General Application

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

Company or organization name

CO2Rail Company
www.co2rail.com

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

US

Name of person filling out this application

Email address of person filling out this application

[redacted]

[redacted]

Brief company or organization description

Rail-Based, Self-Powered, Hybrid Direct Air Carbon Capture.

The CO2Rail System deploys proven technology for the Direct Air Capture of carbon dioxide gas from the ambient environmental air utilizing the massive scale and scope of the global railway network.


HYBRID
HYBRID
DIRECT AIR
CAPTURE
2187


HYBRID
DACX
2021
DIRECT AIR

1. Overall CDR solution (All criteria)

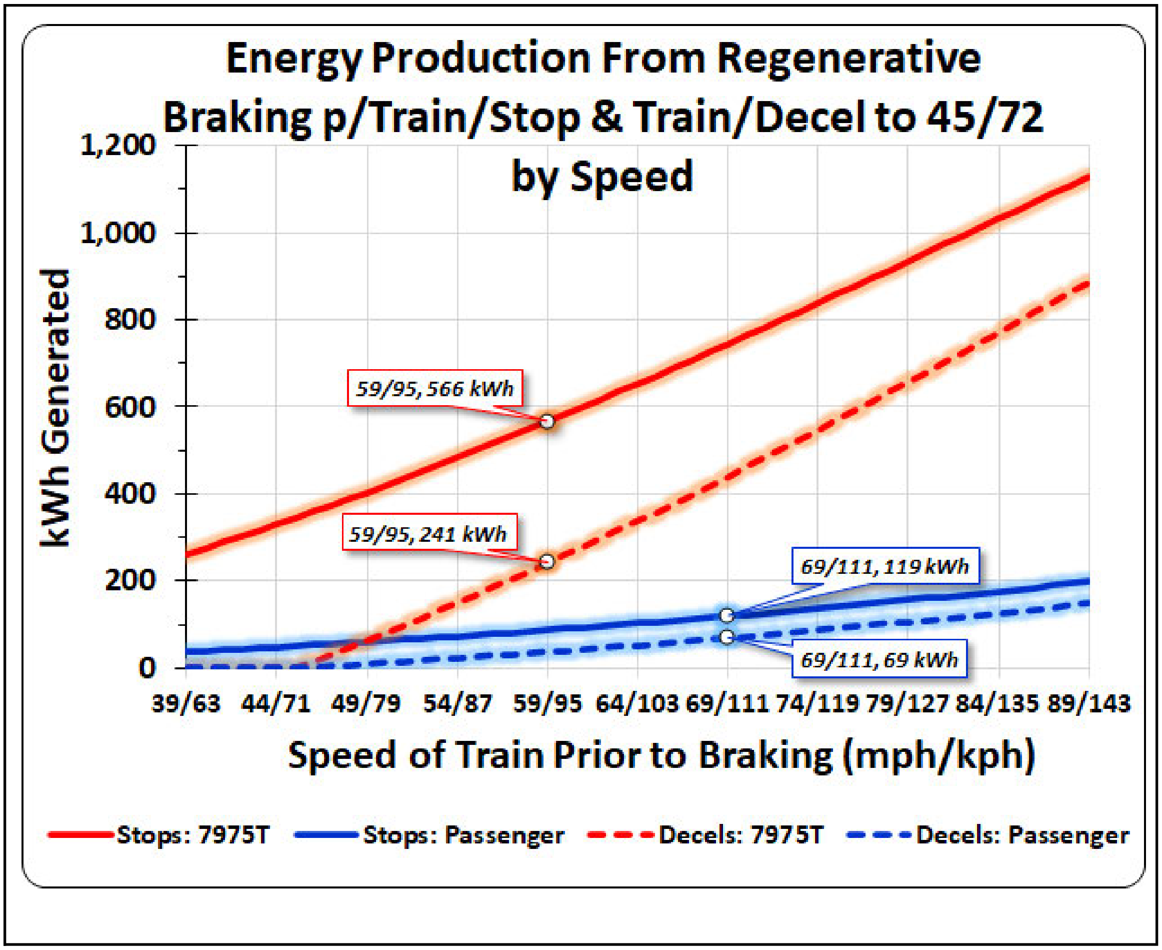
a. Provide a technical explanation of the proposed project, including as much specificity regarding location(s), scale, timeline, and participants as possible. Feel free to include figures and system schematics.

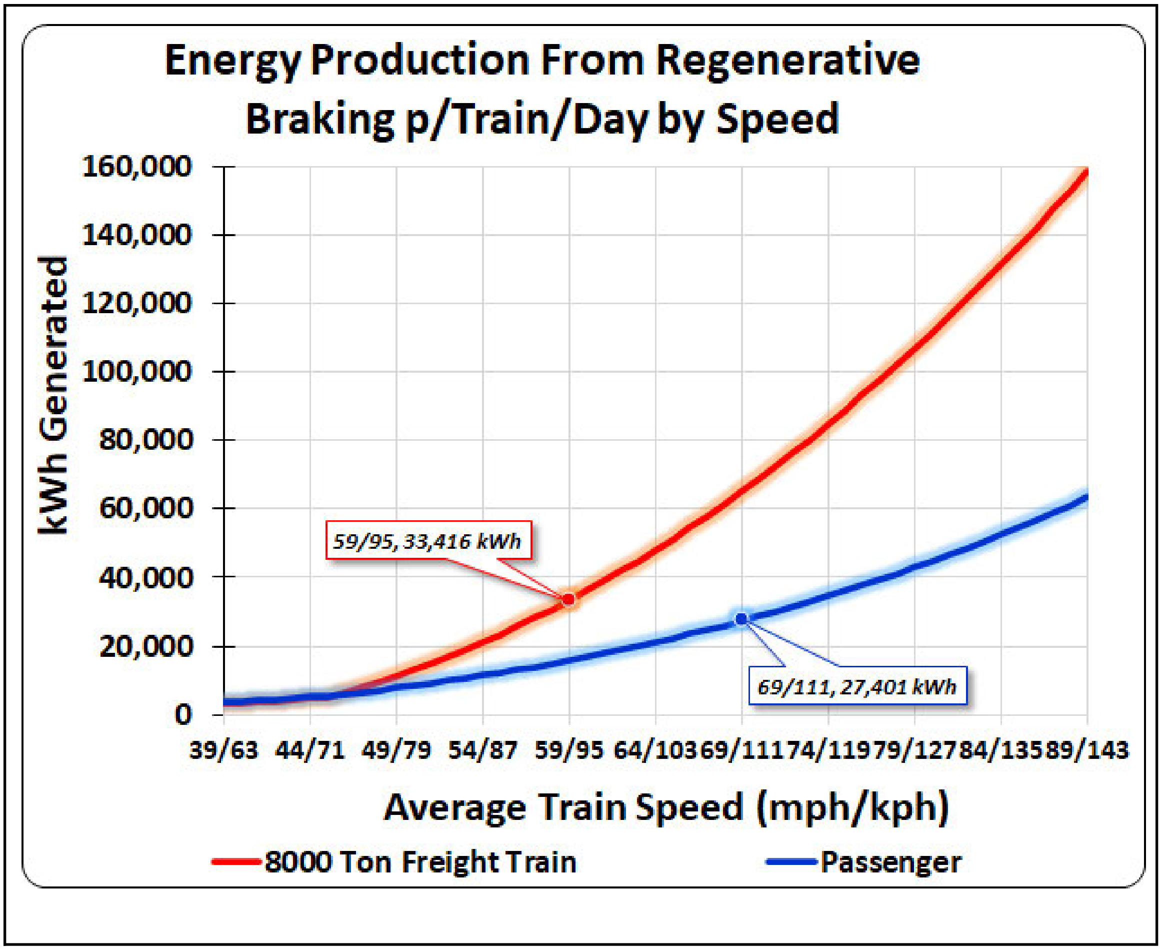
The CO2Rail system centers around the deployment of self-contained, rail-based, mobile DAC railcars that are operated with already running trains in regular service and powered by the currently untapped and incremental cost-free, enormous hybrid regenerative braking energies generated from stopping or slowing an entire train many times per day. Notably, train energy braking is not new or narrowly deployed. In fact, almost 100% of all trains around the world utilize energy braking during each braking maneuver. Currently however, this substantial, reliable, and zero-carbon source of energy is almost universally wasted by immediately converting it into resistance heat during each braking cycle (rheostatic braking). CO2Rail cars are deployed on partner host railroads and the system was designed with broad global compatibility in mind.

CO2Rail cars appear similar to a normal rail tank car and consist of a large main DAC collection chamber, top-mounted air intakes, 2,400-kWh battery array, small 15-tonne CO_2 reservoir to temporarily store the harvested CO_2, and equipment room to contain the required peripheral equipment such as the compressor and control system.
During forward movement of the train, ambient environmental air enters the DAC collection chamber through the large intakes that extend up into the slipstream of the moving train and collect CO_2 feedstock air by fluidic, ramjet-type processes thus obviating the need for the fans required by land-based systems. When the unit's control system determines the sorbent is at capacity, the adsorption stage is ended, and the desorption stage is begun by closing off the collection chamber and then pumping it down to create a partial vacuum within.

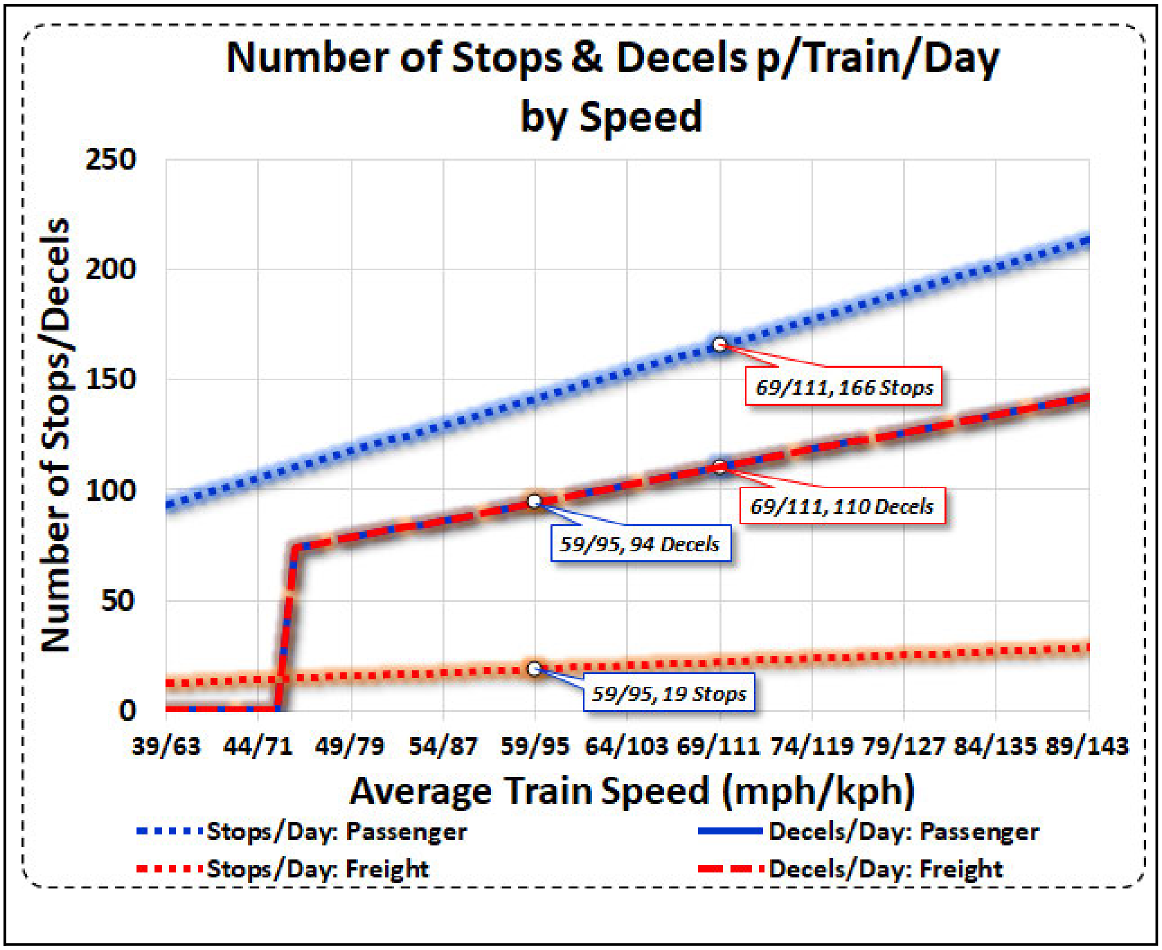
Given CO2Rail's operational flexibility and depending on the sorbent in use at that time, desorption potentiation can take many forms such as temperature, pressure, and/or charge polarity swings. After desorption has been initiated, the gaseous CO_2 begins to flow from the sorbent media and is collected, compressed, cooled by way of the front intake grill heat exchanger, liquified in second-stage compression, and then pumped to the rear of the car for short-term storage within an on-board 15/TCO2 reservoir. The reservoir is then periodically emptied during crew change or fueling stops into a regular tank car for later delivery with others to a nearby sequestration site or commercial partner within the circular carbon economy.

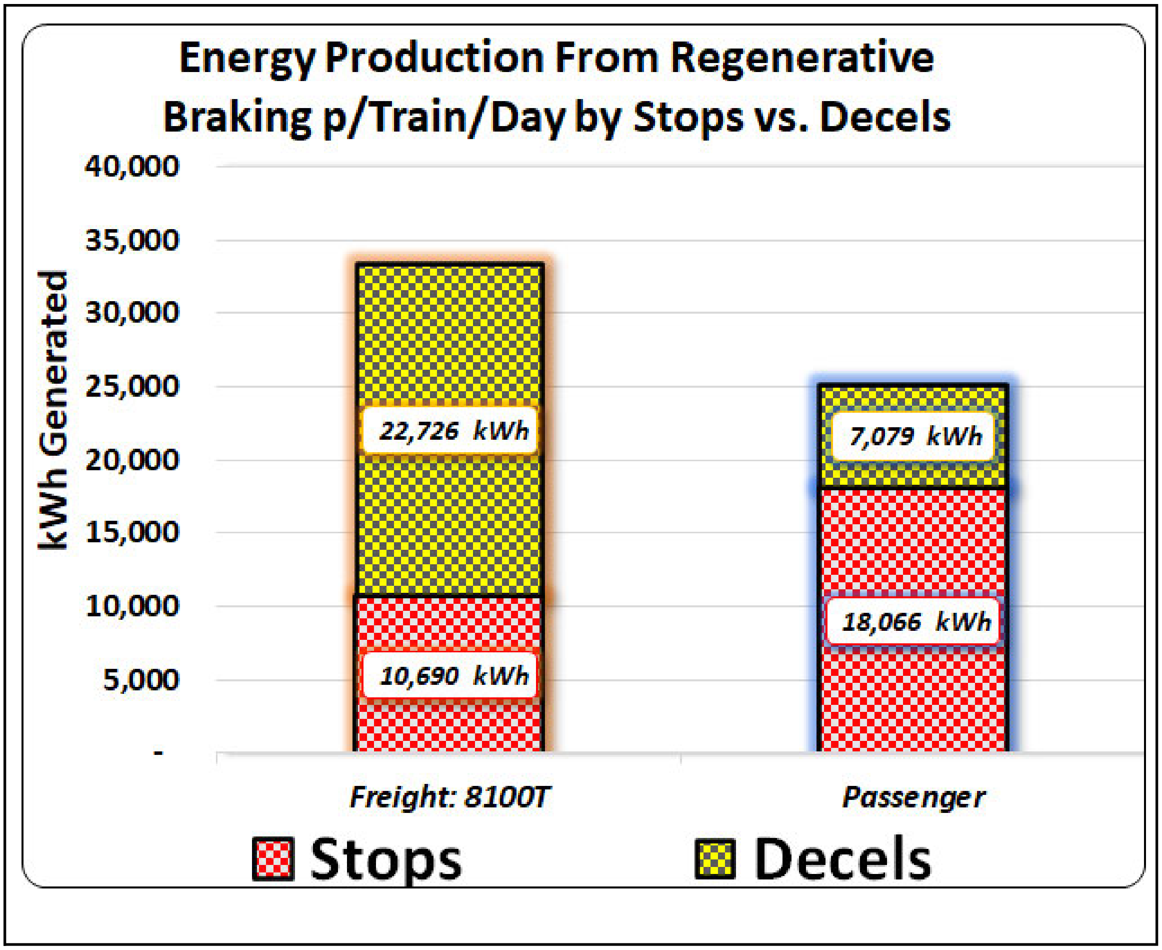
With only minor modifications to the currently configured locomotive fleet, the substantial energy generated from stopping or slowing an entire train many times per day is made regenerative and stored in a battery array for later productive use. CO2Rail utilizes this immense source of sustainable energy to remove CO_2 from the atmosphere without the need for any grid energy or substantial demands on limited sustainable energy sources.

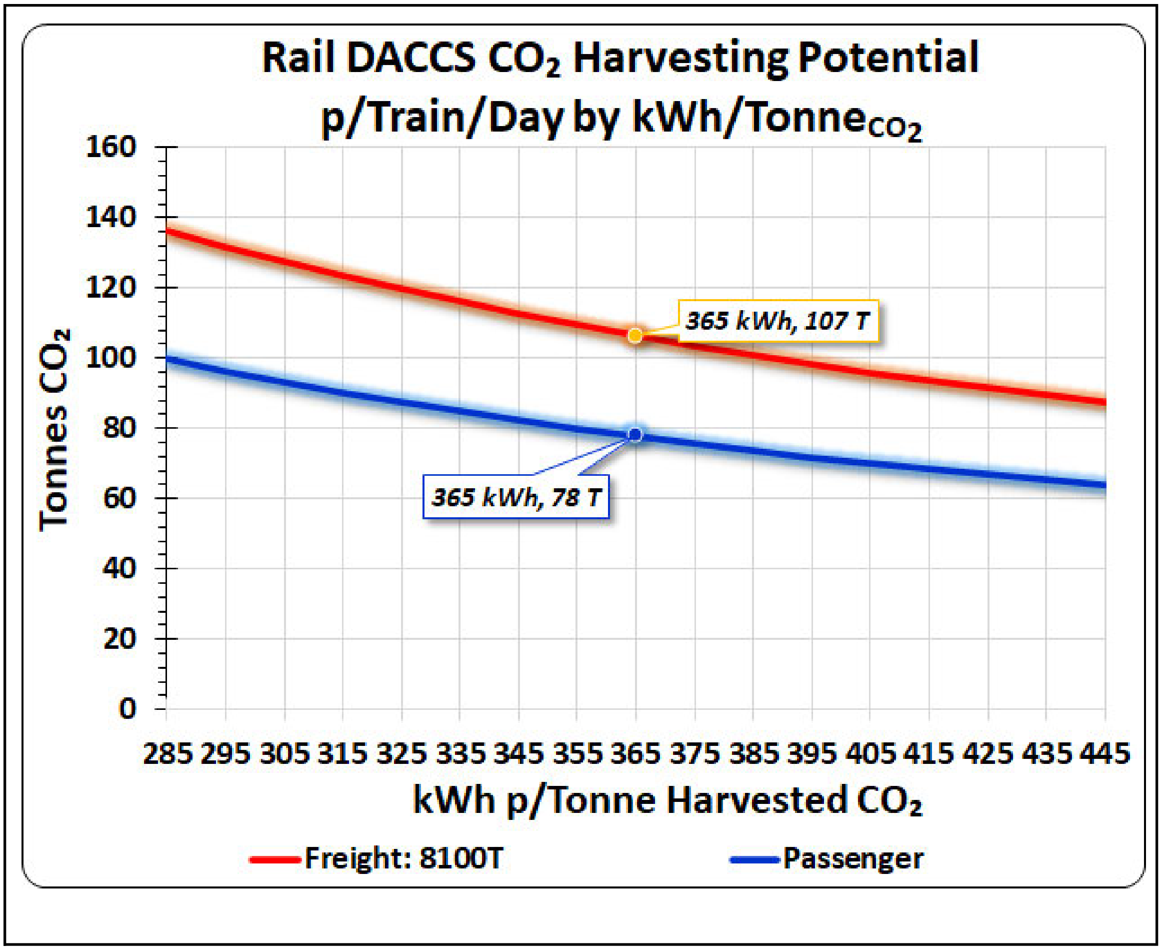

Energy Production From Regenerative Braking p/Train/Stop & Train/Decel to 45/72 by Speed
1,200
1,000
800
600
400
200
0
kWh Generated
59/95, 566 kWh
59/95, 241 kWh
69/111, 119 kWh
69/111, 69 kWh
39/63
44/71
49/79
54/87
59/95
64/103
69/111
74/119
79/127
84/135
89/143
Speed of Train Prior to Braking (mph/kph)
Stops: 7975T
Stops: Passenger
Decels: 7975T
Decels: Passenger

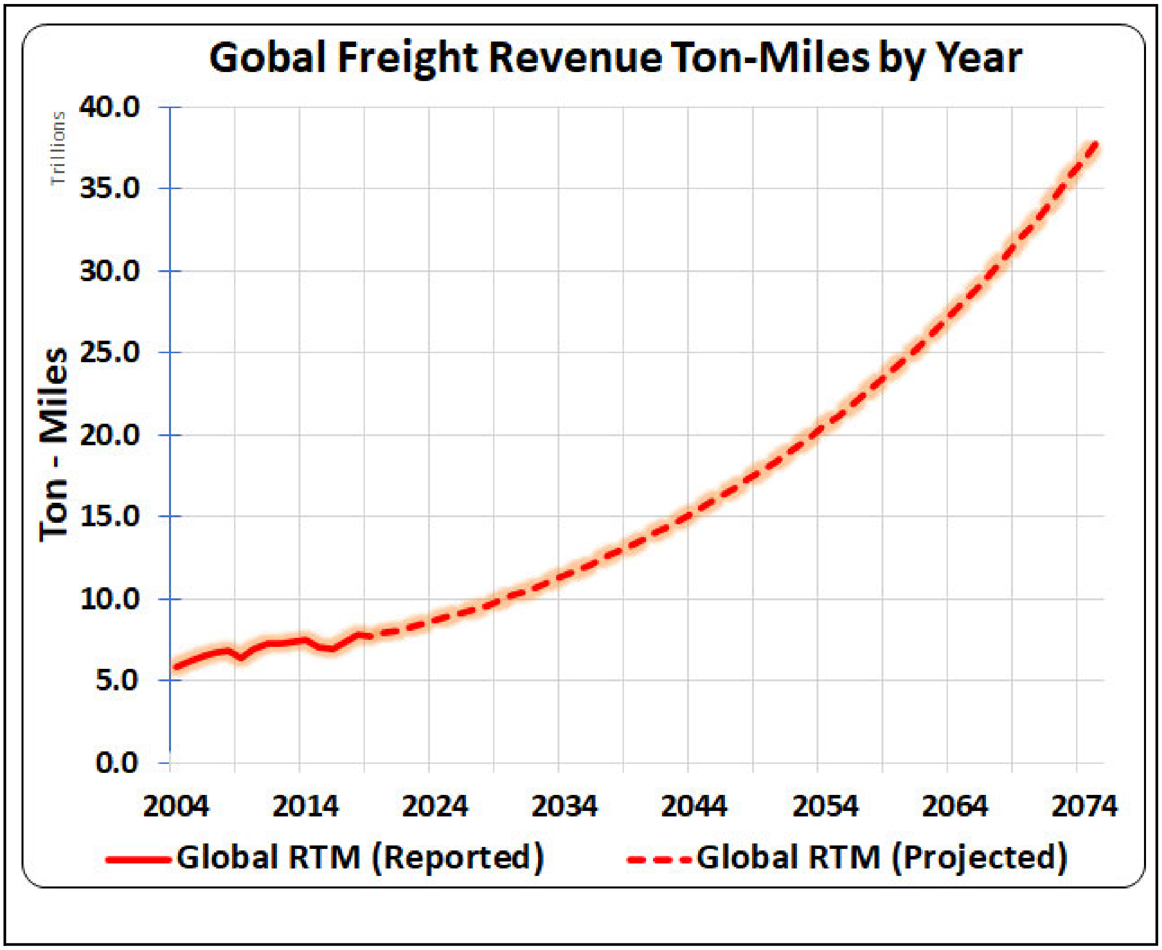


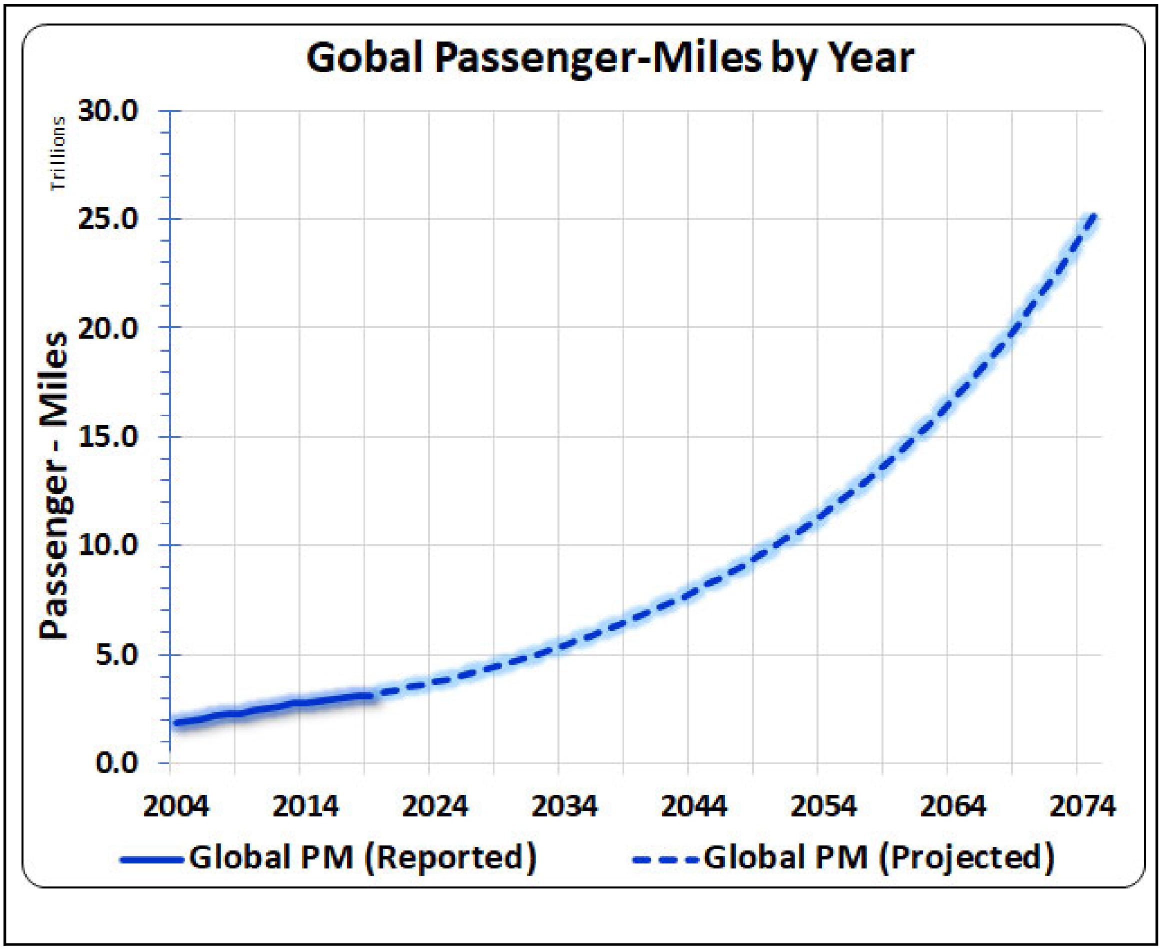
Energy Production From Regenerative Braking p/Train/Day by Speed
kWh Generated
160,000
140,000
120,000
100,000
80,000
60,000
40,000
20,000
0
59/95, 33,416 kWh
69/111, 27,401 kWh
39/63
44/71
49/79
54/87
59/95
64/103
69/111
74/119
79/127
84/135
89/143
Average Train Speed (mph/kph)
8000 Ton Freight Train
Passenger

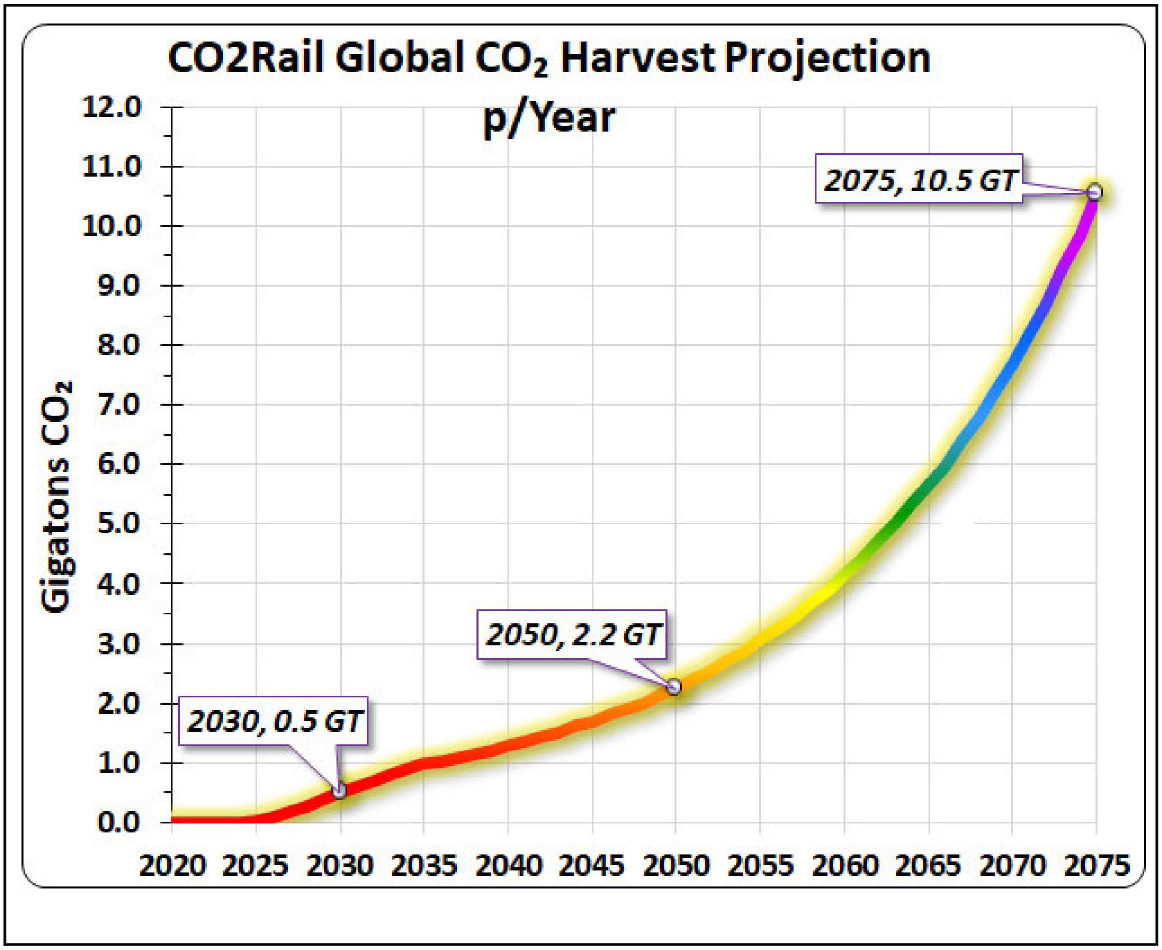

Number of Stops & Decels p/Train/Day
by Speed
Number of Stops/Decels
250
200
150
100
50
0
39/63
44/71
49/79
54/87
59/95
64/103
69/111
74/119
79/127
84/135
89/143
Average Train Speed (mph/kph)
69/111, 166 Stops
69/111, 110 Decels
59/95, 94 Decels
59/95, 19 Stops
Stops/Day: Passenger
Decels/Day: Passenger
Stops/Day: Freight
Decels/Day: Freight

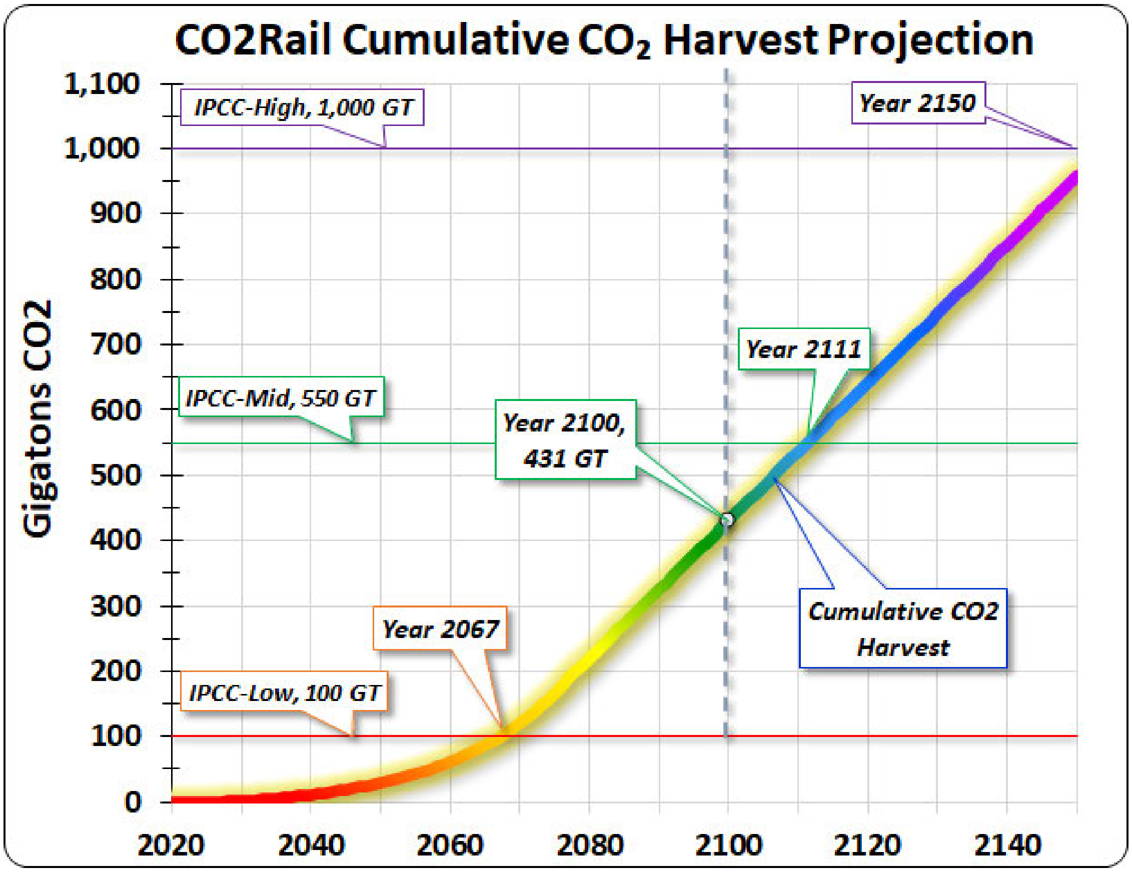

Energy Production From Regenerative Braking p/Train/Day by Stops vs. Decels
40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
-
kWh Generated
22,726 kWh
10,690 kWh
7,079 kWh
18,066 kWh
Freight: 8100T
Passenger
Stops
Decels


Rail DACCS CO₂ Harvesting Potential
p/Train/Day by kWh/Tonne CO₂
Tonnes CO₂
160
140
120
100
80
60
40
20
0
365 kWh, 107 T
365 kWh, 78 T
285 295 305 315 325 335 345 355 365 375 385 395 405 415 425 435 445
kWh p/Tonne Harvested CO₂
Freight: 8100T
Passenger


Gobal Freight Revenue Ton-Miles by Year
Ton - Miles
Trillions
40.0
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
2004
2014
2024
2034
2044
2054
2064
2074
Global RTM (Reported)
Global RTM (Projected)


Gobal Passenger-Miles by Year
Trillions
Passenger - Miles
30.0
25.0
20.0
15.0
10.0
5.0
0.0
2004
2014
2024
2034
2044
2054
2064
2074
Global PM (Reported)
Global PM (Projected)


CO2Rail Global CO₂ Harvest Projection
p/Year
Gigatons CO₂
12.0
11.0
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
2020 2025 2030 2035 2040 2045 2050 2055 2060 2065 2070 2075
2030, 0.5 GT
2050, 2.2 GT
2075, 10.5 GT



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.)*

We developed and own all relevant IP related to the CO2Rail technology.

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

There are three main performance bottlenecks of the CO2Rail system: Energy, Air, Sorbent. Each is uniquely challenging with the primary objective being to engineer around encountered or anticipated bottleneck conditions. However, each is sensitive to engineering solutions to unique degrees. For instance, total recoverable regenerative braking energy is strictly limited at the top-end by the train's total kinetic energy immediately prior to initiating an energy braking maneuver.

This energy ceiling is, obviously, very strict and resistant to enhancements attempted at the system plane but gains can often be made at the macro-scale through approaches that might improve upon overall network speeds and train weights.

Other potential bottleneck conditions are much more sensitive to engineered solutions. One of these is chamber airflow volume through adjustments in the number, size, and configurations of the forward-facing air intake(s) that extend up into the slipstream of the moving train.

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

If confidentiality is assured, our relevant IP can be found here:

1. Confidential S.PPA-6,320,159 Gigaton-Scale, Rail-Based Direct Air Carbon Capture and Air-Pollution Mitigation Device, System and Method
2. Confidential US Pat-7,891,302 System and Method for Providing Head End Power for Use in Passenger Train Sets
3. Confidential US.Pat-8,196,518 Head End Power System for Passenger Train Sets
4. More…

e. Who's the team working on this? What's your team's unfair advantage in building this solution? What skills do you not yet have on the team today that you are most urgently looking to recruit?

Our team includes some of the most respected names in the industry from both the corporate and academic/research side. Such institutions include MIT, University of Toronto, Princeton, University of Sheffield and a well-respected IPCC advisor. On the rail side, our team includes a member with three decades of executive experience in the rail industry and a well-respected rail economist.

2011 Albert Einstein World Science Award goes to Professor Geoffrey Ozin

A new approach to CO2 capture

Our team's already peer-reviewed and soon to be published article in Joule can be viewed at the link below:
Joule Manuscript Link

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 2022 - Jun 2023. The end of this duration determines when Stripe will consider renewing our contract with you based on performance.	Jan 2023 - Dec 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 2022 - Jun 2023 OR 100 years.	Jan 2023 - Dec 2023
Distribution of that carbon removal over time For the time frame described above, please detail how you anticipate your carbon removal 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”.	With the appropriate support, we anticipate beginning construction of the first CO2Rail car in Q4 2022 at a top-notch rail equipment manufacturing facility in Iowa. By design, there exists great similarities between a CO2Rail car and a normal and customary railroad tank car. Surplus rail tank cars will be used not only for the prototypes but also for the production units until such time as the vast supply of these surplus cars is exhausted. Not only will this substantially reduce engineering and production costs but will also mitigate new manufacturing carbon emissions from such sources as steel production and transportation. It is an exciting prospect to repurpose a car that once might

	have been used to transport petroleum products into one that will reverse that trend and actually remove carbon dioxide from the atmosphere. As such, construction of these first CO2Rail cars will go quickly and we anticipate out-shopping within 90 days of delivery. Immediately thereafter, the first unit will begin trials and dial-in on an already arranged midwestern railroad. Ambient air CO2 removal will certainly begin at this point but productivity will be low as the unit is tested and operational parameters are dialed-in. It is anticipated that meaningful quantities of CO2 will begin to show by late Q2 with full delivery being possible by late Q3.
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

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

We rely on the guidance and support of the US Department of Energy which has high confidence in the 1,000+ year durability of geologically sequestered CO2 in appropriate underground formations including saline reservoirs, oil/natural gas reservoirs (*without EOR*), unmineable coal, organic-rich shale, and basalt formations.

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.)*

Again, we rely on the guidance and support of the US Department of Energy in matters pertaining to large-scale geological sequestration of CO2.

Potential large-scale sites are actively being studied by the US DOE and exist at numerous locations across the continent. A significant resource used in our planning developed by the agency is entitled "Carbon Storage Atlas" and can be found at the link below:

US DOE Carbon Storage Atlas

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?

Risks – There are no conceivable negative environmental impacts of broad CO2Rail deployment other than the universal risk of catastrophic failure and leakage back into the atmosphere of a well-used geological sequestration reservoir.

This is why we rely heavily on the guidance and support of the US Department of Energy. Moreso, we strongly support the government selection, ownership, control, monitoring, and management of sequestration sites which are treated care and consideration normally due a strategic national asset.

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.)*

CO2Rail follows the guidance and best practices as set forth by the U.S. Department of Energy (DOE) Carbon Storage Program as well as other federal, state, and/or local regulations (where applicable).

The DOE Best Practices Manual (BPM) for MVA can be found at:
https://www.netl.doe.gov/sites/default/files/2018-10/BPM-MVA-2012.pdf

These extensive best practices manuals result from extensive field research and are focused on practical lessons learned. This MMV BPM provides an extensive discussion of existing and evolving monitoring tools, the information that each tool can provide, the tool's R&D status, and insights into how some of these tools can be used to meet regulatory requirements.

The liquified harvested CO2 is geologically sequestered deep underground at various pre-certified wellhead locations throughout North America following the best practices methodology as set forth by the U.S. Department of Energy (DOE) Carbon Storage Program. Geologic storage is defined as the placement of CO2 into subsurface formations so it remains safely and permanently sequestered. DOE is actively investigating five types of underground formations for geologic carbon storage: saline reservoirs, oil/natural gas reservoirs, unmineable coal, organic-rich shale, and basalt formations at numerous locations across the continent. Over time, the sequestered CO_2 is likely to become carbonate rock in its final form.

However, we strongly support government ownership, control, and open access to strategically placed sequestration sites. This is of critical importance in those geographic areas where such sites might be of limited quantity or quality. State ownership of these strategic assets would not only serve to encourage development and broad deployment of DAC technology by eliminating end-of-chain uncertainty and regulatory hurdles related to private sites but also serve to increase site safety and monitoring, reduce potential diversion of captured CO_2 for purposes of enhanced oil recovery, and eliminate unethical rent-seeking by private or corporate actors.

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	9,031 Tonnes/$_{CO2}$
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	6,886 Tonnes/$_{CO2}$ in reduced locomotive fuel consumption from utilizing some of the excess battery array energy for train propulsion with a less than full complement of CO2Rail cars at this early stage. Additionally, since rail can become the world's only conceivable large-scale carbon-negative mode of transportation using CO2Rail technology, there could be powerful incentives for shippers and passengers to switch to rail and a rail-centered gravitational singularity could develop. As rail is the most efficient form of scale transportation and is five to six times more fuel efficient per tonne transported than truck, any increase in rail traffic away from less efficient forms of scale transportation will certainly have a positive environmental impact in addition to the direct CDR benefits.

b. Show your work for 3(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)*

Our data sets, productivity, efficiency, and projection model is extremely detailed and consists of hundreds of thousands of data points with tens of thousands of calculations.

If confidentiality is assured, our model can be found here:
Confidential CO2Rail Data Set & Projections Model Link

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).

The maximum CO2 capture capacity of a single CO2Rail car is approximately 9,031 $Tonnes/_{CO2}$ per year at the current state of development.

While the system was designed to be used in consist with multiple units per train to maximize regenerative braking energy utilization, the system could operate satisfactorily (but not ideally) at a minimum scale. However, a single car's DAC energy demands would not sufficiently utilize the full regenerative braking energy potential of a typical train and additional attached CO2Rail cars would be ideal so as to not have this zero-carbon energy go to rheostatic waste.

With this situation in mind we are developing a method by which an incomplete consist of CO2Rail cars can resupply the locomotive with excess battery array energies that are not used in DAC operations. This will reduce locomotive fuel consumption by providing the train with battery array energy to be used for direct propulsion.

Iit is important to note that, while beneficial and CO2 reductive, utilizing battery array energy in this manner is not on par with the carbon reduction capability of DAC operations. In fact, using regenerative braking energy for motive power mitigates only around 17% of the emissions that would be possible if that same energy was used for DAC processes.

From the near-term 1.01 GT/year capacity, CO2Rail can be scaled to achieve approximately 4.43 GT/year by 2050 and 10.5 GT/year by 2075. For this to occur:
1. CO2Rail car unit production will need to be scaled to achieve significant yearly deliveries.
2. DAC efficiency will have to increase meaning that the energy required per tonne of CO2 harvested will have to moderately decrease.
3. Rail traffic will have to increase year over year from an estimated 26,000 trains always moving on the rails around the world at any given average time in 2030 to 38,000 trains by 2050, and 67,000 trains by 2075 to achieve the CO2 drawdown targets.
4. Locomotive regenerative braking energy generation efficiency will need to be moderately optimized.
5. Since regenerative braking energy increases with the speed and weight of the train, on average, trains will have to become moderately heavier and faster year-over-year.

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.)*

Electro-Swing DAC sorbent technology only uses electricity to actuate the capture and release of CO_2 and has also been noted to have one of the lowest energy requirements of new DAC technologies and is projected as having a capture efficiency of approximately 415 kWh/t_{CO2} at scale including moving air through the chamber with fans and liquefaction of the captured CO_2. However, since the CO2Rail system does not require air moving equipment during operation, this figure can be reduced by approximately 50 kWh to 365 kWh.

Moreover, since the developer of this DAC sorbent at MIT is also a team member, we are confident in these numbers.

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.co2rail.com*
- *Joule Manuscript Link*
- If confidentiality is assured, our model can be found here: *Confidential CO2Rail Data Set & Projections Model Link*

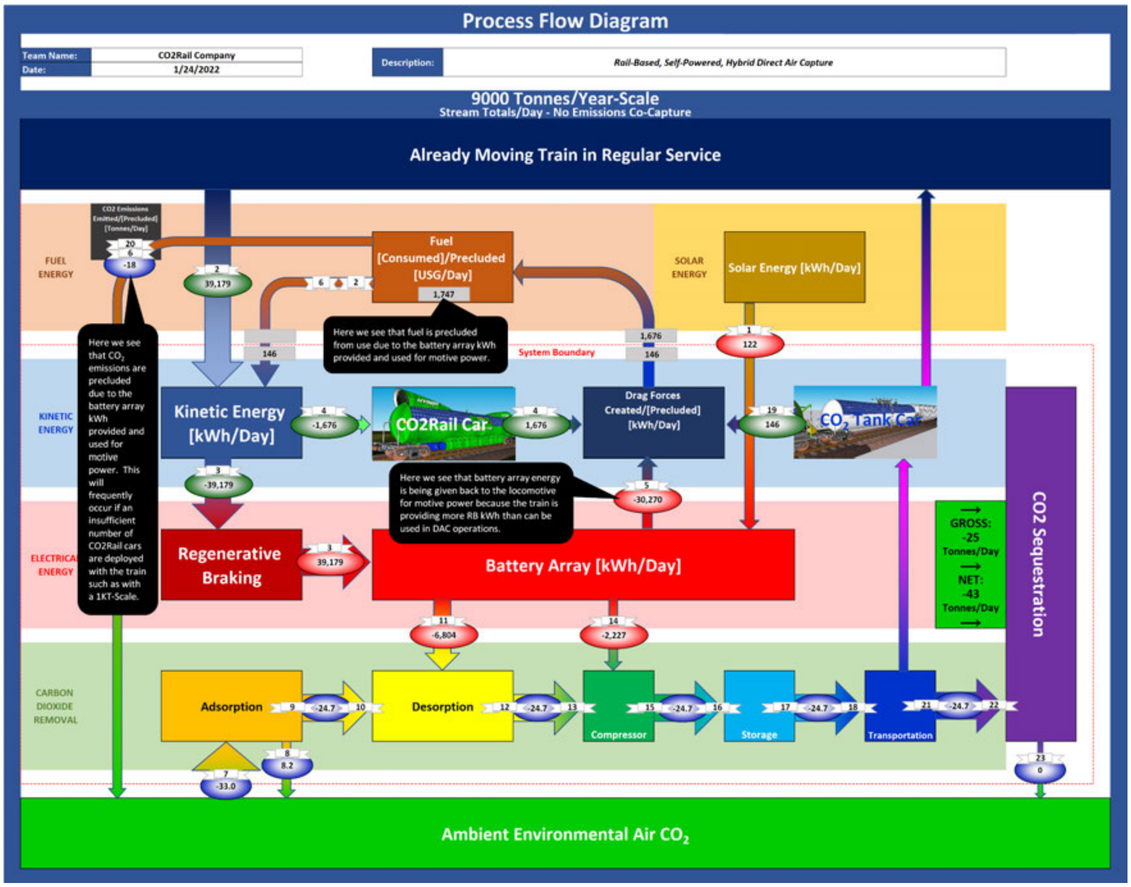
4. Net Capacity / Life Cycle Analysis (Criteria #6 and Criteria #8)

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	**9,031 Tonnes/$_{CO2}$**
Gross project emissions	**416 Tonnes/$_{CO2}$** Or **-6,470 Tonnes/$_{CO2}$** if precluded locomotive emissions from excess battery array energy being supplied back for motive power are included (see below).
Emissions / removal ratio	**4.6%** However, since there is more available train-generated energy than can be used by the limited number of CO2Rail cars applied to the train at this early stage, the excess regenerative braking energy that is not used in DAC operations will be supplied back to the locomotives for use in propulsion during movement. This will reduce locomotive fuel consumption creating a negative emissions scenario where the capture of CO2 using an insufficient amount of CO2Rail cars actually reduces ambient CO2 concentrations even further. The amount of unused regenerative braking energy stored in the CO2Rail car battery array that is supplied back to the train may be as high as 30,148 kWh per 24-hour period. This saves approximately 1,850 US gallons of fuel and 19 Tonnes of CO2 emissions over the same 24-hour period. Ultimately, the realized emissions / removal ratio is **-71.6%** (with additive propulsion effort).
Net carbon removal	**8,615 Tonnes/$_{CO2}$** Or **15,501 Tonnes/$_{CO2}$** (with additive propulsion effort)

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 2020 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.

[Link to Process Flow Diagram & Stream Table]()



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?

Our data sets, productivity, efficiency, and projection model is extremely detailed and consists of hundreds of thousands of data points with tens of thousands of calculations. If confidentiality is assured, our model can be found here: *Confidential CO2Rail Data Set & Projections Model Link*

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.

Some aspects of the system are modeled only. This would include such parameters as chamber air volume throughput. Others are directly measured and certified. This includes the performance of the two sorbent systems we have planned for deployment. For example, the certification for AmbRefin sorbent system developed out of the University of Sheffield in England can be found here: AmbRefin Verification Report We also anticipate the vigorous deployment of the Verdox Electro-Swing sorbent system developed out of MIT. Verdox Captures $80M to Develop Novel Electric Carbon Removal Technology These two systems are not mere vendors for CO2Rail but rather their developers are actual team members and co-authors on our already peer-reviewed and soon to be published article in Joule: *Joule Manuscript Link*

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.

See Above

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 progress.)

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

CO2Rail is innovative technology for deploying specially designed, self-contained DAC railcars outfitted with battery arrays, CO_2 direct air capture systems, compression equipment and ancillary gear that uniquely exploit substantial renewable energy generated on-board the train through regenerative braking as well as from solar panels mounted on compatible railcars. The units are equipped with large intakes that extend up into the slipstream of the moving train and collect CO_2 feedstock air by fluidic, ramjet-type processes thus obviating the need for the fans required by land-based systems.

With transportation built-in, such systems will curate delivery of the harvested CO_2 to on-route sequestration sites for permanent underground sequestration, or delivery to end-users as feedstock for sustainable products and processes and places no pressure on electrical or land resources. The technology will harvest meaningful quantities of carbon dioxide at far lower costs and is projected to reach annual CO_2 capture capacities of 4.43 gigatons by 2050 and 10.5 gigatons by 2075 with each car having an annual capacity of over 5,000 tonnes/$_{CO2}$ in the near term and more as the technology progresses.

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.

Year	Units deployed (#)	Unit cost ($/unit)	Unit gross capacity (tCO_2/unit)	Notes
2022	1	**~1,600,000**	**9,031 Tonnes/$_{CO2}$**	*<50 words*
2021	0			Company formed 2021
2020	0			Company formed 2021
...				

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.)*

Since our company was formed in 2021, we have very few data points from which to draw to answer this question. However, we already notice organic reductions in CO2 sorbent media costs apart from those which will be achievable with economies of scale.

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	**9,031 Tonnes/$_{CO2}$**

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

We are open to purchasing high cost carbon removal today with the expectation the cost per ton will rapidly decline over time. We ask these questions to get a better understanding of your potential growth and the inflection points that shape your cost trajectory. 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 expect to work with you to understand your milestones and their verification in more depth. If you have any reservations sharing the information below in the public application format, please contact the Stripe team.

a. What is your cost per ton of CO_2 today?

$310 Tonne/$_{CO2}$

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." Consider describing your CAPEX/OPEX blend, non-levelized CAPEX costs, assumptions around energy costs, etc.

The above quoted number represents all costs including OPEX, CAPEX, G&A, Engineering Amort, etc. A detailed pro-forma at this relevant scale can be found here:

If confidentiality is assured, a detailed pro-forma at this relevant scale can be found here: Confidential CO2Rail 9000T-Scale ProForma

However, the quoted number does not contain any margin and is quoted at our costs with the anticipation that the US 45Q program will provide such margin (see 9E below).

c. How do you expect your costs to decline over time? Specifically, what do you estimate your cost range will be as you reach megaton and then gigaton scale? We recognize that at this point, these are speculative and directional estimates, but we would like to understand the shape of your costs over time.

Megaton Scale: $75 Tonne/$_{CO2}$ (Hard costs w/o margin)
Gigaton Scale: $45 Tonne/$_{CO2}$ (Hard costs w/o margin)

d. Where are the primary areas you expect to be able to achieve cost declines? E.g., what are the primary assumptions and sensitivities driving your cost projection? What would need to be true for a long-term cost of <$100/ton to be achievable with your technology? (i.e., you are able to negotiate an x% reduction in CAPEX at scale and purchase renewable electricity at $y/kWh)

Cost reductions will be realized from such factors as broader base for G&A and amortization (e.g. R&D costs) allocation.

Moreover, we anticipate CO2 sorbent media costs to decline sharply as well as battery costs especially given Pres. Biden's announcement yesterday of "War Powers Act" implementation in the EV sector:
Biden Poised to Use Cold-War Powers to Boost Battery Metals

Most importantly, per unit costs will decline substantially over time as the manufacturing process develops from "one-of" to "production line" status and significant economies of scale are realized in all areas of procurement.

e. In a worst case scenario, what would your range of cost per ton be? We've been doing a lot of purchasing over the past few years and have started to see a few pieces that have tripped people up in achieving their projected cost reductions: owned vs leased land, renewable electricity cost, higher vendor equipment costs, deployment site adjustments, technical performance optimization, supporting plant infrastructure, construction overruns, etc. As a result, we'll likely push on the achievability of the cost declines you've identified to understand your assumptions and how you've considered ancillary costs. We would love to see your team kick the tires here, too.

With such a drastic cost reduction under the current suite of technologies, accuracy questions must be raised. However, these questions are quickly reduced with analysis of a single cost component – Energy.

As CO2Rail uses only on-board generated sources of clean energy, there is an obvious disruptive economic advantage in the lack of incremental energy costs or costs associated with greenfield development of sustainable energy sources. For comparison purposes using the above outlined near-term energy budget of 415 kWh/t_{CO2} and normal solar-sourced electricity costs of 5.7¢/kWh, CO2Rail has an astounding 24 Billion USD cost advantage per gigaton of CO_2 from energy alone even when considering that both will have similar battery storage costs.

Moreover, when one considers that the approximately 330 TWh of braking energy that will be produced by 2030 across the world's railways could be converted from rheostatic to regenerative, stored and made usable with an investment of approximately 20 Billion USD whereas developing the equivalent scale of carbon-neutral energy sources plus battery storage to power land-based DAC deployments would require approximately ten times that at or near 200 Billion USD, it becomes clear that the CO2Rail technology described herein will achieve a much faster initial deployment with a far reduced initial capital outlay.

Additionally, the substantial tangible and intangible benefit of CO2Rail having no fixed, land-based footprint should not be overlooked. Not only will there be no direct (or indirect) costs associated with acquiring, preparing, and maintaining sizable swaths of land but also no sprawling industrial-looking DAC installations to permanently mar our landscapes or cityscapes and no “not in my neighborhood” impediments to broad deployment. Indeed, with land requirements being as high as 1,700 km^2 per gigaton of CO_2 harvesting potential and approximately 5-10 times that area dedicated to renewable energy sources to power such, direct land costs might be the least of the prudent concerns when environmental and social costs are considered.

As such, we are confident in our numbers and especially so in the megaton and gigaton-scales. In the near-term at the scales being discussed herein, we are less confident but it is anticipated that potential overruns will be R&D in nature and thereby amortizable.

f. 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 description	Target for achievement (eg Q4 2021)	How could we verify that you’ve achieved this milestone?
1	**Milestone 1:** Inspect and purchase inventory of appropriate normal rail tank cars from surplus railcar market. Transport by railroad to rail equipment manufacturing supplier for repurposing and CO2Rail car conversion.	Q3 2022	Photos, inspection reports and Bill of Sale can be provided without problem.
2	**Milestone 2:** Source additional needed material including the CO2 sorbent system. Work daily with rail equipment supplier during construction of Unit #0001 to address any “shop floor” engineering issues.	Q4 2022 - Q1 2023	Documentary invoices can be provided without problem. On-site visit to the rail facility is welcome and encouraged.
3	**Milestone 3:** Take delivery of the unit and immediately deploy on the host testing railroad. Test, dial-in and certify operational parameters of CO2Rail car Unit #00001.	Q1 2023 - Q2 2023	On-site visit to the rail facility is welcome and encouraged.

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	N/A	N/A	<100 words
2	N/A	N/A	<100 words
3	N/A	N/A	<100 words

g. 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	N/A	N/A	<100 words
2	N/A	N/A	<100 words
3	N/A	N/A	<100 words

h. 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?

While not one person, we would ask that the world significantly increase decarbonization efforts. If such efforts are not meaningful in scope, scale, and timing, no amount of CDR will be sufficient to battle the rising tide of atmospheric CO_2 concentrations.

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

- Help get the word out.
- Help generate publicity and social momentum.
- Help us develop the private “carbon off-set” potential of our technology.

7. Public Engagement (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 mechanisms 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 and how your project is working to follow the White House Council on Environmental Quality's draft guidance on responsible CCU/S 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 your 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.

> One of the many synergies inherent with the CO2Rail system is that there already exists an extensive community-level network throughout the global railway sector. This is not only a forum where support of rail operations can be voiced but also a forum where concerns and complaints are expressed and resolved between the community and rail management. It is anticipated that CO2Rail will join this active area of community involvement and also create new beds of involvement where strong community roots can flourish.
>
> This will be especially true in those areas where the many tens of thousands of CO2Rail cars are manufactured. Since the majority of rail equipment manufacturing facilities exist in communities of color and/or low-income areas, tremendous opportunities exist for not only strong community development but also deep community involvement. This is already a topmost corporate priority and will remain so regardless of scale.

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.*

> Again, we lean heavily on the guidance and support of the US Department of Energy in matters pertaining to large-scale geological sequestration of CO2. They are an indispensable resource that all CDR solutions should utilize.
>
> *US DOE Public Outreach*

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?

Public outreach and EJ needs to be incorporated as an integral component of any geologic storage project and be seen by administrators as constituting an inherent, important, and ongoing part of the project. This ideally starts at the time of project conceptualization, as community goodwill built early on in a project cycle can help retain goodwill during the later stages. Importantly, open communication and well-cultivated community goodwill can prevent an inconsequential issue or even an unfounded rumor from snowballing into one that turns the community against the project which then might escalate into a situation that necessitates site closure.

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?

Most forward looking process improvements will come in the development of new or improved CO_2 sorbent systems. This is a fast-moving sector that is constantly developing new solutions. Confidential This includes those that we are developing in-house. For instance, we are just beginning work with the Pacific Northwest National Laboratory (PNNL) (US DOE) to assess liquid-based sorbent systems which would have a much higher capacity to handle the air volumes and velocities found in CO2Rail.

8. Environmental Justice (Criteria #7)

a. What are the potential environmental justice considerations, if any, that you have identified associated with your project? Who are the key stakeholders?

> Apart from successful CDR deployments creating a false sense of security in regards to climate change and thwarting international efforts to decarbonize which would be a gross environmental injustice to all of humanity, we cannot identify any potential EJ concerns but many potential EJ benefits.
>
> Since the CO2Rail system is mobile and has no fixed, land-based footprint, there is no one particular location of operation. The system is mobile and utilizes the massive scale and scope of the global railway network and will be deployed throughout North America and then globally.
>
> Lack of a fixed, land-based footprint is a tremendous advantage of the CO2Rail system. Not only are there no direct or indirect costs associated with acquiring, preparing, and maintaining sizable swaths of land but also no sprawling industrial-looking CDR installations to permanently mar landscapes or cityscapes and no “not-in-my-neighborhood” impediments to broad deployment. Land requirements and costs thereof would encourage – perhaps require – other CDR solutions to locate where land is undervalued. These areas are disproportionately located within Black, Indigenous, other communities of color, low-income, and pristine wilderness geographical areas. In fact, direct land costs might be the least of the prudent concerns when environmental and social costs are considered.

b. How do you intend to address any identified environmental justice concerns?

> Trust me on this. We actively search out any reasonable EJ concern as we hate stating that there are none. :-)
>
> We will certainly address any that are found with all due haste.

9. Legal and Regulatory Compliance (Criteria #7)

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

> We have a strong legal base from which to draw from including one team member that is a well-respected IPO attorney and professor at the University of Toronto.
>
> On the IP side we work with a great firm with a large presence in both domestic and international patent law:

b. What domestic permits or other forms of formal permission do you require, if any, to engage in the research or deployment of your project? 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.

> One-time recertification of the repurposed surplus rail tank car is required from the Federal Railroad Administration (FRA) after prototype build due to the structural modifications of the originally designed car after the CO2Rail car conversion process. Limited railroad operation and testing can be performed under an FRA waiver to prove-out the prototype's safety. Recertification is a common practice in the rail industry and is not anticipated to be onerous or problematic.
>
> Large-scale geological sequestration of the harvested CO2 may require federal, state, and/or local permitting and we are awaiting DOE/USGS guidance on this active area of policy development.

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?

> CO2Rail will be deployed throughout North America and then globally by 2035. Since North America represents approximately 25% of worldwide rail traffic, significant CDR and meaningful atmospheric CO2 concentration reductions can be realized from focusing our initial efforts exclusively in North America before expanding globally while still benefiting the entire global community equally.
>
> In fact, since North America has contributed an inordinate share of CO2 emissions to the environment throughout industrialized history, this continental focus is actually an equitable one as the costs will be mostly borne by the government and industries in the US and, to a lesser extent, Canada.
>
> As such, we have not dedicated much time to the examination of other international regulatory hurdles that may be encountered and we anticipate that this ever changing landscape will look very different over the next decade as more countries conclude that CDR is necessary to any

feasible climate change mitigation strategy and change their regulatory and incentive structures accordingly.

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. Has your CDR project received tax credits from any government compliance programs to-date? Do you intend to receive any tax credits during the proposed delivery window for Stripe's purchase? If so, which one(s)? (50 words)

Since the capture and sequestration of past accumulated CO_2 on a large scale is a public good and historic emitters may likely be long dissolved entities, the ultimate source of funding for gigaton-scale CDR projects must therefore be governmental actors.

As such, we anticipate a major source of our funding coming from government incentive structures such as the anticipated $85/$t_{co2}$ (currently $50/$t_{co2}$) 45Q tradeable tax credit (or similar iteration) offered for carbon sequestration in the US.

In this proposal, we have quoted Stripe our lowest reasonable cost per tonne for the given quantity of CO2 available at this early-commercialization period. We included no margin within this quoted cost as we anticipate such to come from the above noted US incentive structure.

If Stripe would rather proposals be structured where it claims the 45Q credit, please let us know and we can adjust accordingly.

10. 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*	**1,750 out of 8,615 Tonnes/$_{CO2}$**
Delivery window *at what point should Stripe consider your contract complete?*	**< Dec 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.*	**$310 Tonne/$_{CO2}$**

Application Supplement: DAC

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

Note: these questions are with regards only to air capture: e.g. your air contactors, sorbents or solvents, etc. Separately, there exist Geologic Injection and CO_2 Utilization supplements. We anticipate that most companies filling out this DAC supplement should ALSO fill out one of those supplements to describe their use of the CO_2 stream that's an output of the capture system detailed here.

Physical Footprint (Criteria #1 and #2)

1. What is the physical land footprint of your project, and how do you anticipate this will change over the next few years? This should include your entire physical footprint, i.e., how much land is not available for other use because your project exists.

Year	Land Footprint (km^2)
2021	None
2022	None
2023	None

2. What is the volumetric footprint of your contactor? (How big is your physical machine compared to how much you're capturing?) and how do you anticipate this will change over the next few years? These numbers should be smaller than (1) above.

Year	Contactor Footprint (m^3)
2021	The interior volume of the collection chamber is approximately 85 m^3 (3,000 ft^3). It is not anticipated that this will vary substantially over time.
2022	*See Above*
2023	*See Above*

2. Capture Materials and Processes (Criteria #5, #7, and #8)

1. What sorbent or solvent are you using?

Verdox (MIT) Electro-Swing DAC sorbent. Faradaic electro-swing reactive adsorption for CO2 capture

2. What is its absorption capacity? *(grams CO_2 per grams material/cycle)*

See Faradaic electro-swing reactive adsorption for CO2 capture

3. What is its desorption capacity? *(grams CO_2 per grams material/cycle)*

See Faradaic electro-swing reactive adsorption for CO2 capture

4. How do you source your sorbent or solvent? Discuss how this sourcing strategy might change as your solutions scales. Note any externalities associated with the sourcing or manufacture of it (hazardous wastes, mining, etc. You should have already included the associated carbon intensities in your LCA in Section 6)

The CO2 sorbent material will be sourced directly from the manufacturers. As discussed previously, we are deeply involved and have two sorbent developers on our team and view these relationships as integral to our success.

5. How do you cycle your sorbent/solvent? How much energy is required?

Electro-Swing DAC sorbent technology only uses electricity to actuate the capture and release of CO2 and has also been noted to have one of the lowest energy requirements of new DAC technologies and is projected as having a capture efficiency of approximately 415 kWh/tCO2 at scale including moving air through the chamber with fans and liquefaction of the captured CO2. However, since the CO2Rail system does not require air moving equipment during operation, this figure can be reduced by approximately 50 kWh to 365 kWh. Using this as our denominator, each passenger train and freight train of three different weights, will have the capability to harvest approximately 96 and 117 tonnes, respectively, of CO2 each day.

6. What is your proposed source of energy? What is its assumed carbon intensity? What is its assumed cost? How will this change over the duration of your project? (You should have already included the associated carbon intensities in your LCA in Section 6)

The system is solely powered by the train's energy braking. Currently, this energy is dissipated by rheostatic means. CO2Rail will reroute this power to a battery array for use in DAC operations. This can be as high as 30,000 - 40,000 kWh per day in most trains or about 100 tonnes of CO2 capture potential. In the future, this RB energy can be supplemented with train-mounted PV cells providing even more CO2 capture potential.

7. Besides energy, what other resources do you require in cycling (if any), e.g water, and what do they cost? Where and how are you sourcing these resources, and what happens to them after they pass through your system? (You should have already included the associated carbon intensities in your LCA in Section 6) *(100 words)*

None.

8. Per (7), how much of these resources do you need per cycle?

None.

9. How often do you cycle your sorbent/solvent?

Approximately 18 cycles/day depending on environmental and route-specific variables.

10. Does your sorbent or solvent degrade over time? Is degradation driven primarily by cycling, environmental conditions, or both?

The electrochemical cell showed great stability with <30% loss in capacity over 7000 cycles of capture and release. The gradual loss in capacity is mainly due to the electromigration of the shorter polymer chains, from the electrode and into the electrolyte, towards the opposite electrode.

11. In practical operation, how often do you need to replace your sorbent or solvent material, if at all?

Electro-Swing: Approximately every 24 - 36 months. AmbRefin: Approximately every 48 months.

12. Per (11), what happens to your sorbent/solvent at end-of-life? Please note if it is hazardous or requires some special disposal, and how you ensure end-of-life safety.

The framework will likely be stripped of sorbent material past its useful life and remanufactured with new material. It is not hazardous and the solid waste volume will be small.

13. Several direct air technologies are currently being deployed around the world (e.g. Climeworks, which Stripe purchased from in 2020). Please discuss the merits and advantages of your system in comparison to existing systems.

Challenges

At the current state of development, all known DAC deployments are land-based systems that rely on increases in temperature to release the captured CO_2 from either a solid or liquid-based sorbent. These systems use grid electricity to move the air through the system, either waste heat [Climeworks – Switzerland], geothermal heat [Climeworks – Iceland], or natural gas-fired burners [Carbon Engineering – Canada] to drive the desorption cycle, and grid electricity again to power compressors required to collect and store the harvested CO_2. Since one of the largest consumers of energy in any DAC system is the desorption cycle, the Climeworks operations greatly benefit from placement at cogeneration or geothermal resources and are examples of ideal land-based DAC deployments.

However, it is not conceivable that this ideal placement of DAC deployments or using fossil fuels (albeit with co-captured CO_2 emissions) could continue at a scale that would bring meaningful benefits to the environment, and 100% electrically driven systems from carbon-neutral sources will certainly be required. Moreover, some exciting new DAC concepts are being tested at the laboratory scale or are in the early stages of development for commercial implementation which rely only upon electrical power to operate. Indeed, recent studies have estimated as much as 25% of global electrical generation capacity will need to be dedicated to land-based DAC deployments by 2100.

Furthermore, with a reported yearly capture capacity of $50/t_{CO2}$ per typical land-based, solid-media DAC module unit, it will require the manufacture, operation, care and feeding of approximately 20 million of these machines per gigaton of captured CO_2 or hundreds of millions to timely meet the IPCC's recommendations and powered by many thousands of terawatt hours of energy. Since global energy generation in 2019 was approximately 27,000 TWh, credence is given to studies that estimate as much as 25% of global electrical capacity (6,750 TWh) will need to be dedicated to land-based DAC deployments by 2100.

Another challenge associated with the current suite of DAC technologies is that, at scale, they will require tremendous land resources upon which to build farms of modular DAC units. This will necessitate the financial acquisition of, or grant of rights to, vast tracts of land for capture facilities, and even more land upon which to construct the renewable sources of energy necessary to power such. To achieve the IPCC's recommendations in a timely fashion, a capture capacity of 10 gigatons per year or greater is needed. To fulfill this need with land-based DAC deployments and required renewable power sources, a total land area approximately twice the size of Switzerland would be required.

Rail-Based Direct Air Carbon Capture

An alternative to building, powering, and operating approximately 20 million individual land-based DAC modules per gigaton of carbon dioxide capture potential and consuming 25% or more of global energy capacity, is the deployment of self-contained, rail-based, mobile DAC railcars with substantial CO_2 harvesting capabilities that are placed with already running trains in regular service and powered by currently untapped, zero-carbon, on-board generated sources of sustainable energy which is off-grid and cost-free.

All locomotives are driven by electric motors either in diesel-electric or all-electric configurations and most locomotives across the world's rail transportation network have the ability when braking to convert forward momentum into energy generation to create a frictionless braking force upon the train. In rail, this is called "dynamic braking" (rheostatic braking) and is related to the better-known regenerative braking systems found in other forms of transport, but the energy generated during dynamic braking is not used for any practical purpose and is merely converted into resistance heat and discharged during each braking maneuver.

The required energy to perform Direct Air Capture comes from the enormous regenerative braking energy generated from stopping or slowing an entire train many times per day. CO2Rail cars are only attached to trains in regular transportation service and the required air is obtained in a ramjet type manner from the train's slipstream.

Since the CO2Rail system is mobile and has no fixed, land-based footprint, there is no one particular location of operation. The system is mobile and utilizes the massive scale and scope of the global railway network and will be deployed throughout North America and then globally.

Energy & Land Use

Recent studies have estimated as much as 25% of global electrical capacity will likely need to be dedicated to land-based DAC deployments by 2100 to have a chance of meeting IPCC targets and remain under 2.5°C of warming. CO2Rail requires none as all operations are powered on-board by the substantial and currently unused supply of train regenerative braking energy. A source that has been growing sharply due to rail's organic environmental strengths.

As CO2Rail uses only on-board generated sources of zero-carbon energy, the obvious disruptive advantage is its complete lack of demand upon our grid energy or sustainable energy supplies. Moreover, since the CO2Rail system is mobile with no fixed, land-based footprint, permanent adulterations to our landscapes and cityscapes can be avoided.

Adjunct Benefits

The shining star that sets CO2Rail apart from other CDR solutions may be in its scaling-related adjunct benefits unrelated to rail or even carbon capture. For instance, broad CO2Rail deployment will come part and parcel with improvements in critical national infrastructure, transportation safety, rail utilization, speed, and efficiency. This will reduce traffic congestion, accidents, and highway fatalities with corresponding increases in workforce productivity and overall quality of life. Legions of skilled, high-paying jobs will be created as well as legislative, popular, and corporate support of climate change mitigation and carbon removal programs.

A comprehensive national push to increase rail utilization and broad CO2Rail deployment will drastically reduce rail, truck, plane, and even auto-related emissions due to rail's dramatically improved efficiency and CO2Rail's emission co-capture capabilities. In this way, by increasing rail utilization to increase CO2Rail's global CO2 harvesting capacity, co-occurring further significant reductions in CO2 emissions can be achieved.

Beyond ambient air DACC, certain specially configured CO2Rail cars can remove the emissions from the locomotives themselves with only minor exhaust routing modifications required thereof. This will make rail transportation the world's first carbon-neutral mode of heavy transport in addition to its primary carbon-negative role of removing anthropogenic CO_2 from the atmosphere. Importantly, since CO2Rail units are deployed only with already running freight or passenger trains in regular service, there is almost no additional carbon debt incurred from operation even if emissions went uncaptured.

Application Supplement: Geologic Injection

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

Feedstock and Use Case (Criteria #6 and 8)

1. What are you injecting? Gas? Supercritical gas? An aqueous solution? What compounds other than C exist in your injected material?

Standard CO2 rail tank cars will be delivered to the injection site within which the harvested CO2 is in a liquified state. As these cars are unloaded and the gas is geologically injected, in most instances, it will become supercritical. Post-injection, the CO2 will remain trapped in the formation and eventually be taken up by surroundings to become carbonate rock.

2. Do you facilitate enhanced oil recovery (EOR), either in this deployment or elsewhere in your operations? If so, please briefly describe. Answering Yes will not disqualify you.

No. Such known use of CO2Rail harvested CO2 is prohibited by our mission statement.

Throughput and Monitoring (Criteria #2, #4 and #5)

3. Describe the geologic setting to be used for your project. What is the trapping mechanism, and what infrastructure is required to facilitate carbon storage? How will you monitor that your permanence matches what you described in Section 2 of the General Application?

We do not anticipate vertically integrating within the company the actual geological injection aspect of the project within the foreseeable future. Our action plan involves the delivery of filled regular CO2 tank cars to a contracted qualified injection facility or, in the future, anticipated government operated sites viewed as strategic national assets. However, all contracted injection facilities will be pre-certified and approved for utilization by the criteria set forth by the US Department of Energy. A non-inclusive example of such guidance can be found below: Best Practices: Operations for Geologic Storage Projects Best Practices: MVA for Geologic Storage Projects US DOE Carbon Storage Atlas

4. For projects in the United States, for which UIC well class is a permit being sought (e.g. Class II, Class VI, etc.)?

See Above

5. At what rate will you be injecting your feedstock?

See Above

Environmental Hazards (Criteria #7)

6. What are the primary environmental threats associated with this injection project, what specific actions or innovations will you implement to mitigate those threats, and how will they be monitored moving forward?

See Above

7. What are the key uncertainties to using and scaling this injection method?

See Above