puro·earth

METHODOLOGY FOR VERIFICATION AND QUANTIFICATION OF CARBON REMOVAL

Geologically stored carbon

Draft Version 0.9 – Comments received Oct- 2020 and Feb 2021 have been integrated

This methodology sets the requirements for eligibility and quantification of the Net CO2 Removal impact achieved by activity carbon sequestration and geo-storage, where CO2 is captured from the atmosphere and stored permanently into deep geological formations by a CO2 Removal Supplier.

Net CO2 removal impact is calculated as net carbon balance of emissions and storages. The gross carbon increase in the geo-storage must be larger than the GHG emissions caused over life-time of the activity.

Capturing CO2 from the atmosphere means either 1) direct air capture, where CO2 is captured from the atmosphere through chemical sorption or by membrane separation or 2) biogenic CO2 capture, where plants have originally captured CO2 from the atmosphere through photosynthesis.

Stored permanently means that CO2 or carbon-containing substance is stored in geological storages in deep, confined rock formations from where the CO2 cannot escape back to atmosphere.

CO2 Removal Supplier is the party contractually responsible for the complete activity with the intent of creating permanent carbon storages by capturing carbon from a biogenic source or directly from the atmosphere and storing into geological storages.

This methodology is applicable to CO2 removal certificates (CORCs) issued by Puro.earth.

1. Eligibility Requirements

1.1. Eligible activity type

Eligible is activity capable of increasing geological carbon stock by storing CO2 captured directly from atmosphere or from biogenic sources. The CO2 Removal is achieved by storing CO2 into a geological storage. Activities increase the geological carbon stock permanently.

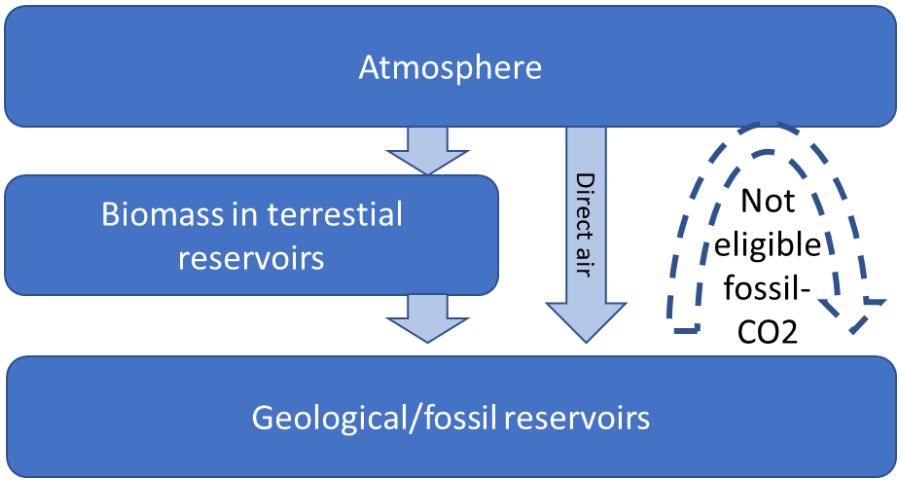

Figure 1. Carbon stocks and eligible and non-eligible CO2 removal activities

Eligible Geological Storage types[1]:

A. Direct injection of CO2 into deep geological formations (EPA CLASS VI or EU CCS directive)
B. Injection of carbon containing substance into reservoir (EPA CLASS I, II and V)
C. Oil and gas reservoirs as part of EOR+ (EPA CLASS II)
'EOR+' refers to Enhanced Oil Recovery by injecting CO2 into oil and gas reservoirs so that more CO2 remains underground than what is contained in the oil extracted by EOR in that reservoir.

Eligible Carbon capture types:

A. Direct air capture (DAC)
B. Biogenic CO2 from combustion of biomass, bioliquids or biogas (BECCS)
C. Biogenic CO2 fraction from incineration of biomass mixed with other substances (Waste + CCS)
D. Biogenic CO2 from biogas upgrading process (Biogas + CCS)
E. Biogenic CO2 Carbon capture from oxidization of biogenic materials in industrial processes
F. Biogenic carbon-containing substance (carbonaceous liquids, bio oil, carbon-containing slurry, ethanol, phenol)

1.2. Requirements for activities to be eligible

1.2.1 The source of CO2 is biogenic or directly from the atmosphere, i.e. CO2 is captured from atmosphere either through photosynthesis or chemical sorption or by membrane separation.

1.2.2 The carbon is stored into geological storages permanently[2]. Eligible geological storages are controlled by EU or US laws and authorities or following similar requirements as set out by those legislations.

1.2.3 In case the CO2 source is biogenic, the biomass used is to be sustainable.[3]

1.2.4 In case the captured CO2 contains mixed sources (i.e. exhaust or flue gases with both fossil and biogenic sources of CO2), only the biogenic fraction of the CO2 captured is eligible.

1.2.5 Non-eligible activities: If the source of the CO2 is purely fossil, the activity is not qualified as Carbon Removal. Fossil point sources of CO2 capture and storage activities are non-eligible because they do not present a net increase of carbon stock in in the geological/fossil storage.

1.2.6 The activities should do no net harm[4] to environment or society, e.g. cause deforestation, loss of biodiversity or arable land, chemical emissions or health risks.

1.2.7 The eligibility of the complete activity for the CO2 Removal is determined in the Audit.

[1] In EU area, CCS Directive, see https://ec.europa.eu/clima/policies/innovation-fund/ccs/directive_en. In the US, EPA criteria for wells used for geologic sequestration, see: https://www.epa.gov/uic/class-vi-wells-used-geologic-sequestration-co2

[2] Typically, extensive cap rock or barrier at the top of the formation and impermeable salt caverns are the geologic characteristics associated with storage sites able to contain the CO2 permanently. A caprock is not needed when CO2 is injected within its solubility trapping phase. https://www.globalccsinstitute.com/wp-content/uploads/2018/12/Global-CCS-Institute-Fact-Sheet_Geological-Storage-of-CO2.pdf and https://www.nature.com/articles/s43017-019-0011-8?proof=t

[3] Sustainable biomass criteria as defined in EU directive RED II https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A02018L2001-20181221

[4] Carbon capture and geological storage (CCS) has significant potential to help mitigate climate change internationally. However, the benefits must outweigh the disadvantages.

1.3 Requirements for the eligibility CO2 Removal Supplier

1.3.1 The Auditor verifies that the CO2 Removal Supplier is capable of metering and quantifying the Net CO2 removal impact, i.e. capable of providing all the calculation parameters in a reliable and consistent manner, for the Quantification of net CO2 Removal as defined in section 4 and Verification evidence as defined in section 5.

1.3.2 The Auditor verifies the CO2 Removal Supplier can prove with contracts or authorization its sole ownership of the carbon removal attribute of the permanently stored carbon.[5]

1.3.2.1 A certified trade registry extract or similar official document stating that CO2 removal Supplier is validly existing and in compliance with the laws of the host country.

1.3.2.2 Contracts with the Capture Operator:

- A certified trade registry extract or similar official document stating that the Capture Plant and its operator are validly existing and in compliance with the laws of the host country.
- Contracts stating that the CO2 Removal Supplier is in contractual agreement with Capture Operator, with the intent of creating permanent carbon storage.
- Proof of sole ownership to CO2 captured or the carbon-containing substance and attestation of no claim to the carbon removal attribute by the Capture Operator[4]
- Contract to allow auditing the Capture Operator's equipment and documents for Carbon Removal Certificate Issuance purposes

1.3.2.3 Contracts with the Storage Site and Operator,

- Proof that the Storage Operator is authorized Geological Carbon Storage Provider under national laws and a certified trade registry extract or similar official document stating that the Storage Site is validly existing and in compliance with the laws of the host country.
- the Storage Operator has legal permit and license to store in the reservoir the amount contracted by the project over its entire lifetime
- Contracts stating that the CO2 Removal Supplier is in contractual agreement with Storage Operator, and the carbon captured is to be received by Storage Operator, injected and stored into permanent storages.
- Attestation of no claim to the carbon removal attribute by the Storage Operator
- Contracts to allow auditing the Storage Operator's equipment and documents for Carbon Removal Certificate Issuance purposes.

1.3.2.4 Contracts with the Logistics Operator (if not the same as Storage Operator),

- A certified trade registry extract or similar official document stating that the Logistics Operator is validly existing and in compliance with the laws of the host country.
- Contracts stating that the CO2 Removal Supplier is in contractual agreement with Logistics Operator, with the intent of creating permanent carbon storage
- Attestation of no claim to the carbon removal attribute by the Logistics Operator
- Contracts to allow auditing the Logistics Operator's equipment and documents for Carbon Removal Certificate Issuance purposes

[5] The attribute ownership requirement will be revisited when the pending discussion on Paris Agreement Article 6 has been finalized.

2 Point of creation of the CO2 Removal Certificate (CORC)

2.1 The point of creation of the CO2 removal certificate (CORC) is the moment when CO2 or carbon-containing substance has been injected into the geological storage and the data records can be verified. [6]

2.2 The CO2 Removal Supplier can be the operator of the carbon capture system / the owner of the carbon capture system / the owner of the captured CO2. The CO2 Removal Supplier does not need to be the same as the operator of the process creating the CO2 to be captured (e.g. the biogas or bioenergy producer or waste treatment facility operator). [7]

2.3 The CO2 Removal Supplier must prove with contracts or authorization its sole ownership[8] of the carbon removal attribute of the permanently stored carbon.

3 Activity boundary for Net-negativity

Net CO2 removal impact is calculated as net carbon balance of GHG emissions and carbon sequestration over life-time of the activity (Life-cycle assessment, LCA). The activity boundaries (system boundaries) determine the processes and their CO2 emissions/storages that are to be included in the Net CO2 removal quantification.

3.1 The activity boundary includes all activities existing solely for the purpose of CO2 Removal. These include the carbon capture, transportation and storing into the geological storages. See figure 2 below.

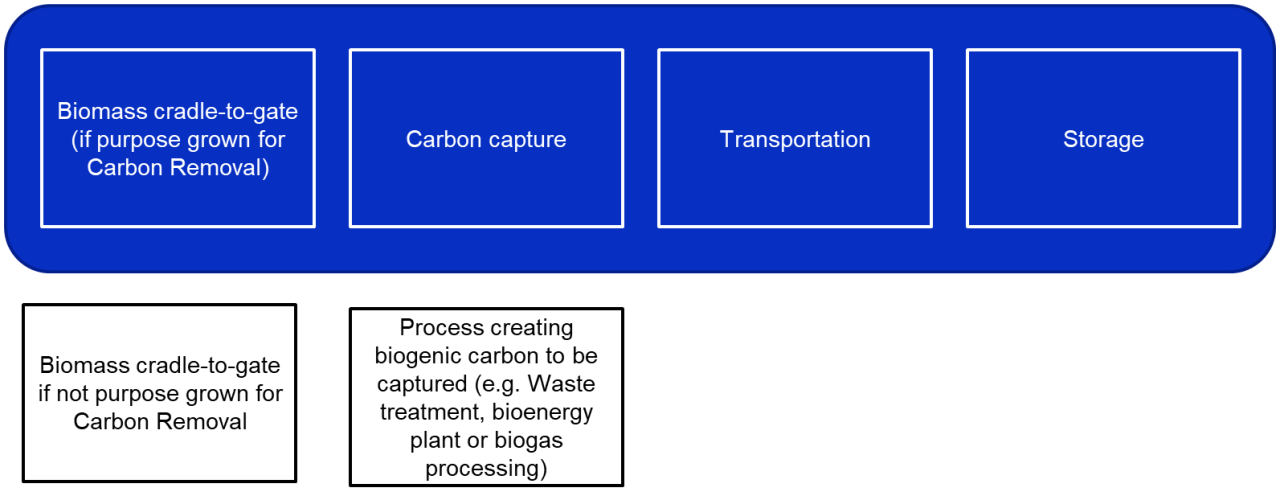

Figure 2: Activity boundary for inclusion in net CO2 Removal impact calculation. (Dark blue activity =emission included in quantification, White activity = emissions not included)

3.2 Emissions included within the boundary: All activities related to capturing (e.g. capture, liquefaction), transporting (e.g. through pipelines or by shipping) and storing (e.g. intermediate storages, injection) of the CO2 and CO2 emissions resulting from these activities.

[6] Time of injection is the point when a complete data trail is available for verification of the end to end quantities captured and stored. After injection, the CO2 will continue to stabilize through mineralization for years or centuries inside the reservoir.
[7] The Capture Operator is assumed to be the party responsible for the complete activity of CO2 Removal. To avoid possibility for double issuance, the Storage Operator cannot at the same time be the CO2 Removal Supplier to whom the CORCs are issued. The assumption of Capture Operator's leading role was a consensus view of the expert group.
[8] The sole ownership requirement will be revisited when the pending discussion on Paris Agreement Article 6 has been finalized.

3.3 Emissions included within the boundary: Purpose-grown biomass (e.g. emissions from cultivation, harvesting and transportation of the biomass cradle-to-gate) if the biomass is solely grown for CO2 removal purposes. Note: For all activities with biogenic CO2 capture, the biomass must be sustainable, even if the biomass is not purpose-grown but residues or side streams are used.[9]

3.4 Emissions included within the boundary: Purpose-built equipment and facilities[10] (e.g. emissions from materials and construction) shall be included if they are solely built for CO2 removal purposes. These emissions are included in the carbon balance since they are estimated to be significant (they are more than 1 % of the total emissions)[11]. If CO2 Removal Supplier can show that these emissions are less than 1% they can be omitted.

3.5 Emissions outside the activity boundary: Other activities that do not exist solely for the purpose of CO2 removal even if they are physically connected to carbon capture. These can be e.g. bioenergy production, biogas production or waste treatment. This means that such activities are not considered as integrated but as two separate suppliers: supplier of bioenergy/biogas/waste treatment and supplier of carbon capture (Capture Operator).

4 Quantification of CO_2 Removal – calculation methodology

4.1 Net CO2 Removal calculation

Net CO2 Removal volume (in kgCO2e) for the Project within the activity boundary is to be calculated according to the equation

$\mathbf{C}_{\mathbf{CAPTURED}}$ - (minus) $\mathbf{E}_{\mathbf{PROJECT}}$ - (minus) $\mathbf{C}_{\mathbf{LOSS}}$ = (equals) Net-Carbon-Dioxide-Removal (kg).[12]

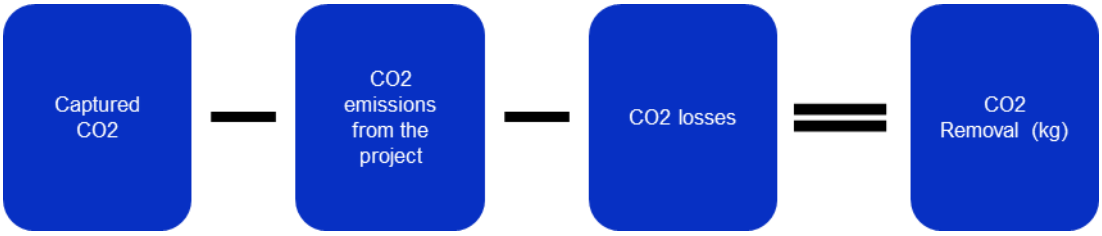

Figure 3. Equation for Calculation of Net CO2 Removal (in kg CO2eq.).

4.2 Captured CO2 (in kgCO2e)

4.2.1 The CO_2 Removal Supplier provides data and documentation on the planned and/or implemented activities for carbon capture.

9 Sustainable biomass criteria as defined in EU directive RED II https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A02018L2001-20181221

10 If equipment for transport and storage are shared among multiple users, emissions related to constructing and manufacturing those are not included.

11 Emission factor such as by Defra for Construction of facilities 0,37 kgCO2e per £ and for Machinery and Equipment: 0,56 kgCO2e per £. Source: Defra 2011, https://www.gov.uk/government/statistics/uks-carbon-footprint, Table 13 - Indirect emissions from Supply chain emission factors for spending on products: kgCO2e per £. Alternatively, a peer reviewed LCA assessment on a material inventory of construction and equipment emissions can be used.

12 The formula is based on captured CO2 quantity instead of injected CO2/carbon quantity, since the CO2 Removal Supplier is defined as the carbon capture operator (see 2.1.2). However, the CO2 Removal Supplier shall have responsibility by contractual agreements end-to-end over the whole activity boundary from capture until the storage phase.

4.2.2 The CO2 Removal Supplier provides proof of eligible quality of the captured CO2. In the case of direct air capture, the Supplier shall prove that the origin of their CO_2 is atmospheric by providing operational data records that are able to rule out other origins of the CO_2.[13] In the case of biogenic CO2 capture, the Supplier shall utilize carbon isotope (C14) results based on ISO 13833 or ASTM D6866 methods demonstrating biogenic fraction of the captured CO2.[14]

4.2.3 In case of carbon-containing substance the quantity of captured CO2e is determined by the carbon content (%) of the substance.

4.2.4 In case of EOR+, the quantity of the oil extracted from the same reservoir is deducted (in kgCO2e) from the quantity of CO2 injected (in kgCO2)

4.2.5 The CO2 Removal Supplier provides data and documentation on the capture volume (in kgCO2e) of the eligible type of CO2 in the capture site.

4.3. CO2 Emissions from the project and CO2 losses

4.3.1 Emissions from the Project is the sum of GHG emissions from the activity (geo-stored carbon) included within the activity boundary. Those are: direct emissions (scope 1 and 2) from capture, transportation and injection as well as emissions from chemicals, membranes and purpose-built equipment including the construction and materials for the equipment.[15]

4.3.2. CO2 losses are regarded as any difference between CO2 captured (total in kgCO2e) and CO2 injected to storage (total in kgCO2e) (see section 4.4 calculation parameters).

4.3.3. Energy consumption is substantial in carbon capture activities. All emissions from energy use are within the activity boundary and are accounted for when quantifying the net CO2 Removal. Energy used for geo-stored carbon activities is not required to be 100 % carbon free.[16]

[13] DAC operator has to provide internal control sheets where the amount of CO_2 captured is according to directly measured plant performance. If more CO_2 is delivered than the actual/maximum plant performance allows, it becomes evident that some of the CO_2 is of other non-atmospheric origin.

[14] ISO 13833:2013 Stationary source emissions — Determination of the ratio of biomass (biogenic) and fossil-derived carbon dioxide — Radiocarbon sampling and determination, https://www.iso.org/standard/54332.html or ASTM D6866 Standard Test Methods for Determining the Biobased Content of Solid, Liquid, and Gaseous Samples Using Radiocarbon Analysis https://www.astm.org/Standards/D6866.htm

15 GHG emissions have to be assessed and reported following the LCA calculation principles of ISO, WRI or PAS2050.

16 Typically, CCS activities aim to use renewable electricity sources either self-generated or contractually sourced. Use of carbon neutral electricity for CCS activities is not considered as “renewable energy leakage” constraining use of renewable energy for other purposes. CO2 Removal Supplier is not responsible for the availability of renewable electricity in the local market.

4.4. Calculation parameters data provided for verification

$$C_{CAPTURED} - E_{PROJECT} - C_{LOSS} = CO2\ Removal\ (kg)$$

$$E_{PROJECT} = E_{CAPTURE} + E_{TRANSPORT} + E_{INJECTION} + E_{EQUIPMENT}$$
$$C_{LOSS} = C_{CAPTURED} - C_{INJECTED}$$

$C_{CAPTURED}$ = CO2 measured at the capture site (in kg CO2e).Eligible fraction is calculated (see 4.2.2-4.2.4)

$E_{PROJECT}$ = Sum of all emissions of all activities within the activity boundary of the CO2 Removal project

$E_{CAPTURE}$ = Emissions from capture phase, emissions from energy use in capture, compression and liquefaction (in kgCO2e). Emissions from purpose-grown biomass sourcing and conversion to bio-oil cradle-to-gate (see 3.3). (in kgCO2e) Emissions related to capture membranes or chemicals manufacturing and maintenance/regeneration.

$E_{TRANSPORT}$ = Emissions from transportation of captured CO2 from capture site to injection site (in kgCO2e)

$E_{INJECTION}$ = Emissions from injection phase, i.e. emissions from energy use in injection and possible related activities such as intermediate storage (in kgCO2e)

$E_{EQUIPMENT}$ = Emissions from construction of CCS equipment and emissions of materials used for construction of CCS equipment (in kgCO2e). If data of actual emissions is not available, equipment emissions are estimated utilizing the investment (CAPEX) for the equipment with a spend-based emission factor[17]. Emissions from construction are to be amortized fully before issuing first CORCs.

$C_{INJECTED}$ = The amount of CO2/carbon injected into geological storage (in kgCO2e)

$C_{INJECTED}$ For single-user storage site or clearly separate injection wells to the same reservoir, the amount of CO2/carbon injected (in kgCO2e) is measured at the point of injection. Eligible fraction is calculated (see 4.2.2-4.2.49

$C_{INJECTED}$ For multi-user transport and/or storage sites where the injected amount cannot be measured unambiguously per user the amount of injected CO2 (in kgCO2e) if the injected CO2 is a mix from multiple CO2 providers. Thus verifying end-to-end amount of CO2 needs reporting of data regarding the efficiency of logistics and injection: $C_{LOSS} = C_{CAPTURED} - (C_{TRANSPORT} \times CEfficiency_{LOGISTICS} \times CEfficiency_{INJECTION})$, where

- $C_{TRANSPORT}$ = Amount of total CO2 fed into logistics operator's system (e.g. to pipeline or to CO2 carrier vessel)

[17] Emission factor such as by Defra for *Construction* of facilities 0,37 kgCO2e per £ and for *Machinery and Equipment*: 0,56 kgCO2e per £. Source: Defra 2011, https://www.gov.uk/government/statistics/uks-carbon-footprint, Table 13 - Indirect emissions from Supply chain emission factors for spending on products: kgCO2e per £. Alternatively, a peer reviewed LCA assessment on a material inventory of construction and equipment emissions can be used.

- $CEfficiency_{LOGISTICS}$ = Efficiency of CO2 logistics (in %), i.e. [the amount of CO2 handed over to storage provider] / [the amount of CO2 fed into the logistics operator's system]. Data and documentation given by logistics operator.
- $CEfficiency_{INJECTION}$ = Efficiency of CO2 processing at the injection and storage site (in %), i.e. [the amount of CO2 injected] / [the amount of CO2 received from logistics operator]. Data and documentation given by storage provider.

4.5 Uncertainty assessment and mitigation

4.5.1 If there is uncertainty in measurement of $\mathbf{C_{CAPTURED}}$, $\mathbf{C_{INJECTED}}$ or $\mathbf{C_{TRANSPORT}}$ the lower end of the range is to be used in the quantification.

4.5.2 If there is uncertainty metering the carbon content of carbon-containing substance biogenic fraction of the captured CO2 due to sampling or testing techniques, the lower end of the range is to be used in the quantification.

4.5.3 All measurement equipment has to be calibrated according to manufactures specification and frequency.

5 Verification and evidence from the CO2 Removal Supplier

Verification is needed to confirm that the requirements set in this methodology have been fulfilled. Verification is performed by a recognized third-party auditor by inspecting relevant evidence and validating calculations. Evidence provided to the auditor consists of data records, documents or other relevant information which allows the requirements to be verified. If the auditor is able to conclude based on the evidence presented that the carbon removal activity is compliant with these requirements the validated amount of CO2 Removal Certificates (CORCs) is issued to the CO2 Removal Supplier.

5.1. Evidence of the source of CO_2

5.1.1. In the case of direct air capture, the Supplier shall prove that the origin of their CO2 is atmospheric by providing operational data records that are able to rule out other origins of the CO2. DAC operator has to provide internal control sheets where the amount of CO2 captured is according to directly measured capture plant performance. If more CO2 is delivered than the actual/maximum plant performance allows, it becomes evident that some of the CO2 is of other non-atmospheric origin.

5.1.2. In the case of biogenic CO2 capture, the Supplier shall utilize radiocarbon isotope analysis (14C, C-14, Carbon-14) (C14) results based on ISO 13833 or ASTM D6866 methods demonstrating biogenic fraction of the captured CO2.[11] The isotope analysis is required for all activities capturing gaseous CO2, both for with mixed CO2 sources and single CO2 sources. Activities capturing CO2 directly from air (DACCS) are excluded from isotope analysis. The CO2 sampling for the isotope analysis can be performed periodically or continuously by accredited persons or calibrated equipment.

5.1.3. Evidence of the sustainability of the biomass used.

- Where applicable, Biomass used as feedstock for CO2 capture is in accordance with RED II sustainability criteria.[18] This applies both to the case where biomass is purpose-grown for CO2 removal activities (and included activity boundary, such as bio-oil to geological storage) and for the case where biogenic CO2 is captured as side stream/by-product from other activities using biomass (such as BECCS, biogas + CCS).
- Where applicable, The monitoring and verification are done according the process as determined by RED II directive and as implemented by national authorities.
- If CO2 Removal Supplier's activities are in an area in which the above mentioned directive is not applied, similar criteria is to be fulfilled and proof is to be presented, where relevant.

5.2. Evidence of Net-negative carbon balance (in kgCO2e)

5.2.1. Report of activity emissions and sequestration

GHG emissions have to be assessed and reported following the LCA calculation principles of ISO, WRI or PAS2050. A professionally made carbon balance assessment over life-time of the project is required covering the activity boundary set in Chapter 3 and having been independently verified by a 3rd party.

5.2.2. Data record of captured CO2 quantity

- The quantity needs to be proven, as it is the basis of the number of Certificates to be issued to the CO2 Removal Supplier.
- Capturer provides a Report, containing data and documentation on the amount of captured CO2 (in kg) for the whole capture period, showing any significant changes or stops in the capture process

5.2.3. Data record of transported CO2 quantity (in multi-user case)

- In multi-user case the transported CO2 quantity needs to be proven, as it is the basis of the amount of Certificates to be issued to the CO2 Removal Supplier.
- Logistics operator provides a Report, containing data and documentation on the amount of CO2 (in kg) fed into the pipeline system or the CO2 carrier vessel/vehicle and the amount of CO2 (in kgCO2) handed over to the storage Operator

5.2.4. Data record of injected CO2/carbon quantity

- The injection CO2 quantity needs to be proven, as it is the basis of the amount of Certificates to be issued to the CO2 Removal Supplier.
- Storage Provider provides Report, containing data and documentation on the amount of injected CO2/carbon (in kgCO2e)
- In multi-user case the Storage Operator provides Documentation on the efficiency of storage process, measurements of the CO2 (in kgCO2) taken over from the logistics operator and amount of CO2 injected(in kgCO2) into the geological storage. Documentation must include the date of injection of full amount of the CO2 received from the CO2 Removal Supplier, i.e. the date which the Carbon Removal Supplier becomes eligible to receive CORCs.

[18] Sustainable biomass criteria as defined in EU directive RED II https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A02018L2001-20181221

5.3. Evidence of the permanent storage

- Shipping documentation of the delivery of the captured CO2 to an injection and storage site, indicating that it is going to be used in permanent storage of carbon.
- Documentation that the storage site is classified and permitted under EU CCS or EPA criteria, as described in 1.1 Eligible Geological Storage types19or following similar regulation, if the storage site is not in an area to which the mentioned criteria applies to.

5.4. Evidence of no double counting or double claiming

5.4.1. Contracts or attestations of no double counting on the carbon removed by another party: Evidence that the CO2 stored is owned by the CO2 Removal Supplier and no claims concerning the same CO2 certified by CO2 Removal Supplier can be made by other parties, such as those involved in the activity boundary (logistics or storage operator).[20]

5.4.2. Evidence of no double counting[21] on the carbon removed by CO2 Removal Supplier: An attestation from the Removal Supplier that it does not include the certified CO2 Removal as a part of its own carbon balance. No marketing or branding claims of carbon neutrality or net negativity can be associated with other possible services provided by CO2 Removal supplier (such as waste treatment) if the decoupled CO2 Removal certificate has been sold to and cancelled by another stakeholder.

[19] In EU area, CCS Directive, see https://ec.europa.eu/clima/policies/innovation-fund/ccs/directive_en . In the US, EPA criteria for wells used for geologic sequestration, see: https://www.epa.gov/uic/class-vi-wells-used-geologic-sequestration-co2

20 The methodology is based on CO2 Removal Supplier acting as the leading operator (see 2.1.2). The CO2 Removal Supplier shall have responsibility by contractual agreements end-to-end over the whole activity boundary from capture until the storage phase.

[21] No double counting requirement will be revisited when the pending discussion on Paris Agreement Article 6 has been finalized