MUSK FOUNDATION

CONTENTS

XPRIZE Carbon Removal Rules - Phase 1

These rules supplement the Competition Guidelines and are issued for Phase 1 of the competition. Rules specific to Phase 2 will be published as a revision to this rule set following the Milestone Awards. Each of the following evaluation criteria (originally published in the XPRIZE Carbon Removal Guidelines) is addressed in the Phase 1 rules:

EVALUATION CRITERIA	Operational Requirements	Fully considered Cost per Tonne	Sustainably Scalable
PHASE 1 COMPETITION REQUIREMENT	1. 1000 Tonne/year Carbon Dioxide Removal Project Proposal. (Kilotonne Scale) 2. Demonstration of Key Component of Carbon Dioxide Removal Solution. (Any Scale) 3. 3rd party verification of the demonstration performance. (Any Scale)	4. Definition of the Megatonne Scale Carbon Dioxide Removal Project. (Megatonne Scale) 5. Cost of Carbon Dioxide Removal. (Megatonne Scale)	6. Durable Carbon Dioxide Sequestration. (Kilotonne Scale) 7. Net-Negative Performance. (Kilotonne Scale) 8. Social License & Environmental Justice. (Up to Gigatonne Scale) 9. Scaling to Gigatonnes per Year. (Up to Gigatonne Scale)
SCALES OF CONSIDERATION	Milestone Demonstration = Any scale Kilotonne scale = 1000 net metric tonnes of CO_2 per year Megatonne scale = 1 million net metric tonnes of CO_2 per year Gigatonne scale = 1 billion net metric tonnes of CO_2 per year		

OPERATIONAL REQUIREMENTS

1. 1000 tonne/year Carbon Dioxide Removal Project Proposal

At the milestone round, each team must describe the 1000 tonne/year (minimum) carbon dioxide removal Project that they intend to develop by the end of the prize. This proposal must include details on the process design and engineering, and must encompass the full cradle-to-grave of CO_2 removal to ensure that the process is net-negative. Teams must also describe the execution strategy for the project, including the anticipated schedule, budget, and project plan.

Scale of Carbon Dioxide Removal Project:

1.1. The target scale for XPRIZE Carbon Removal is at least 1000 tonnes/year of CO_2 durably sequestered.

1.2. CO_2 is considered durably sequestered if it can be stored in a stable and safe manner for at least 100 years. In the event that a fraction of the sequestered CO_2 is likely to be re-emitted within 100 years, that CO_2 should not be considered sequestered for the purpose of calculating the system scale, and should be accounted for as an emission source in the Lifecycle Analysis.

1.3. *Tonnes/year* refers to the rate of CO_2 removal, averaged over time, measured in metric tonnes per year, after deducting all emissions associated with the process and any expected re-emissions within 100 years (in other words, *net removal*).

1.4. Net removal can be calculated using the following formula:

$$Removed_{net} = Removed_{gross} \times (1 - Reemission_{100}) - Emissions$$

Where:

$Removed_{net}$ is the Net annual CO_2 removal rate (tonnes/year)

$Removed_{gross}$ is the total mass rate of CO_2 removed from the air or ocean (tonnes/year)

$Reemission_{100}$ is the fraction of sequestered CO_2 that can be expected to re-emit within 100 years (%)

$Emissions$ is the annual rate of emissions associated with the carbon dioxide removal project (tonnesCO_{2e}/year), not including re-emission of sequestered CO_2.

1.5. Teams must durably sequester at least 1000 tonnes of CO_2 in the final year of competition (February 1, 2024 to February 1, 2025).

Scope of Carbon Dioxide Removal Project:

1.6. The project must describe all steps of Carbon Dioxide Removal, from the point of capture through durable sequestration.

1.7. CO_2 must be captured from the air or surface layer (ie. epipelagic zone) of the ocean.

1.8. CO_2 may be sequestered as CO_2 (as in the case of some forms of geological sequestration) or it may be chemically converted into another substance as part of the sequestration strategy.

1.9. Only removals that are additional (i.e. they will not happen on their own without intervention) may be considered.

1.10. Teams may employ the help of partners (other individuals or organizations) to aid in any aspect of the Carbon Dioxide Removal project (for example, a sequestration partner), provided those partners supply the technical and project documentation required by the XPRIZE Carbon Removal Submission, and submit to verification site visits upon request.

Documentation Requirements:

1.11. Each team must provide a Process Flow Diagram, Stream Table, and Mass & Energy balance to provide the judges with a thorough understanding of the proposed carbon dioxide removal project.

1.12. Additional documentation requirements are established in the Technical Submission.

2. Phase 1 Demonstration of Key Component of Carbon Dioxide Removal

Each team must demonstrate the operation of a "key component" of their Carbon Dioxide Removal solution. The demonstration should establish the team's ability to successfully complete their proposed 1000 t/y carbon dioxide removal project. The performance attributes or metrics for the key component of the demonstration relevant to the Carbon Dioxide Removal proposal should be stated, with data collected during demonstration provided to support those claims.

Scale of Demonstration

2.1. The demonstration may operate at any scale, but should support the expected performance of the team's proposed 1000 t/year carbon dioxide removal demonstration.

Scope of Demonstration

2.2. Demonstrations should establish the performance of one or more aspects of their proposed 1000 t/y carbon dioxide removal project. Demonstrations may include one or more of the following, as examples (this list is not exclusive):

- CO_2 Capture from the air or ocean
- Efficacy of a new catalyst or sorbent
- Conversion of CO_2 to a durable, sequesterable state
- Durable sequestration of CO_2
- Cultivation method for a CO_2-removing plant
- Deployment method for a CO_2-removing mineral
- Ecosystem mapping or management methods that will enable CO_2 removal

2.3. The demonstration should be operated for long enough to provide data showing steady and stable operation.

2.4. There are no requirements or limitations on the demonstration location.

Documentation Requirements:

2.5. Teams must provide technical documentation which allows the judges to understand the operation of the demonstration.

2.6. Teams must provide sufficient performance data to allow the judges to confirm that the performance claims are supported by data collected during the operation of the demonstration.

3. Phase 1 3rd Party Verification

Independent verification of the team's solution is focused on ensuring that there is:

- Quality evidence that the technology is operational, and that observation of its operation supports the team claims that it can achieve specified levels of performance; and
- The data collected and submitted to document the claimed technology performance is collected using acceptable and defensible methods, approaches, and test equipment, resulting in high quality data.

Verifier Qualifications:

Independent 3rd Party Technology Verifiers must meet the following requirements to be considered credible:

3.1. *Technical Competency:* Verifiers must have :

3.1.1. An in-depth technical knowledge of the technology type under verification;

3.1.2. Knowledge of specific risk areas associated with performance of such technologies (i.e. common failure points, performance issues, barriers to scaleup);

3.1.3. Knowledge of the environmental implications related to the use of the technology from a life cycle perspective, such as impact of the technology on lifecycle CO_2 emissions and carbon dioxide removal;

3.1.4. Knowledge of relevant applicable test methods and standards for evaluating performance or impact of the technology;

3.1.5. Knowledge of relevant calculation, modeling, and statistical methods in order to assess test results and calculations of performance metrics and uncertainty, as applicable

3.2. *Independence:* Verifiers must:

3.2.1. Be a third-party organization or individual independent of the team registered for the XPRIZE Carbon Removal;

3.2.2. Not be directly involved in the design, manufacture or construction, marketing, installation, use or maintenance of the specific technologies submitted to XPRIZE for verification, or represent the parties engaged in those activities.

3.2.3. Not be a part of a legal entity that is engaged in design, manufacture, supply, installation, purchase, ownership, use or maintenance of the items inspected. For example, the verifier should not work at a university at which a team has registered for the XPRIZE Carbon Removal.

Scope of Verification:

Verification must include:

3.3. Review of the overall process proposed by the team, including:

3.3.1. The required process steps and operations to achieve carbon dioxide removal via review of the Process Flow Diagram and mass, carbon, and energy balances;

3.3.2. The claimed means of carbon dioxide removal and its method of durable removal

3.4. Review of the specific key component to be demonstrated and verified to ensure:

3.4.1. It is a critical component to ensuring successful carbon dioxide removal by the process

3.4.2. Its performance and impact can be measured and evaluated

3.4.3. Specific performance metrics are identified and adequate to document the performance of the component(s)

3.5. Observe the operation of the demonstrated key component(s) to:

3.5.1. Document the observed process is operational;

3.5.2. Ensure all input and outputs of the demonstrated component(s) are accounted for

3.5.3. Ensure data collected during observation is representative of data submitted;

3.5.4. Ensure measurements, analytical methods, or other data collection methods are adequate and properly implemented

3.6. Review performance data collected during the observation period to ensure that

3.6.1. The performance claims are supported by the observed process

3.6.2. Calculations are performed correctly

Documentation Requirements

3.7. Teams must submit a Verification Checklist noting the identity and qualifications of the verifier, and the scope and results of the verification activities.

3.8. Along with the Verification Checklist, any documentation which supports the verification of the demonstration may be submitted.

FULLY CONSIDERED COST PER TONNE

Costs must be modeled at a hypothetical project scale of 1Mt/year (average net CO_2 removal capacity of at least 1 million metric tonnes per year). The calculation must include all costs anticipated over the life of the project.

4. Definition of the Megatonne Scale (Mt/year) Project

Scale of the Megatonne Scale Project

4.1. The cost calculation must be for a CO_2 removal project which removes an average of 1 Megatonne (Mt, 1 million metric tonnes) of CO_2 per year (on a net & additional basis) over the operational life of the project. Teams should assume that the project under consideration is implemented from scratch.

Scope of the Megatonne Scale Project

4.2. The project must be based on the same underlying scientific and engineering principles as the 1000 tonne/year demonstration being developed for the XPRIZE Carbon Removal final demonstration. The project may be centralized (i.e. one large facility) or distributed (i.e. a set of smaller projects or facilities based on the same technologies which remove 1Mt/year in aggregate).

4.3. The project proposal must include all of the steps required to remove CO_2 from the atmosphere (or surface layer of the ocean) and sequester it durably. The cost analysis must include:

- Capital costs: All of the 'fixed' costs required to prepare the project for operation, including machinery, land, on-site energy generation & storage, and any estimated EPC (engineering, procurement, and construction) costs related to commissioning the project.
- Operational costs: All costs related to the operation of the carbon dioxide removal project including feedstocks & other raw materials, energy, fuel, labor, etc.
- Costs related to monitoring and maintenance of the sequestered CO_2 over time to ensure that, on net, the sequestered CO_2 remains sequestered durably (as CO_2 or in another chemical form) for at least 100 years.

4.4. The calculation must assume that the project begins construction today, in USD and using 2021-2022 technology and costs.

Documentation Requirements

4.5. Each team must provide a Process Flow Diagram, Stream Table, and Mass & Energy balance to provide the judges with a thorough understanding of the proposed carbon dioxide removal project.

4.6. Additional documentation requirements are established in the Technical Submission.

5. Cost of Carbon Dioxide Removal

Standardized Costs:

5.1. In order to ensure a consistent set of underlying assumptions across all teams, XPRIZE will establish a certain level of standardization in some elements of costs. The following costs will be established by XPRIZE for several regions of the world (using a 2020 basis year):

Cost Category	Subcategory
Land	High value land (industrial) Medium value land (agricultural) Low value land (floor cost)
Water	Tap water Well water
Labour	High income Middle income Low income
Electricity	Grid electricity (supplied) Solar electricity (generated)* Wind electricity (generated)* Diesel electricity (generated)
Fuel	Gasoline Diesel Propane/LPG Natural Gas

* Teams must account for the intermittency of these energy sources in their designs by applying an appropriate capacity factor and/or on-site energy storage, as appropriate.

5.2. Each team must specify the region that is applicable to their Megatonne scale project, and use the costs supplied for that region:

- Africa
- Oceania & Pacific Islands
- Central/East Europe
- East Asia
- Central & South America
- Middle East

- North America
- West Europe

5.3. The total estimated capital cost will be converted to an operating cost using a 20% capital recovery factor. The capital recovery factor is meant to account for all 'soft costs' related to the project, including taxes, depreciation, cost of capital, all other owner's costs, and contingencies.[1]

Team-Defined Capital Costs include:	20% Capital Recovery Factor includes:
Process Equipment Supporting Facilities Direct & Indirect Labor EPC Contractor services Land (standard rates are provided) Infrastructure (access roads & railroad tracks, water & sewage piping, electrical transmission lines, etc) Vehicles Other direct, up-front costs associated with building a MT scaled project	Cost of capital/financing costs Cost of debt Inventory capital Income & property tax Depreciation Permitting costs Legal fees Royalties & other fees Process & project contingencies Other owners' costs

Team-specified Costs:

5.4. Each team must specify all of the 'other' costs that apply to their system as applicable, including:

- Feedstocks
- Non-feedstock inputs (catalysts, sorbents, etc)
- Specialized equipment
- Facilities
- Transportation

[1] The requirements for capital cost estimations were informed by extensive conversations with academics, investors, and professional engineers, and also by the following resources, which you may consult for more details:

Zimmerman, A., Wunderlich, J., Buchner, G., Müller, L., Armstrong, K., Michailos, S., Marxen, A., Naims, H., Mason, F., Stokes, G., & Williams, E. (2018). *Techno-Economic Assessment & Life-Cycle Assessment Guidelines for CO2 Utilization*. Global CO_2 Initiative, University of Michigan.

NETL. (2011). *Quality guidelines for energy systems studies: cost estimation methodology for NETL assessments of power plant performance*. U.S. Department of Energy, National Energy Technology Laboratory. (Report DOE/NETL-2011/1455).

- Infrastructure (roads, pipelines, transmission lines, etc)

5.5. Cost estimates provided by teams should be provided with as much precision as is reasonable for the current state of development of the technology. For Phase 1 cost calculations, 'order of magnitude' levels of accuracy (between -30% to +50%, in line with the AACE Class 5 estimation standard). Any of the following estimation methodologies may be used. They are listed here in order of preference:

1. Vendor Quotes
2. Comparative or Parametric estimating methods
3. Scaling Factors
4. Stochastic methods (Lang Factors, Hand Factors, etc)
5. Cost databases (Public data is preferable to private data)

5.6. When researching team-specified pricing information, use the following guidelines:

5.6.1. Every effort should be made to produce cost estimates that are recent (2020 or newer). A common basis year should be used wherever possible.

5.6.2. Where recent estimates are unavailable, the consumer price index, GDP deflator, or similar method (as appropriate) may be used to correct older values.

5.6.3. If prices are volatile (year-over-year variations of 20% or more) a 5-year average should be used.

5.6.4. All pricing values should be provided for a consistent region. Local values should be used wherever possible, in the following order of preference:

1. FOB Project Location
2. Country Values
3. Regional values (See the regional breakdown used in
4. Global averages should only be used where regional values are unavailable.

Costs related to Risk & Externalities

5.7. In Phase 1 of the competition, costs related to risk & externalities shall be explored qualitatively. These issues will be addressed in Section 9 of the written submission.

Revenue & Value Creation

5.8. Revenues may be claimed to offset the cost of CO_2 removal via the sale of valuable goods (i.e. CO_2 derived products or valuable co-products, provided the resulting end-use does not re-emit the captured carbon and all end-of-life emissions are accounted for).

5.9. Any tangible & measurable environmental co-benefits (e.g. improved biodiversity, improved crop yields, improved fisheries, ecosystem services, removal of other greenhouse gasses, etc.) may also be claimed.

Uncertainty Analysis

5.10. To estimate uncertainty of cost estimates teams must identify the top 5 drivers of cost, and produce a 'spider diagram', which demonstrates the sensitivity of the cost estimate against each of the major drivers of cost. Detailed instructions for this will be provided in the Cost Worksheet Template provided by XPRIZE.

Documentation Requirements

5.11. Each team must calculate their cost of CO_2 removal using the Cost Worksheet Template provided.

SUSTAINABLY SCALEABLE

6. Durable Carbon Dioxide Sequestration

The durability threshold for the competition is 100 years. This means that to be considered removed, CO_2 must be sequestered (on a net basis) over at least 100 years. Only removals that are additional (i.e. they will not happen on their own without intervention) may be considered. Solutions which are inherently less durable than 100 years (in particular, certain nature-based solutions) are still fully eligible so long as they are paired with management practices that ensure that, on net, the claimed quantity of CO_2 is removed and sequestered for at least 100 years. Similarly, solutions that offer inherent durability in excess of 100 years, without active intervention (e.g. some forms of mineralization or geologic sequestration) are also fully in scope.

6.1. Durability can be achieved in one of two ways. First, the carbon dioxide removal solution may generate a form of carbon that is well known to have a lifetime much longer than 100 years (e.g. calcium carbonate, as just one example). Proper storage or custody of that form of carbon can then ensure durability over 100 years. Second, the carbon dioxide removal solution may generate a form of carbon that is not itself stable over 100 years (e.g. a protein in a living plant), however with active or passive management of the solution, ongoing repetition of the removal process, and/or monitoring, the overall system can ensure that on net, CO_2 remains sequestered on net over 100 years (e.g. a healthy ecosystem or actively managed ecosystem, as just one example). It is the responsibility of each team to provide the judges with confidence that their carbon dioxide removal solution will result in ongoing additional removals that are durable for at least 100 years.

6.2. In the event that a fraction of the sequestered CO_2 is likely to be re-emitted within 100 years, the re-emitted CO_2 should not be considered sequestered for the purpose of calculating the system scale, and should be accounted for as an emission source in the Lifecycle Analysis.

Documentation Requirements

6.3. Each team must establish the durability of their sequestered CO_2. This may include references to (this list is not exhaustive):

- The chemical stability of the sequestered CO_2
- The team's strategy for managing the sequestered CO_2 to minimize re-emission or otherwise capture CO_2 in sufficient quantities that a net CO_2 flux of 1000/year can be expected to remain sequestered for at least 100 years.

- Experimental work conducted by the team supporting their claims of durability
- Other standards which establish the durability of the proposed method of CO_2 sequestration

7. Net Negative Performance (Lifecycle Analysis)

For Phase 1 of the competition, the Lifecycle Analysis will focus on a quantitative cradle-grave CO_2 footprint analysis. Teams must demonstrate net-negative and durable CO_2 removal.

Scale

7.1. The Lifecycle Analysis must reference the proposed 1000 tonne/year carbon dioxide removal project.

Scope

7.2. The scope of the emissions assessment is cradle-to-grave with reference to the removed CO_2, from the point of capture (from the air or ocean) and inclusive of all processing, transportation, storage, and post-sequestration management.

7.3. Scope 1, Scope 2, and Scope 3 emissions from all systems, subsystems, and processes in the system must be included.

7.4. Emissions associated with the durable storage of the removed CO_2.

7.5. Projects must account for emissions from the process, its supply chain, and potential leakage or loss from storage.

Documentation Requirements

7.6. Each team must submit an emissions intensity worksheet, which defines emissions sources, sinks, and reductions associated with the system. The values put into the worksheet must be consistent with the other technical documentation prepared for the 1000 tonne/year system.

7.7. An independent party will determine the overall emissions intensity of the process based on the submitted worksheet.

8. Social License & Environmental Justice

Teams must discuss their plans for addressing and achieving broad social license and acceptance, equity, and environmental justice. XPRIZE considers these attributes to be important goals in and of themselves, and also significant barriers to deployment at low cost and at Gigatonne scales if ignored. At the milestone phase, teams must explore these issues in the context of their proposed 1000 tonne/year demonstration.

Documentation Requirements

8.1. Each team must review a brief selection of materials on Social License & Environmental Justice, and describe a strategy for addressing these issues as part of their project development plans.

9. Scaling to Gigatonnes per Year

Teams must explicitly address the non-CO_2 environmental impacts of the proposed solution, including energy, land, water, and other natural resource needs, benefits, positive or negative impacts on biodiversity and other ecosystem services, and constraints of their solutions.

Demonstration Considerations

9.1. Teams are responsible for maintaining the health and safety of their teams and the environment over the course of their participation in the prize. Teams must comply with all laws and regulations which apply to their participation in the prize. XPRIZE reserves the right to expel teams who do not uphold reasonable standards of safety and ethics.

Documentation Requirements

9.2. Teams must describe the most significant non-CO_2 environmental risks and impacts of their systems, both positive and negative, and how these may be mitigated or managed as the solution reaches scale.

APPENDIX A. Milestone Submission Questions

Proposal Instructions:
Milestone Submissions are due by **noon (12:00pm) PST on February 1, 2022**. Submissions can be modified or updated until this deadline. Submissions must be written in English. After the deadline, Judges may reach out for further clarification or additional information if needed.

The Milestone Submission will be completed in the XPRIZE Prize Operations Portal (POP) and will consist of the following three fillable forms:

1) Part 1: Shareable Team Summary

2) Part 2: Technical Submission
    - Written Questions. Maximum word counts are provided for each question.
    - Five templates are referenced in the written submission. They can also be found on the "Resources" tab in POP under Milestone Submission Templates (linked here) and in the POP submission directly.
        - Process Flow Diagram, Stream Table, and Mass & Energy Balance
        - Demonstration Performance Worksheet
        - Verification Checklist
        - Cost Worksheet
        - Lifecycle Emissions Intake Form
    - Other uploads are referenced in the technical submission. You may upload any supporting documents and files in response to these questions.

3) Part 3: Environmental Justice Questionnaire (See Appendix B).

IMPORTANT NOTE REGARDING CONFIDENTIALITY:

This submission may require you to disclose sensitive and confidential technical and commercial details to XPRIZE. All information submitted to XPRIZE is considered confidential (subject to section 11 of the Competitor's Agreement) except where explicitly indicated. Confidential information will not be shared with any individuals beyond the XPRIZE Carbon Removal project staff and Judges, all of whom are subject to non-disclosure agreements. XPRIZE does not claim or intend to claim any interest in any team Intellectual Property.

SHAREABLE TEAM SUMMARY

The information in the shareable section will be used publicly in XPRIZE communications if you are selected for a Milestone Award. Please do not include any confidential information in this section that you would not like shared about your project.

- Team Name
- Legal Entity Name (if different than Team Name)
- Type of Entity (e.g. startup, subsidiary, university group, etc.)
- Name of Team Leader
- Team Website
- Country
- Project Description - What is your project's elevator pitch? What sets it apart from other ideas? Please describe your project at a high-level in language that the general public would understand.
- University Affiliation (optional)
- Partner Affiliations (optional)
- Technology Readiness Level (TRL)
- Track that most closely represents your carbon dioxide removal solution

TECHNICAL SUBMISSION: SUMMARY QUESTIONS

Data submitted in this section may be published in aggregated and anonymized form. Your answers will otherwise be kept strictly confidential.

Budget and Fundraising

- What stage of funding are you currently in?
- How much capital is required to compete in the 4 year competition (USD equivalent)?
- How much capital has been raised to date (USD equivalent)?
- What type of funding are you seeking

Tons of CO_2 Removed

- Is this a proposal for CO_2 removal from the air and/or oceans?
- How many tons are you currently removing annually? (Ok to enter 0)
- Have you sold any carbon removal credits to date?
- What is your estimated all-in cost of removal ($/tonne) for a Megatonne scale project? (refer to cost spreadsheet)
- What is your estimated date of achieving 1 Megatonne (Mt/year) capacity?
- What is your estimated date of achieving 1 Gigatonne (Gt/year) capacity?
- What is the inherent durability of the sequestered CO_2 (years)?
- Do you have a plan to ensure the removed CO_2 remains durably sequestered for at least 100 years?

Phase 1 Milestone Demonstration Details

- Where is your Phase 1 Milestone demonstration location (country)?
- What is your Phase 1 Milestone demonstration start date?
- What organization is your verifier affiliated with?
- What is your date of verification?
- Do you affirm that your verifier is independent of your team and free of any conflicts of interest?

Phase 2 Demonstration Project Details

- Where is your proposed Phase 2 demonstration location (country)?
- Will the proposed 1000 t/year demonstration project be carbon negative on a lifecycle basis?

TECHNICAL SUBMISSION: OPERATIONAL REQUIREMENTS

1. 1000 tonne/year Carbon Dioxide Removal Project Proposal

Use your answers in this section to describe the 1000 tonne/year (minimum) carbon dioxide removal project you intend to demonstrate to win the grand prize. If you have already achieved a scale of 1000 tonne/year, describe your current operating carbon dioxide removal project.

1.1. Project Description (200 words).

Briefly describe your proposed project in plain language. Include the following:

- What do you plan on building?
- Where will the project operate?
- What are the steps involved in removing and sequestering CO_2, from an operational perspective?

1.2. Technical Summary (200 words).

Provide a high-level written description of the major technological and scientific concepts which underlie your project. Include descriptions of:

- The mechanism of CO_2 capture.
- Any chemical and/or natural processes that describe the transformation, processing, or treatment of the captured CO_2.
- The mechanism of durable sequestration of the CO_2.

1.3. Project Scale (150 words).

Discuss each of the following elements of your proposed 1000 tonne/year project.

- How many tonnes per year of CO_2 will your project capture from the air or ocean (gross removal)?
- What fraction of the captured CO_2 can be considered durably sequestered (ie, for more than 100 years)?
- How much Land or Ocean Area is required by your project (Ha)

1.4. Energy Sources (150 words).

- What sources of energy (electricity, fuel, or other sources) will you rely on for your demonstration? If multiple energy sources are used, what is the breakdown? If steam is required, specify the quality of steam required.
- If renewable sources of energy are used, explain how you will overcome the intermittency of the energy source.

1.5. Project Plan (100 words).

- Describe 5 major milestones of the project over the full life of the project (through at

least February 1 2025, and beyond if applicable).

1.6. Intellectual Property (150 words).
- Describe the relevant IP required for the project, explain who currently owns it, and your plan for licensing or acquiring it.

1.7. Permits & Regulatory Compliance (100 words).
- List the permits that you will need to acquire before constructing and/or operating your carbon dioxide removal project, and the dates by which each permit will need to be acquired.
- If there is no jurisdiction in which you can lawfully operate your project today, explain your strategy for operating legally by February 2024.

1.8. Upload a *Process Flow Diagram (PFD), Stream Table, and Mass & Energy Balance* for the proposed 1000 tonne/year project.
- Refer to the template provided.

1.9. Upload any additional engineering drawings, schematics, or renderings of your project design (Optional).

2. Demonstration of Key Component

Each team must demonstrate the operation of a "key component" of their Carbon Dioxide Removal solution. The demonstration should establish the team's ability to successfully complete their proposed 1000 tonne/year Carbon Removal project.

2.1. Demonstration Description (500 words).
Describe the demonstration of the key component of your carbon dioxide removal project. Include the following:
- What was demonstrated?
- What makes the demonstrated component(s) the 'key component'?
- Discuss how your demonstration is critical to the performance of your proposed 1000 tonne/year carbon dioxide removal project.

2.2. Demonstration Results (500 words).
Include descriptions of:
- The major strengths of the key component which was demonstrated.
- Any weaknesses and areas for improvement.
- Steps that need to be taken to integrate the demonstration into a complete carbon dioxide removal system.

2.3. Upload a *Demonstration Performance Worksheet*.

- Refer to the template provided.
- Include a chart showing the performance of your demonstration over time
- Include a process flow diagram (if applicable, this may be an annotated version of the PFD provided in your 1000 tonne/year carbon dioxide removal Project Proposal) which indicates how your demonstration fits within the full carbon dioxide removal project proposal.
- Include summary-level data showing the performance of your demonstration over time or over a range of performance conditions (as applicable).

2.4. Upload technical documentation showing the design of your key component demonstration.

- Provide additional drawings and schematics which show the design of the demonstrated system. Include specifications, data sheets, or other engineering documentation for each of the major pieces of equipment included in the key component demonstration.

2.5. Upload any additional performance data related to your demonstration (Optional).

2.6. Upload photos of the key component demonstration setup.

2.7. Upload video of the demonstration being operated (maximum 2 minutes).

3. 3rd Party Verification

Independent verification of the team's solution is focused on ensuring that:

- There is quality evidence that the technology is operational, and that observation of its operation supports the team claims that it can achieve specified levels of performance;
- The data collected and submitted to document claimed technology performance is collected using acceptable and defensible methods, approaches, and test equipment, resulting in high quality data.

3.1. Verification Summary (250 words).
Describe what steps have been taken to verify your demonstration:

- Who performed the verification? When?
- Summarize the verification process
- Discuss the results and conclusions of the verification process.

3.2. Upload a completed *Verification Checklist.*

- Refer to the template provided.

3.3. Upload a Verification Report, prepared by your verifier, with any additional attachments and evidence of the verification activities defined in the checklist.

TECHNICAL SUBMISSION: FULLY CONSIDERED COST PER TONNE

The cost assessment is intended to provide an estimation of technology costs consistently across all teams in the competition, and include all significant drivers of the solution cost at an average net rate of 1 million tonnes of CO_2 durably sequestered per year.

4. Definition of the Megatonne Scale (Mt/year) Project

This section defines the Megatonne scale project that will be the basis for the cost estimate.

4.1. Megatonne Scale Project Description (250 words).
- Briefly explain what the 1Mt/year project will look like and how it will operate.
- Discuss any key design changes required to scale up from 1000 tonnes/year to 1Mt/year.

4.2. Project Scale (150 words).
- Describe the land or ocean area required for the project.
- Describe the raw materials that will be needed to construct/build the project.
- Describe the requirements for water consumption and management.

4.3. Energy Sources (150 words).
- Describe the major energy sources used by the project.
- If steam is being used, describe how the steam is generated, and the quality of steam required.
- If renewable sources of energy are used, explain how you will overcome the intermittency of the energy source.

4.4. Upload a *Process Flow Diagram (PFD), Stream Table, and Mass & Energy Balance* for the Megatonne scale system.
- Refer to the template provided.
- This document is separate from the PFD uploaded as part of the 1000 tonne/year document uploaded to the demonstration proposal section, but should be updated to reflect any anticipated changes as the solution scales from the kilotonne to

Megatonne scale. Please include annotations that highlight any major differences between the two project scales.

- This document must include the full scope of CO_2 capture, processing, and sequestration at the 1Mt/year scale of CO_2 removal.

5. Cost of Carbon Dioxide Removal

Use the provided worksheet to calculate your cost per tonne, using the project basis described in the previous section.

5.1. Cost Summary (50 words).

Summarize the following from the completed Cost Worksheet:

- Annual tonnes durably removed (tonnes)
- Capacity Factor (unitless)
- Capital Recovery ($/tonne)
- Fixed Operating Expense ($/year)
- Fixed Operating Expense ($/tonne)
- Anticipated Revenues ($/tonne)
- Total Cost ($/tonne)

5.2. Revenue & Value (250 words).

- Describe any valuable goods that may be sold (including CO_2 derived products or valuable co-products). What is the quality of these products? What emissions are associated with the goods' use and end of life?
- Describe any tangible & measurable environmental co-benefits (eg improved biodiversity, improved crop yields, improved fisheries, ecosystem services, removal of other greenhouse gases, etc.).

5.3. Upload a completed *Cost Worksheet*.

- Refer to the template provided.

TECHNICAL SUBMISSION: SUSTAINABLY SCALEABLE

6. Durable Sequestration

The goal of the competition is to ensure that at least 1000 tonnes/year of CO_2 will remain sequestered for at least 100 years. Teams must account for any anticipated re-emission within that time frame in their project design and management approach.

6.1. Description of Sequestered CO_2 (100 words).

- What is the final chemical form of the sequestered CO_2?
- How stable is the CO_2 in its final form, without any intervention or active management?
- Describe exactly where and how the CO_2 will be sequestered.

6.2. Durable Carbon Dioxide Removal (500 words).

- What fraction of the total sequestered CO_2 can be expected to remain sequestered for longer than 100 years? What fraction is expected to be re-emitted?
- What risks exist that would lead to partial or complete re-emission of the sequestered CO_2?
- How have you accounted for expected or unexpected re-emission of the sequestered CO_2 in your designs or management strategy?

6.3. Monitoring, Measurement & Verification (100 words).

- Describe your planned Monitoring, Measurement, or Verification activities.

7. Net Negative Performance (Lifecycle Analysis)

The Lifecycle Analysis must indicate a reasonable likelihood that the proposed system can achieve the target 1000 tonnes/year of net sequestration.

7.1. Assuring CO_2 Negative performance (250 words).
Describe what steps you have taken to ensure that your proposed demonstration will achieve net CO_2 removal of 1000 tonnes/year.

7.2. CO_2 Negative performance at larger scale (250 words).
Describe how you expect your lifecycle analysis to change as your solution scales to sequester Megatonnes of CO_2 per year?

- What economies of scale can be expected that will improve your lifecycle emissions?
- What aspects of the process will become more emissive at scale?

7.3. Upload a *Lifecycle Emissions Intake Form.*

- Refer to the template provided.

8. Social License & Environmental Justice

Complete the provided *Sustainability, Social License, & Environmental Justice Submission Questionnaire.* (See Appendix B).

9. Scaling to Gigatonnes per Year (Gt/year)

Solutions must demonstrate that they can, in principle, achieve Gigatonne scale (at least 1 billion tonnes of CO_2 removal per year), and that there are no fundamental natural or physical barriers to achieving that scale. Teams must also articulate whether and how their solutions can be deployed in an environmentally sustainable way now (i.e. at the 1000 tonne/year scale), and in the future as they scale to consume Gigatonnes of CO_2 per year and more.

9.1. Scaling to Gigatonnes per year (150 words).
Describe at a high-level how Gt/year scale can be achieved using your specific carbon dioxide removal approach.

- How can Gt/year scale be achieved? (eg. increase size of each project? Increase number of projects? Both? Other?)
- What key design elements will need to be altered to facilitate massive scale?

9.2. Limits of Scale (150 words).

- Describe the major potential constraints your carbon dioxide removal approach will encounter on the path to the Gt/year scale (e.g. energy, land, raw material) and how you will navigate these constraints.
- What are the issues that are most likely to limit growth?

9.3. Environmental Impact & Risk (500 words).

- Describe the most significant non-CO_2 environmental impacts (and risks of impact) associated with your solution, both positive and negative, and how these may be mitigated or managed as the solution reaches scale.

APPENDIX B. Sustainability, Social License, & Environmental Justice

The following questionnaire will be available as a fillable form on POP:

Carbon180 | XPRIZE CARBON REMOVAL | MUSK FOUNDATION

Sustainability, Social License, & Environmental Justice
Phase 1 Submission Questionnaire

Overview: Environmental Justice (EJ) is a critical component of climate innovations and solutions. Historically, issues of equity and justice have been considered very late in the lifecycle of a project, if at all. Experience in many industries and communities has shown that this leads to worse outcomes for solution developers and local communities. In an effort to establish a more productive conversation around EJ and carbon dioxide removal, we are introducing equity and justice considerations earlier in the development cycle of new solutions, so that issues can be identified and addressed well before project implementation. We understand that many solution developers are not experts in EJ — that is why we see this process as one of learning and exploration. Judges will have access to these questions and to your responses, but they will not be used for the Phase 1 Milestone Award submissions to either award or eliminate any team from the competition at this stage. XPRIZE will then work with Carbon180 to refine the requirements for EJ considerations in Phase 2.

Over the course of the XPRIZE Carbon Removal, the collective data and experience of the teams competing in the prize will be analyzed by a panel of EJ advocates organized by Carbon180. The learnings from these experiences will be published for the benefit of the carbon dioxide removal community. All data collected on this form will be aggregated and anonymized in any analysis.

Reading Materials
Please familiarize yourself with the resources on the provided list available here, and fill in this questionnaire with these materials in mind.

Submission Questions

Project Description

1. Provide an overview of your demonstration project for the XPRIZE Carbon Removal. (200 words)

Project Location

2. Where will your XPRIZE Carbon Removal demonstration project occur? Why did you choose the project location that you did for your carbon dioxide removal Project? Have you already started work at this location, or have your plans for this location been finalized? (100 words)

Demographic Information

3. What are the demographics of the populations in the areas local to your demonstration project? What percentage are low income (X% below poverty line)? (100 words)

4. What existing environmental burdens have been identified in the local region of your proposed project? (100 words)

Legacy Pollution Analysis

5. How have you considered relevant public health data concerning the potential for exposure to human health and environmental hazards? Specific to the region you identified in question 1, are there any historical patterns of exposure to environmental hazards, to the extent such information is reasonably available? (200 words)

Environmental Sustainability

6. For your demonstration project, what are the local environmental impacts from your project (including from your sources of energy and materials) on air and water quality, as well as biodiversity or other natural resources? Thinking ahead to the full deployment of your solution up to Gigatonne scale, how do the impacts change or grow as you move to Gigatonne scale?

   a) What are the negative environmental impacts? (200 words)

   b) What are the positive environmental impacts (aside from CO2 removal itself)? (200 words)

Incorporating Community Engagement

7. What steps will you take to ensure that voices from the communities in which you are building projects are represented in a way that ensures their concerns are being met? (200 words)

Quantitative Assessment

8. Based on the provided EJ reading materials (see link above), discuss what you think are the most important EJ considerations for your project. (200 words)

9. Please rate your level of concern for each of the following issues as they relate to your project. Your selections will be used for research purposes only.
    a. Moral hazard - Moral hazard - the perception that the development of your CDR solution lessens or eliminates the urgency and need to reduce current GHG emissions
    b. Involvement of the oil and gas industry- any investments or ties to companies that participate in oil and gas
    c. Expansion of infrastructure (such as transportation pipelines or truck traffic)
    d. Land use competition (such as growing food, siting renewable energy, preserving biodiversity, and timber harvesting, among others)
    e. Environmental health (such as groundwater contamination or seismic activity)
    f. Workforce development - making sure good-paying, local jobs are readily available for community members
    g. Other (free entry)

APPENDIX C: Revision History

Version 1.1, November 29, 2021

- Initial Release

Version 1.2, December 9, 2021

- Page 4, updated and clarified language to define "net CO2 removal".
- Page 16, Appendix A, added hyperlinks to templates for Milestone Submission.
- Page 19, Technical Submission question 1.3, minor text clarification that the question is referring to “Gross tonnes removed”.
- Page 20, Technical Submission question 1.8, minor text clarification that the scope of the required upload is the 1000 tonne/year system.
- Page 21, Technical Submission questions 2.3 & 2.4, minor text update to more accurately reflect the scope of the “Demonstration Performance Worksheet”.
- Page 22, Technical Submission question 4.4, minor text update to clarify the scope and purpose of the required upload.
- Page 26, added link to Carbon180’s environmental justice reading materials.
- Page 28, Appendix B, Revised question 9a.

Version 1.3, December 20, 2021

- Page 11, Section 5.3, Added clarity about the scope of the “Capital Recovery Factor”.
- Updated hyperlinks to the templates, to point to the “POP Resources” page, rather than to the documents directly, to facilitate updates to those resources.