Carbon CharStore

Classification System for Carbon Removals

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A Comprehensive Classification System for Carbon Removals

Executive Summary:

The first classification system suitable for all carbon removals irrespective of the technology or sequestration pathway, has been developed by Carbon Char Store.

Focusing on the contributions all carbon removals must make towards achieving **Net-Zero and averting catastrophic climate change, the system** details the 7 major dependencies of this problem and builds a scoring system for each one which is applied in turn to any carbon removal claims.

To ensure the scoring reflects both current scientific knowledge and explains current market pricing of removals, the system has been developed with **Dr. Saran Sohi of the UK Biochar Research Centre at the University of Edinburgh**.

Our CCS carbon removal classification system provides a unique tool for producers, buyers, academics and anyone wishing to remove carbon and help achieve Net Zero. It provides an explanatory link from the Net Zero challenge to the factors key to achieving it successfully. As concerned individuals and organizations, this highlights the details we need to consider to ensure the removals address the Net Zero goal.

A Classification System for Carbon Removals

Carbon Removal: An essential, unavoidable pathway in addressing Climate Change

When 196 nations signed the Paris Agreement at COP 21 in December 2015, they agreed to take action to limit global warming to 1.5°C and achieve Net Zero carbon emissions by 2050.

But in early April 2022, the United Nation's Intergovernmental Panel on Climate Change warned that without immediate and deep emissions reductions across all sectors, limiting global warming to 1.5°C is beyond reach[1]. If action is taken now, the IPCC believes a 50 per cent reduction in carbon emissions by 2030 is achievable.

However, the IPCC noted that emissions reductions alone are not enough to achieve Net Zero and prevent catastrophic Climate Change. An additional, essential and unavoidable requirement is the removal of carbon dioxide (CO_2) from the atmosphere using a combination of trees, technologies and geological sequestration.

Given that current anthropogenic CO_2 emissions are calculated to be 42.5 billion tonnes a year, the scale of required removals is huge. Estimates suggest 10 billion tonnes of CO_2 will need to be removed annually from the atmosphere by 2050, then doubled by 2100[2].

Classification of Carbon Removals: Targeting Net Zero by Design

Carbon dioxide removal (CDR) denotes any process where a known mass of CO_2 is taken from the atmosphere and sequestered into the lithosphere ("Geological" CDR) or biosphere (if that removes it from the active carbon cycle, "Biological" CDR).

A variety of carbon removal options already exist, and more technologies are certain to be developed. To date, however, there has been no systematic attempt to classify the level of carbon removal benefit or the potential disadvantages or issues that different removal options present. This paper aims to address an increasing need to link the various characteristics of carbon removal processes with the required scientific attributes that are essential to address climate change. We aim to trace and assign relative value to those links whilst also recognising the requirement for robust reporting that should accompany any claims. This paper describes the development of our carbon removals classification system, which differentiates and ranks current removal options based on their specific characteristics and level of contribution to Climate Change mitigation and the achievement of Net Zero.

While any classification system is open to subjectivity, we have made every effort to base all the inputs on existing scientific knowledge in order that removal options given the highest ranking make the greatest contribution in terms of the permanence of carbon removal and resource efficiency. By designing the classification to be technology agnostic we also aim to have a system that can be revised to accommodate both scientific progress and any future coalescing views on how best to tackle climate change. As new technologies replace old, an evolution within the classification will be required that reflects any changes in best practices. However, the classification system also recognises that removals in the lower and lowest ranks still make a positive contribution, while offering i) lower permanence of removal than the highest grades, ii) lower resource efficiency (e.g. the life cycle analysis of the removal would reveal associated emissions or risks of considerable emissions if scaled up), iii) less certainty in the level of the impact they will have or iv) a combination of all three. Therefore, while even our lowest ranked options make a qualified and quantified contribution to carbon removal, they may not meet the requirements of those wishing to secure the best available carbon removal.

[1] Climate Change 2022: Mitigation of Climate Change. Contribution of Working Group III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change

[2] National Academies of Sciences, Engineering, and Medicine 2019. Negative Emissions Technologies and Reliable Sequestration: A Research Agenda. Washington, DC: The National Academies Press. https://doi.org/10.17226/25259.Summary, p.9.

The World needs rapidly to reach Net-Zero to avert catastrophic climate change.

This, put succinctly, is the target problem the world faces. There are competing options on how to deal with this problem. Potential approaches can be distinguished by a simple analysis to draw out what they have in common and where they differ. A robust classification system for Carbon Dioxide Removal (CDR) options should identify the common features among these options while acknowledging differences of opinion on their potential efficacy and limitations. For instance, a sound system would accept that Geological and Biological sequestration of CO_2e are both beneficial to our aim but recognise that the former offers a higher and more certain level of permanence to any removal than the latter because Biological sequestration varies according to the character of the sequestration site in question.

Criteria affecting efficacy of Carbon Dioxide Removal

Assessments regarding the efficacy of carbon removal options rest partly on scientific evidence and partly on more subjective points of view. To prioritise the former and minimise the more subjective elements within a classification system, we must assume a worst-case scenario with respect to the target problem for any generalisations we make. In order to do this, we have derived 6 major dependencies within the target problem. These 7 dependencies then give rise to numbered conclusions that the classification system can be built from and commensurate rules that any potential CDR must adhere to. This list of dependencies or criteria, provide a logical link from the target problem to the structure of the classification system and then to the hurdles that any CDR must clear to be included.

The 7 Key dependencies of the problem

The **target audience for this system is global.** Classifications of removals must align with the needs of those likely to demand and supply them. This ensures buy-in from those able to reduce net emissions (whether through emissions reduction or physical CO_2 removal, or the financing of these). But fundamentally, the classification must actually contribute in the sense that it quantifies and grades a removal's impact on the primary challenge. **A classification system must directly address the utility of a removal towards the challenge and ignore other virtuous aims that do not directly impact CO_2e atmospheric concentrations (1)**. In practice this means that removing two tonnes is twice as good as removing one tonne and that any uncertainty in the mass of biogenic CO_2e sequestered counts against that claimed tonne. Non-carbon impacts are excluded to ensure (i) comparability across processes (so equally graded processes are equally good at addressing the problem) and (ii) fungibility of equally graded removals (so that achieving 10x removal contributes 10x as much).

The **purpose of any classification is to support but also inform individuals' motivation.** A classification system must offer an intuitive guide for those wishing to address the problem, whatever their level of understanding around climate change. **There must be simple links between the grading of removals and the target problem and those links must be transparent and trustworthy (2).** A system that links intuitively the act of CO_2 removal and achieving Net Zero, will engage better and more extensively with those who should seek to use it. In addition, trust in the system across all levels of expertise leads to wider adoption and a feeling of confidence that the challenge can be met.

There must be a **focus on quantification towards the target problem**. Net Zero is a global objective to which CDR contributes. The scale of this contribution is a function of our ability to reduce existing emissions and our ingenuity in achieving CDR technologies that can scale rapidly. In addition, the balance between reduction and removal efforts will be driven by the economics of which is more palatable at any given future point. This focus leads to three further dependencies:

Transparency and trustworthiness require processes to be open to public inspection so that the reported attributes of any removal are supported by the requisite evidence. **The classification system must take into account the accuracy of the record keeping and its resultant claims (3)**. In practice this means assessing a removal's record-keeping's inherent suitability to the whole removal technology and the chosen sequestration pathway. The classification then assigns a contribution to the overall score that reflects the level of clarity and openness that those records contribute to the overall claimed contribution towards the target problem.

To ensure further confidence in the quantity of any CO_2 Removal, it must be expressed net of the emissions associated with its creation: That is to say, any emissions associated with the process, count against that process. **The most transparent route to achieving this is to require that all CO_2 removals are calculated according to a common carbon accounting protocol. (4)**.

The problem also has one highly contentious aspect that we need any system to deal with. Net Zero is the point where emissions and removals are equal. This suggests we are aiming to match CO_2 removal to any rate at which carbon continues to be released from the lithosphere and biosphere. However, this assumes that no removed CO_2 re-enters the atmosphere naturally. **Consideration of Permanence and in-situ Stewardship are a key feature of any classification system (5)**. Unfortunately, twice the longevity does not mean twice the benefit in terms of the target problem, because the timescale over which removal should be assessed is a critical consideration.

The target problem's urgency means emphasising timescale. Delay in a CDR response means a higher peak in global surface temperature. The non-linear response of the Earth's system means exponentially greater damage to eco-systems and economies, so it is not contentious to argue for urgency in CDR response. [Fankhauser, Nature Climate Change, 2022]. **Encouraging rapid adoption of CDR means erring on the side of generosity in relation to inclusion but not ignoring the matter of quality (6).** This means adhering to the underlying science but accepting that permanence is less important than the amount of CO_2 removal (removing 2 tonnes for 50 years is better than removing 1 tonne for 100 years). It also calls for a pragmatic approach where the current scientific uncertainty associated with a removal can be recognised within the classification system (say, a process where the removal pathway provides storage with an uncertain longevity, rather than to exclude it it should be allowed though scored lower. This is not to say the system should tolerate inaccuracies (that would devalue them) but that grading within the system should accommodate technologies that provide proven CDR quantities but with uncertainties regarding their ultimate quality.

The issue of **Additionality cannot be ignored**. Broadly, Additionality is a concept whereby any removal would not have happened were it not for the financial value assigned to that removal:

- The "urgency" issue argues against this conception of Additionality, in the sense that any removal, whether it would have occurred with extraordinary financing or not, is a positive with respect to the problem.

- The "urgency" requirement supports Additionality in the sense that we need more and more removals going forward (Net Zero assumes increasing removals not just decreasing emissions) and need a mechanism to funnel financing to otherwise uneconomic activities.

Additionality must be included in any classification system to give confidence that it encourages an efficient allocation of economic resources such that we maximise the probability of Net Zero. That said, we must recognise that removals are not directly paid for, they occur as a result of processes that might have ongoing financing needs or one-off, often up-front needs or indeed, both. To reflect this, we must include measures of:

- how much any removal process relies on expected lifetime additional revenue from removals credits to achieve initial financing – [Lifetime additionality], and
- how much additional revenue from removals credits impacts the ongoing rate of removals viz. that processes removals volumes' sensitivity to price of those removals – [Instantaneous additionality].

Including both ensures a high additionality score for processes that would otherwise be non-financeable whilst recognising that incentives must be in place for ongoing removals processes to keep maximising the quantum of removals achievable (as it is more economic under the second point).

Including both lifetime and instantaneous additionalities limits the risk that revenues from CDR credits compromise the potential of other processes being realised. We can illustrate this with an example of a process that has a high lifetime additionality score but nevertheless has no forward sensitivity to removals price, (i.e. it is instantaneously non-additional):

- This process will score, for example, 6/10 for lifetime additionality and zero for instantaneous additionality (once the process is financed, no more removals occur if the price paid for them increases). If we then consider a similar technology, with the same lifetime additionality but more cost efficient (through better management or innovation, that facilitates a maximisation of the ongoing removals because it can be run faster or with better environmental attributes (which both come at economic cost to the base case) then it will score marginally higher than its inefficient competitor on account of its instantaneous additionality. Scoring higher will ultimately lead to being able to command a higher price for its removals and eventually it will outcompete its less-innovative rival thanks to better economics.

Additionality should not mean rewarding the least profitable removals processes first, neither should it exclude removal processes that are profitable. Additionality should help channel removal credits' revenue to processes that are best placed to use that extraordinary revenue to increase removals. It is this ability to improve on the quantum of removals per dollar vs the counterfactual of that process not existing that any classification system should promote. **Additionality, in the sense of additional CO_2 removal per unit dollar received, is a key attribute. (7)**.

The above 7 numbered dependencies can be utilised by a classification system by providing a clear relation between that classification's inherent grades (e.g. AAA, A, C etc) and the derivation of those grades from attributes of the CDR in question. It is important to be able to trace the characteristics of a CDR technology to its impact on all facets of the target problem. This then leads to the classification promoting inclusivity, as benefits from one type of technology might be entirely orthogonal to the benefits of another but both are needed. If no removals exist that are not prohibitively expensive, then no financing will exist to square the need. It is better to provide entry level removals (say those someway down the classification hierarchy) and maximise the market than have no market at all.

The Classification of Carbon Removals

Summarising the points above (point numbers below correspond to numbered bold type aims above) the classification system must have the following features:

1 A measure of the mass of removals (separate to any grading of those removals) including an assessment of the accuracy of that measure (which will be included as an input to the grading in schedule 1.1).

2. Simple segregated gradings within the system that have a direct link to the target problem. We propose the 10-tier letter grading system used in other fields (AAA, AA, A, BBB, BB, B, CCC, CC, C and D). Each grading should represent a band of scores calculated as the sum of scores any specific removal process receives for each attribute.

3. The second attribute to score a removal on is its accuracy, and mode, of recordkeeping of the process that leads to the Removal and its sequestration. This is best summarised as an assessment of the supply-chain record and its contribution to the classification is covered in schedule 1.2. Claiming X tonnes of removals requires a transparent record of how that removal occurred and is likely to be monitored on a forward basis (examples being: biomass amount, carbon content, treatment process leakage, transport records, sequestration percentages, etc.) with the contribution revolving around the accuracy of all those individual inputs. The mode of recordkeeping is then a bar that must be maintained such that any lack of recordkeeping or periods that lack transparency leads to the disqualification of removals from the grading system (or the assignment of very low grades in certain circumstances).

4. All removals must adhere to the GHG protocol standards of carbon accounting. This means the overall process is correctly accounted for with any associated emissions included. We also require those carbon accounts to be current (annually updated) so as to prohibit the use of out-of-date counterfactual inputs where technological advance has since altered any process' operative landscape. This limits the crowding out of new technologies by incumbents and so ensures qualifying carbon removals are helping towards the target problem. Though assessment standards of inputs into those accounting records can be captured within other attributes of the grading system the treatment of the inputs themselves, whether they are off-settable against certain emissions etc., is to be determined using the protocol's standardised rules. This is another bar that has to be met for inclusion into the classification process (for ease of reference, acceptance criteria are related back to the dependency they are derived from in the table "classification suitability criteria").

5. Once a removal has been sequestered, that mass of carbon must be assessed for permanence so as to fully measure the removals impact on the target problem. This permanence score will reflect both a scientific assessment of the time it will take for the sequestered carbon to re-enter the atmosphere under controlled conditions (a function of the carbon's chemical and morphological attributes as well as the mode of sequestration) as well as an assessment of the risk that those controlled conditions are violated (e.g., susceptibility of the sequestration pathway to destruction through fires etc.).

6. Providing there is confidence in the quantum of removals achieved (e.g. the relevant carbon accounting is third party verified) then admission to the classification scheme is assured. However, to ensure quality within the classification is recognised each attribute needs to be scored for any given removal process and those scores added to give a final grade. As different attributes are scored out of different amounts (with weightings derived from an independent academic review process updated every 1-2yrs) the total score for any CDR process, adjusted to be out of 100, determines the grade it receives within the classification.

7. The Additionality score for removals is the sum of two attributes of the process that produces them: The lifetime additionality plus the instantaneous additionality. Both are subject to the test that the removal is not mandated by local legislation though some score will be allowed if the removals achieved are over that required by that legislation. Lifetime additionality tests the counterfactual "would the removal process have been funded if it were not for the expected lifetime revenues from removal credits". Instantaneous additionality assesses the sensitivity a process' quantum of removals has to the price received of those removals and that the credits received are instrumental in causing an increase in removals (the amount of that increase being key to the score).

A summary of any qualifying Carbon Removals' list of attributes

Before issuance of any certificates under this classification the following shall be pre-requisites for any Removals process:

- A complete and ongoing set of open-source records that detail the route for any process that organic matter takes from its CO_2 absorption phase to its sequestration in the lithosphere.
- A 3rd party verified GHG protocol compliant assessment of the process that represents the process no older than 12months.

Further details for admission are under "Suitable Criteria" and then detailed in full in schedules 1.1-1.6. In this sub-section the classification also provides a guide as to the exact dependency any pre-required rule derives from. This provides a logical path from the target problem to its dependencies then the rules of admission that flow from those dependencies and ultimately the scores achieved by any qualifying CDR.

The grading of any given process' token will then depend equally on the following attributes (each attribute of the process is given a score out of a pre-set total as set out in schedule 1.):

- Certainty of net biogenic CO2e removed (scientific assessment)
- Documentation of the CO_2 removal process (including emissions)
- Inherent stability of the removed C (chemical recalcitrance)
- Security of C under initial storage conditions (longevity)
- Resilience and susceptibility of storage (stewardship)
- Novelty, Additionality and exclusivity (opportunity cost)

The aim of this Classification System for Carbon Removals is to provide a complete comparative measure for any technology claiming to address the target problem.

Classification Suitability Criteria

Questions	Notes (NO to any of the following questions excludes the proposed project from classification)	Relevant Dependency
Is the carbon dioxide removal (CDR) project documented to include: date, mass and quantity of the biogenic recorded accurate to within 4 standard deviations?	Documentation must explain: • the derivation of the estimated mass (or just a report of how the mass is measured e.g., DAC or pure CO_2 streams). • a report of unknowns and errors associated therein. • potential biases with mitigation of those biases and associated errors therein. • contain a declaration of compliance less than one year old from claim of grading.	1
Does the CDR project have a standardised and easily accessible record keeping process?	Transparency of proof of quality of removals is achieved through the simplicity of the records and the open nature of any information relating to the quality of the removals. Easily obtained records add to the overall quality of the removal by building confidence that the inherent claims about any removal are traceable back to physical records which themselves represent real life industrial processes.	3
Are the records of the CDR project complete?	Continuous monitoring can include offloading all recording above to a 3rd party or immutable automated (e.g. blockchain) record keeper. Written reports must verify all features above requiring declaration of compliance. Declarations of compliance must be annual and performed by an officer of the process entity.	4
Are the associated emissions of the project over 50% of the claimed CDR?		4
Is the CDR project method of removal and its expected permanence of sequestration fully supported by unanimous academic or governmental evidence?	A review of existing academic and governmental research relating to the sequestration method should be supplied with the application for classification of any removals. Conversion to the % present after 100yrs should use a conservative estimate from that academic research. It will thus require either the expected permanence at some confidence level or the half-life of the sequestration method (stripping out the half-life of the sequestrate itself). A reasonable estimate of the certainty of the permanence of sequestration mode should be made by reporting the range of values found within the academic/governmental literature.	5

Classification Suitability Criteria

Questions	Notes (NO to any of the following questions excludes the proposed project from classification)	Relevant Dependency
Are potential leakages or loss of a portion of the sequestrate during the sequestration process measured and accounted for?	Though emissions post transfer to the sequestering agent (e.g., pipeline owner or aggregate haulier) are accounted for under schedule 1.1, losses of actual removals are not likely captured and so should be assessed here. This is less of a hurdle to acceptance, more of a reminder that claims towards solving the target problem cannot be part abrogated to the steward post sequestration.	5
If at the time of removal claim the sequestrate requires ongoing stewardship, has this responsibility been contractually agreed?	Stewardship covers the ongoing responsibility to maintain the mode of sequestration from the initial point in time of sequestration. The level of risk scored assesses only the likelihood that the initial care of duty will not persist into the future (commensurate with the permanence of the sequestrate). Risks associated with physical changes to the sequestrate that are not due to duty of care changes (i.e., changes in physical storage due to natural causes) are assessed within schedule 1.4 "Permanence".	5
Does the CDR project take place due to existing laws or legislation?	CO_2 removals that are entirely required by law do not receive an 'additionality' score. They take place without the sale of the carbon removal and therefore demand for these removals does not affect supply. This is true for the lifetime assessment, where no revenue could be expected from removals as they are a mandated feature of the otherwise economic process AND of the instantaneous assessment where there can be no sensitivity of removals amounts to price as they are mandated by law.	7
Is the CDR project a distinct project? That is to say would the removals not normally take place.		7
Is the CDR project financially attractive without the sale of carbon dioxide removals?	Any process where credit revenues enhance the quantum of removals must provide documentation to support that enhancement on a period-to-period basis such that it documents each batch's reliance on that additional cost (which makes it sub-optimal economically). The baseline to which the uplift is measured must be a process scenario that could be adopted at least as easily as the removal optimised scenario to eliminate esoteric scenarios.	7

Classification Matrix

Attribute of Removal	Sub-assessment criteria	Contribution to overall score	Notes
(1) **Mass of Biogenic CO_2e plus scientific certainty**	• Mass in Kgs • Likely S.D. in measurement of mass • Adherence to accounting protocols • 3rd party oversight provisions of	• None • 0-7 (banded by S.D. e.g., <2% scores 7 • 0-6 • 0-3 (banded by oversight frequency)	All removals should be measured such that the errors are symmetrical around the claimed mass e.g. E(mass) = claimed mass.
(2) **Carbon Removal Process and assessed emissions – documentation quality**	• Quality of record keeping (e.g., completeness towards proving removal quality*). • 3rd party oversight of records.	• 0-13 (banded by completeness of records pertaining to removal quality**) • 0-3 (banded by accessibility/openness)	The key guidance to a high score is transparency of relevant information to support confidence in the claimed removals legitimacy.
(3) **Stability of the Sequestrate – Chemical Recalcitrance**	• Stability due to physical form (e.g., morphology or gas mix) • Stability due to chemical form (e.g., C/O ratio)	• Combined score 0-20 (banded by probability of 90% of sequestered material being present pari passu after 100yrs)	Questions arise around accuracy of science around these measures and judgement around 100yrs being target or longer?
(4) **Longevity of sequestration mode**	• Assessment of actual process of sequestration. • Scientific evaluation of sequestration method.	• 0-3 (banded by % of leakage likely in sequestration process) • 0-13 (banded by likelihood of 90% of sequestered material being present pari passu after 100yrs)	As above plus assessment of second feature must include consideration of efficiency of sequestration mode. (no crowding out of future sequestration)
(5) **Stewardship of sequestrate**	• Likelihood of change of circumstances affecting sequestered mode.	• 0-16 (banded by likelihood of 90% of sequestered material being present pari passu after 100ys)	Guidelines likely to be needed for assessment of P(change) e.g. asphalt being recycled.
(6) **Additionality and Novelty of Removal Process**	• Assessment of legislative basis on removals process. • Lifetime additionality • Instantaneous additionality • Assessment of the frequency and thoroughness of the above.	• A qualifying feature as well as discounting the below. • 0-7 (banded by 3 criteria that measure process financing viability) • 0-5 (banded by link between credit value and extra removals caused) • 0-4 based on documentation of lifetime and frequency of instantaneous assessment	Care taken over orthogonality to other measures. Aim is to preserve AAA grades as coming from processes maximising the causal link between a credits' value and maximum removals.

* Quality as defined by physical attributes of any removals (Stability, Permanence and Stewardship as defined in schedule details 1.4-1.6).

Schedule 1.1: Volume

Attribute 1 – Mass of removed CO_2. (+ scientific assessment of certainty of mass)

Sub-assessment Criteria	Detailed Checklist	Scores	Notes
Mass in Kgs	• Mass in Kgs • Date/time produced.	• Fundamental mass of CO_2 captured and sequestered in the assessed process. • Only atmospherically derived CO_2 (direct or via a biogenic pathway) qualifies. • Date/Time is not an assessed value it is merely for tracking purposes.	A "batch" of removals is one with all the same attributes under this scheme and should be grouped as such. As a result, each batch will have the same grade and can be deemed as non-fungible with other batches for the purpose of assignment to purchasers. Continuous processes with non-varying attributes (e.g., DAC) can create batches by choosing a date/ time period of the producers' choosing.
Likely S.D. in measurement of mass	• Documentation of methodology in assessing the mass of biogenic CO_2 in each batch prepared as a Project design document. • Estimate of S.D of the distribution of mass measurements as well as proof that biases in the process are corrected from time to time ensuring no meaningful skew in the measurement distribution. (Declaration of compliance). • Annual reassessment process. (Including declaration of compliance)	• Possessing 3rd party validated project documentation is a pre-requisite for any score. • Once a logical estimate of S.D within the measurement is obtained scores should be: <1S.D **- 7** 1S.D to 2S.D **- 5** 2S.D to 3S.D **- 2** <4S.D **- 1** Other 0 • Annual reassessment and declaration of compliance is required to carry score forward to next year.	Documentation must explain: • the derivation of the estimated mass (or just a report of how the mass is measured e.g., DAC or pure CO_2 streams). • a report of unknowns and errors associated therein. • potential biases with mitigation of those biases and associated errors therein. • Contain a declaration of compliance less than one year old from claim of grading.
Adherence to accounting protocols	• Any process that gives rise to "batches" of claimed removals must be assessed under the GHG Protocol. (Annual declaration of compliance required) and a report provided. • Batches should, under the above Protocol have an associated footprint estimate. This is split into two categories i) With counterfactual processes included ii) Without counterfactual processes.	• Possessing documentation of a <1yr old GHG Protocol compliant report of the process is a pre-requisite • For removals not requiring a counterfactual consideration, associated emissions (total scope I,II & III as a % of total removals claimed): <20% of claimed total **– 6** >20%, <50% **– 3** >50% not admissible to scheme. • For removals requiring a counterfactual consideration, associated emissions: <20% **- 4** >20%<50% **- 2** >50% not admissible to scheme.	A full set of carbon accounts is required each year to continue grading compliance. In addition, a re-assessment of any counterfactuals has to be made on the same annual basis of the accounts and a declaration of compliance made.
3rd Party oversight	• 3rd party verification by recognised ISO16064-3 or alike body must be sought before application to the scheme. • Verification must include all features requiring a declaration of compliance above. • Verification frequency.	• Batch specific, onsite monitoring continuous in nature plus annual audit and written report **– 3** • Annual audit of process, accounting numbers and counterfactual claims including written report **– 2** • Annual Statement of compliance of above **- 1**	Continuous monitoring can include offloading all recording above to a 3rd party or immutable automated (e.g. blockchain) record keeper. Written reports must verify all features above requiring declaration of compliance. Declarations of compliance must be annual and performed by an officer of the process entity.

Schedule 1.2: Process

Attribute 2 – Carbon Removal Process – record keeping – emissions assessment

Sub-assessment Criteria	Detailed Checklist	Scores	Notes
Completeness of record keeping	• Is there an industry standard protocol or 3rd party oversight governing the data required to detail the process? • Does the provided process protocol or description include corrective measures to eliminate biases? • Are the records kept timely given the process details and the potential variations across batches of removals resultant from those process details?	• No industry standards and no oversight **– 0** • Either industry standard or 3rd party oversight **– 1** • Both **– 2** • No, only data recorded at source is ever used **– 0** • Yes, data from orthogonal testing is meaningfully introduced to correct biases **– 2** • Data points do not match potential changes in quality of removals. **- 0** • Data points somewhat match potential changes in quality of resultant removals. **- 1** • Data points are driven by potential changes in quality of resultant removals **- 2**	Completeness of record keeping is essential in maintaining transparency for any given process and its removals claims. The value of any removal is derived from its perceived quality, the evidence surrounding that claimed quality and the trust held in that evidence being an accurate description of the physical process itself. Where there are natural variations in the process or unavoidable variances in the data itself, all records kept should both note those variances and strive to remove them through some orthogonal testing protocol.
Quality of record keeping	• Are the records kept in an easily accessed uniform format or are they of varying format? • Are the records open source or at least available on demand? • Are there features of the records that confer immutability?	• Varied **– 0** • Standardised (e.g. computerised rather than docket form) **– 1** • No **- 0** • At least 50% of documentation relating to the quality of the removal is available in an open-source form. **– 2** • At least 80% of documentation relating to the quality of the removal is available in an open-source form. **– 3** • Are >50% of the records pertaining to the removal quality immutable i.e., either verified immediately by a 3rd party or on some other immutable database? If Yes **– 3**	Transparency of proof of quality of removals is achieved through the simplicity of the records and the open nature of any information relating to the quality of the removals. Easily obtained records add to the overall quality of the removal by building confidence that the inherent claims about any removal are traceable back to physical records which themselves represent real life industrial processes. Immutability further enhances transparency by ensuring that past biases are there to be seen as are the remedies. Where unknown biases occur the combination of immutability and open-source data allow for easy discovery and ultimate remediation.
3rd Party oversight	• Is there 3rd party verification of the stipulated correction measures in terms of measures required?	• No **– 0** • Yes, that verification extends to a written report commenting on best practices and all recommendations are in place. **– 3**	Most processes are complicated and a thorough assessment of what data is sufficient to describe and report a process needs to be handled by an expert that is nevertheless not conflicted.

Schedule 1.3: Stability

Attribute 3 – Inherent Stability of the Removed C – Chemical Recalcitrance

Sub-assessment Criteria	Detailed Checklist	Scores	Notes
Stability of sequestrate based on physical attributes	• Physical heterogeneity – is the sequestrate a physical mix of different forms? • Is the sequestrate all the same molecule? I.e. a CO_2 gas from DAC or a rich biochar from a pyrolysis plant (approx. 95% C) • Is the heterogeneous nature known with certainty or is it only approximate due to the nature of the sequestrate? • If it is not all the same to what degree is that known?	• Homogenous or a gas mix **– 4** • Physically heterogenous but only on microscopic inspection (not visibly heterogenous) **– 3** • Visibly heterogenous **– 1** • Certain (either through reason of documented process or through testing with 5% tolerance, across samples, of morphological attributes **– 2** • Uncertain **– 0**	Physical Heterogeneity of any bulk sequestrate points to both i) variation in the amount of biogenic carbon in any given sub-sample of the overall sequestrate and ii) chemical differences in the form of that carbon and elemental fractional differences across sub-samples. Both are highly correlated with an uncertainty in the chemical attributes scored below that ultimately measure the stability of the removed C in terms of duration.
Stability of sequestrate based on chemical attributes	• Given a full sample analysis that includes elemental make-up and characterisation of the carbon forms inherent therein (must include C:O ratio, C:H ratio, CO32- percentage, aromaticity percentage, inorganics percentage) order these for the sample. • Were multiple samples of the same bulk removal batch taken with the worst sample (in terms of chemical attributes score above) assessed?	• If sample is gaseous CO_2 or most prevalent form is aromatic carbon **– 10** • If the most prevalent form is CO32- **- 5** • If the most prevalent form is carbon likely combined in saccharide/carboxylic acid/high oxygen percentage molecules **– 2** • Yes **- 1** • No **- 0**	Chemical stability of the sequestered carbon is highly dependent on the availability of oxygen to bind with causing conversion to CO_2 which is then lost to the atmosphere as sequestration modes for solids rarely guard against gaseous lability. The aim of the scoring is to assess the rate of degradation of the sequestered carbon (i.e. it is a proxy for the half-life of the carbon in its initial sample form). A “worst of” multiple samples approach should be rewarded as it removes some variation mentioned in the physical attributes above.
Academic supporting documents	• Is there substantial academic evidence to support the case that the samples used for analysis would be stable (80% present after 100yrs)?	• Yes **– 3** • No **– 0**	The stability of a sample, in terms of likelihood that 80% of the claimed mass of removed carbon is still sequestered at 100yrs should have a detailed set of documents to back this up. These should link relevant academic findings to the chemical attributes found when testing the sample. If no research exists then a score of zero merely reflects this uncertainty within the claim.

Schedule 1.3: Stability

Attribute 3 – Inherent Stability of the Removed C – Chemical Recalcitrance

Sub-assessment Criteria	Detailed Checklist	Scores	Notes
Stability of sequestrate based on physical attributes	• Physical heterogeneity – is the sequestrate a physical mix of different forms? • Is the sequestrate all the same molecule? I.e. a CO_2 gas from DAC or a rich biochar from a pyrolysis plant (approx. 95% C) • Is the heterogeneous nature known with certainty or is it only approximate due to the nature of the sequestrate? • If it is not all the same to what degree is that known?	• Homogenous or a gas mix **– 4** • Physically heterogenous but only on microscopic inspection (not visibly heterogenous) **– 3** • Visibly heterogenous **– 1** • Certain (either through reason of documented process or through testing with 5% tolerance, across samples, of morphological attributes **– 2** • Uncertain **– 0**	Physical Heterogeneity of any bulk sequestrate points to both i) variation in the amount of biogenic carbon in any given sub-sample of the overall sequestrate and ii) chemical differences in the form of that carbon and elemental fractional differences across sub-samples. Both are highly correlated with an uncertainty in the chemical attributes scored below that ultimately measure the stability of the removed C in terms of duration.
Stability of sequestrate based on chemical attributes	• Given a full sample analysis that includes elemental make-up and characterisation of the carbon forms inherent therein (must include C:O ratio, C:H ratio, CO32- percentage, aromaticity percentage, inorganics percentage) order these for the sample. • Were multiple samples of the same bulk removal batch taken with the worst sample (in terms of chemical attributes score above) assessed?	• If sample is gaseous CO_2 or most prevalent form is aromatic carbon **– 10** • If the most prevalent form is CO32- **– 5** • If the most prevalent form is carbon likely combined in saccharide/carboxylic acid/high oxygen percentage molecules **– 2** • Yes **- 1** • No **- 0**	Chemical stability of the sequestered carbon is highly dependent on the availability of oxygen to bind with causing conversion to CO_2 which is then lost to the atmosphere as sequestration modes for solids rarely guard against gaseous lability. The aim of the scoring is to assess the rate of degradation of the sequestered carbon (i.e. it is a proxy for the half-life of the carbon in its initial sample form). A "worst of" multiple samples approach should be rewarded as it removes some variation mentioned in the physical attributes above.
Academic supporting documents	• Is there substantial academic evidence to support the case that the samples used for analysis would be stable (80% present after 100yrs)?	• Yes **– 3** • No **– 0**	The stability of a sample, in terms of likelihood that 80% of the claimed mass of removed carbon is still sequestered at 100yrs should have a detailed set of documents to back this up. These should link relevant academic findings to the chemical attributes found when testing the sample. If no research exists then a score of zero merely reflects this uncertainty within the claim.

Schedule 1.4: Longevity

Attribute 4 – Security of C under initial storage conditions - Longevity

Sub-assessment Criteria	Detailed Checklist	Scores	Notes
Assessment of actual process of sequestration	• Is there potential degradation or loss of a portion of the sequestrate during the sequestration process e.g., through leaks or through losses during transport to the sequestration site?	• No potential for loses **– 3** • Small, <1% of mass of sequestrate is likely to be lost (to the atmosphere or biosphere) in the process **- 2** • Medium >1%, <5% likely to be lost **– 1** • Large >5% likely to be lost **- 0** • If larger than 10% adjustment to quantum of claimed removals must be made 1 for 1 with loses.	Though emissions post transfer to the sequestering agent (e.g., pipeline owner or aggregate haulier) are accounted for under schedule 1.1, losses of actual removals are not likely captured and so should be assessed here.
Scientific evaluation of sequestration method	• Academic evidence relating to permanence to sequestration method.	• All sequestration methods must be fully described with supporting (academic or governmental) evidence relating to their expected permanence, as a minimum, to be classified.	A review of existing academic and governmental research relating to the sequestration method should be supplied with the application for classification of any removals.
	• Claimed permanence in terms of likelihood of highly stable sequestrate still present after 100yrs.	• >99.7% **- 8** • >95%, <99.7% **- 6** • >68%, <95% **- 4** • >5%, <68% **- 2** • <5%, **0**	Conversion to the % present after 100yrs should use a conservative estimate from that academic research. It will thus require: either the expected permanence at some confidence level or the half-life of the sequestration method (stripping out the half-life of the sequestrate itself).
	• Variation within those claims	• High level (>25% variance in the probability value above within general academic literature) **– 0** • Low level (<25% variance in the probability above within academic literature) **- 3**	A reasonable estimate of the certainty of the permanence of sequestration mode should be made by reporting the range of values found within the academic/ governmental literature.
	• Crowding out effect of storage	• Is sequestration site limited in capacity and the sequestrate uses less than 50% of other potential sequestrates? Yes **– 0** No **– 2**	This feature is to reward avoidance of crowding out. This is where inefficient use of limited sequestration sites occurs e.g., flue gas, rather than high conc. CO_2, into extracted gas fields.

Schedule 1.5: Stewardship

Attribute 5 – Resilience and susceptibility of storage - Stewardship

Sub-assessment Criteria	Detailed Checklist	Scores	Notes
Stewardship of sequestrate	• At the time of removal claim does the sequestrate require any ongoing stewardship? • What type of entity is trusted to maintain the sequestered material? • If sequestrate is <100yrs permanence	If the sequestrate doesn't require stewardship, there are no future risks tied to and assuming there is sufficient documentation to support this claim, the removal scores **– 16** Stewardship covers the ongoing responsibility to maintain the mode of sequestration from the initial point in time of sequestration. The level of risk scored assesses only the likelihood that the initial care of duty will not persist into the future (commensurate with the permanence of the sequestrate). Risks associated with physical changes to the sequestrate that are not due to duty of care changes (i.e., changes in physical storage due to natural causes) are assessed within schedule 1.4 "Longevity". If duty of care is the responsibility of: • Government **– 12** • Large Corporate (>$1bn cap) **– 9** • Small Corporate (<$1bn) **– 6** • Private entity, NFPO, individual **– 4** • Score **- 1**	We assume that governments will always protect removals that they are responsible for and will do so even in the case that it is heavily uneconomic to do so. We assume that a larger organisation is subject to more robust regulation and is more likely to continue to be able to steward the removal. This greater oversight and lower credit risk should represent a smaller risk that the claimed quantum of carbon re-enters the atmosphere. We assume that as entities become economically smaller their risk of not being able to continue their duty of care, as was originally foreseen, increases regardless of their initial intentions.
Stewardship related emissions	• At the time of removal claim does the sequestrate include any further carbon emissions? For example: transport to site. • Does maintaining the sequestrate have an emission? For example: managing a landfill.	• Both examples of these emissions are directly attributable to the project itself and so should be included under the GHG Protocol approach and thus contribute via section 1.1 of this system.	Though emissions relating to ongoing stewardship should be contained at the project level there can be circumstances where this is not the case e.g., companies that exist purely for stewardship of removals where they are claiming an element of removals themselves (as their paid for service increases the likelihood of a stable duty of care). In these cases, "Stewardship" can be assumed to have passed to that entity, fully and the sequestered material can be treated as requiring no ongoing stewardship from the assessed processes point of view.

Schedule 1.6

Attribute 6 – Additionality and Novelty – Opportunity Cost

Sub-assessment Criteria	Detailed Checklist	Scores	Notes
Is the removal mandated by local laws?	• Is the removal affected by existing laws or legislation? • To what effect (is it the only reason for the activity or it is a driving factor or a minor factor)? • Are there other parts of the sequestration path, other than the process under review, covered by legal obligations (e.g. a certain type of sequestration has to happen) and if so what is the impact on i) the lifetime economics and ii) the instantaneous economics of the process?	• Removals that are required by law cannot be included in the system. • However, if widespread non-compliance exists or legislation does not mandate all of the removals activities, only some, then admission is allowed but only the non-mandated portion of removals are to be considered. • Scores below should only assess those removals outside of those mandated for scoring.	CO_2 removals that are entirely required by law do not receive an 'additionality' score. They take place without the sale of the carbon removal and therefore demand for these removals does not affect supply. This is true for the lifetime assessment, where no revenue could be expected from removals as they are a mandated feature of the otherwise economic process AND of the instantaneous assessment where there can be no sensitivity of removals amounts to price as they have to happen by law.
Lifetime Additionality (LA)	• At the point of financing the project, did the expectation of removals credits impact the IRR of the investment? • What was the result of that impact in terms of achieving financing?	Considering only non-mandated removals: CDR credit revenue stream: • impactful but not necessary **– 3** • Necessary **– 5** • The only reason for financing **– 7**	An assessment of the process' economics should be presented with a clear IRR with and without removals credits factored in (the value of these removals shall be estimated by comparison to the price achieved by a similar but independent process. Justification shall be provided as to why this caused the claimed shift in financeability.
Instantaneous Additionality (IA)	• What additional rates of removal can be made that are sub-optimal economically for the process? • What evidence is provided on an ongoing basis to exhibit that credit revenue is causing extra removals • What % of extra removals are attributable to sub-optimal operation?	Considering only non-mandated removals with supporting timely evidence: Uplift in removals volumes on an ongoing basis caused by credit revenue: • 10-20% uplift of existing removals **– 2** • 20-50% uplift of existing removals **– 3** • 50-80% uplift of existing removals **– 4** • 100%+ uplift of existing removals **– 5**	Any process where credit revenues enhance the quantum of removals must provide documentation to support that enhancement on a period-to-period basis such that it documents each batch's reliance on that additional cost (which makes it sub-optimal economically). The baseline to which the uplift is measured must be a process scenario that could be adopted at least as easily as the removal optimised scenario to eliminate esoteric scenarios.
Assessment of the frequency and thoroughness of documentation	• (LA) Detail and corroboration provided for the IRR uplift analysis. • (LA) 3rd party evidence of expectation of removals revenue stream being instrumental in the financing process. • (IA) detail and corroboration provided for the % of extra removals attributable to operating a sub optimal economic model. • (IA) 3rd party evidence of extra removals occurring on account of sub-optimal economics.	• Sufficient detail must be provided to qualify for the LA scoring. An example would be engineering throughput reports coupled with independent verification of pricing of resultant products e.g., electricity prices. • 3rd party verification of over 50% of IRR determinants **– 2** • As above sufficient, ongoing detail of economic drivers for the process needs to be supplied with a clear reason why sub-optimal operation leads to extra removals. • 3rd party verification of over 50% of data supplied **– 2**	Providing justifications that prove the link between revenues received from credits and the production of the removals they represent is key to additionality. It enhances confidence that credit purchases cause more removals to occur at the margin. Scores should reflect the degree to which that is true as well as the quality of the audit trail that supports the claim. For IA, documentation needs to be supplied such that it proves that any given sub-optimal course was followed for all of the period for which the removals, claiming that given additionality score, occured.

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