
Today: approximately 55% of our costs are bio-oil, 37% transport, and 8% injection. This is an extremely inefficient configuration. The bio-oil is produced "over quality" for our purpose and must currently be transported nearly 3,000 km to the injection site.

In ~5 years: bringing bio-oil production near the site of injection, achieving some economies of scale on the fast pyrolysis equipment, and negotiating bulk rates on injection slashes the cost dramatically.

In ~20 years: achieving meaningful-but-standard economies of scale (30% unit cost savings for first three 10x in capacity built) for fast pyrolysis plants, commissioning our own injection wells, reducing electricity costs from $0.12 to $0.08/kWh and eliminating 90% of electricity consumption by using internal char for combustion (also improves carbon balance), reducing *waste* biomass costs from $30/ton to $20/ton, reducing transport costs through co-location with injection well, and lowering the cost of capital to 15% 5-year IRR due to widespread existing proof points.

Scale
Biomass availability is a potential constraint on scale. We can estimate lower and upper bounds on the biomass constraints:

- *Lower bound*: rice straw, sugar cane bagasse and corn stover are examples of large-scale agricultural waste products that have little value in replacing fossil fuels. They are commonly burned in the field or allowed to rot. For example, 3-5% of rice straw is estimated to be collected and used, none of it for fossil fuel replacement use cases. These three crops alone yield 1.7 Gt/year of waste biomass:
    - Rice straw: 3.7 tons/ha over 158 million ha = 580 Mt/yr
    - Bagasse: 300 Mt/yr
    - Corn stover: 43 billion bushels at 2 tons recoverable / 100 bushels = 860 Mt/yr
- *Upper bound*: globally we generate roughly 140 Gt/year of waste biomass, or roughly 35 Gt/year on a dry basis. Of this, only a portion is available, accessible and usable for bio-oil production... let's say an upper bound of 20% or 7 Gt/year. Bio-oil conversion is 70% efficient and bio-oil:CO_2e sequestered is 1:1.3 ratio, so that suggests very approximately an upper bound of 7 Gt CO_2e/year of potential from bio-oil sequestration.

Geological sequestration capacity is another potential constraint on scale. The EPA estimates a theoretical global capacity for CO_2 storage (which is far less dense than bio-oil per ton of carbon) at 13,000 Gt. This would be at least 1,800 years at 7 Gt/year (not accounting for the massively better carbon density of bio-oil than CO_2). Additionally, we've extracted at least 150 Gt of crude oil, implying we could refill 150 Gt of bio-oil. Geological sequestration capacity is unlikely to be limiting.

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Section 8: Only for projects with significant land usage

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

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

The current project does not have substantial land use associated with it.

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

In the long-term we plan to enter offtake agreements for waste agricultural residues, with growers (eg. corn farmers) or processors (eg. nut processors, sugar mills). We will not own or operate the land directly. It could eventually become interesting to look at purpose-grown, high-yield biomass crops, but that has significant land use change impacts that would need to be more deeply understood and considered.

18. Land use: For forest projects, please provide details on forest composition as well as forest age and basal crop area/density. For soil projects, please provide details on land use and crop type (if agricultural), soil organic carbon baselines, and regenerative methodology. For BECCS, biochar, or wooden building materials projects, please provide details on biomass crop type and methodology as applicable.
Max 500 words

In the long-term we expect to primarily depend on waste agricultural residues like nut shells, corn stover, bagasse, rice straw. These target residues are specifically chosen because they are generally not used as fossil fuel replacements. This ensures that the sequestration of the downstream bio-oil has a carbon impact relative to rotting/burning as opposed to fossil fuel avoidance. Each of these crops has different nuances to ensure that the residue usage does not create additional unexpected emissions. For example, corn stover represents 860 Mt/yr of potential residues. However, either a groundcover crop or a small portion of the stover should be left on the field to protect the ground from direct rainfall (which can decrease soil porosity and cause soil-based CO_2 emissions). While not applicable for our current project, future projects will need to design and account for these nuances on a residue-by-residue basis.

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

Many environmental reviews in places like California focus on environmental impact potential like emissions of particulate and NOx, or increased road traffic. For some crops, like nut shells, which are already processed at central facilities, we expect to decrease particulate, NOX and road traffic by condensing (and possibly injecting) bio-oil immediately on-site rather than grinding up the shells and applying them across broad areas.

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For other crops, like corn stover, which are generally not processed centrally, we will slightly increase particulate, NOx, and road traffic by offtaking this biomass from the fields to bring it to a local bio-oil conversion and injection site. This will need to be considered as part of any environmental review prior to building a permanent conversion and injection plant.

Injection wells are believed to cause increased seismic activity by lubricating interfaces between rock layers. This is an area for concern that needs further research. However, as a rough order of magnitude, approximately 3-10 Gt/year of brine and other waste material is already injected into wells in the US today.

Section 9: Other

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

Max 100 words

We have more capacity than Stripe can buy at present, we welcome introductions to additional purchasers.

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

Max 500 words

Section 10: Submission details

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

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

Name of company or person submitting this application

[redacted]

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

[redacted]

Date on which application is submitted

[redacted]

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