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Working Paper

Coverage of novel CDR and CCUS in GHG inventories – needs for IPCC guidance

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Wolfram Jörß, Lorenz Moosmann

Öko-Institut e.V. / Oeko-Institut e.V.
info@oeko.de
www.oeko.de

Geschäftsstelle Freiburg / Freiburg Head Office
Postfach / P.O. Box 17 71
79017 Freiburg. Deutschland / Germany
Phone: +49 761 45295-0

Büro Darmstadt / Darmstadt Office
Rheinstraße 95
64295 Darmstadt. Deutschland / Germany
Phone: +49 6151 8191-0

Büro Berlin / Berlin Office
Borkumstraße 2
13189 Berlin. Deutschland / Germany
Phone: +49 30 405085-0

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Abstract

Novel methods for carbon dioxide removal (CDR) and carbon capture and use or storage (CCUS) are widely being explored to achieve greenhouse gas (GHG) neutrality. These novel approaches are linked to activities that are not yet sufficiently covered in available guidance for GHG inventories. This working paper summarises a list of subjects to be possibly addressed in the IPCC Methodology Report on Carbon Dioxide Removal Technologies, Carbon Capture Utilisation and Storage, which is to be elaborated by 2027. The subjects covered in this working paper comprise reporting approaches and definitions as well as quantification methodologies for carbon dioxide removals from the atmosphere, for carbon captured from off-gases, for emissions from CCU products and also related to biogenic carbon pools. The paper has been drafted as an input for further consideration to the IPCC Workshop on Carbon Dioxide Removal Technologies and Carbon Capture Utilisation and Storage to be held in Vienna, Austria, on 1-3 July 2024.

Zusammenfassung

Neuartige Methoden zur Entfernung von Kohlendioxid (CDR) und zur Kohlenstoffabscheidung und -nutzung oder -speicherung (CCUS) zum Erreichen der Treibhausgasneutralität werden in großem Umfang erforscht. Diese neuartigen Ansätze sind mit Aktivitäten verbunden, die in den verfügbaren Leitlinien des IPCC für Treibhausgasinventare noch nicht ausreichend abgedeckt sind. Dieses Arbeitspapier fasst eine Liste von Themen zusammen, die in dem bis 2027 zu erstellenden IPCC-Methodenbericht über Technologien zur Entnahme, Abscheidung, Nutzung und Speicherung von Kohlendioxid behandelt werden könnten. Die behandelten Themen umfassen Berichterstattungsansätze und -definitionen sowie Quantifizierungsmethoden für die CO_2-Entnahme aus der Atmosphäre, für aus Abgasen abgeschiedenes CO_2, für Emissionen aus CCU-Produkten sowie für biogene Kohlenstoffpools. Das Working Paper wurde als Beitrag für die weitere Erörterung beim IPCC-Workshop über Technologien zur Entfernung von Kohlendioxid und zur Nutzung und Speicherung von Kohlendioxid verfasst, der vom 1.-3. Juli 2024 in Wien stattfinden soll.

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1 Introduction

Novel methods for carbon dioxide removal (CDR) and carbon capture and use or storage (CCUS) are widely being explored as a means to achieve greenhouse gas (GHG) neutrality. These novel approaches are linked to activities that are not yet sufficiently covered in available guidance for GHG inventories.

In this context, this working paper summarises a list of subjects to be possibly addressed in the upcoming IPCC Methodology report on Carbon Dioxide Removal Technologies, Carbon Capture Utilisation and Storage to be elaborated by 2027 by the Task Force on National Greenhouse as Inventories (TFI) at the request of the IPCC Panel at its 60th session in January 2024 (Decision IPCC-LX-9[1]).

The present working paper has been drafted as an input for further consideration to the IPCC Workshop on Carbon Dioxide Removal Technologies and Carbon Capture Utilisation and Storage to be held in Vienna, Austria 1-3 July 2024.

This working paper covers the following thematic areas:

- Reporting approaches and definitions (section 2)
- Quantification methodologies for removals from the atmosphere (section 3)
- Quantification methodologies for carbon captured from off-gases (section 4)
- Quantification methodologies for emissions from CCU products (section 5)
- Quantification methodologies related to biogenic carbon pools (section 6)

Where fundamental reporting approaches, inventory categories and amendments to the IPCC tabular format are discussed it is well noted that respective guidance, if taken up in the expected IPCC methodology report, would serve to inform parties to Paris Agreement in their review and possible update of the Modalities, Procedures and Guidelines (MPGs) for the Enhanced Transparency Framework (ETF), including potential amendments to the Common Reporting Tables (CRT).

2 Reporting approaches and definitions

2.1 Definition of removals in inventory and climate policy context

The IPCC methodology could explicitly clarify the fundamental difference in the definitions of ‘removals’ in inventory and in climate policy contexts, e.g.:

- One-year time horizon in GHG inventories vs. ‘permanence’ discussion in climate policies and carbon markets
- Reporting of ‘absolute’ anthropogenic emissions / removals in GHG inventories (stock changes of carbon pools in LULUCF) vs. comparison to counterfactual baseline in climate policies/carbon markets

[1] https://www.ipcc.ch/site/assets/uploads/2024/02/IPCC-60_decisions_adopted_by_the_Panel.pdf

2.2 CCU reporting principles: upstream vs downstream

In the case of CO_2 capture for use cases where CO_2 is bound to be (re-)emitted after only short storage duration the 2006 IPCC guidelines state: "*Quantities of CO_2 for later use and short-term storage should not be deducted from CO_2 emissions except when the CO_2 emissions are accounted for elsewhere in the inventory.*" (2006 IPCC Guidelines Vol 3:1.2.2 page 1.7).

Thus, the 2006 guidelines allow for two fundamentally differing reporting approaches that we call the ***upstream approach*** and the ***downstream approach***.

In the **upstream approach**, CO_2 emissions are reported in the category of first CO_2 generation, and carbon capture for short-term CCU would not be reported. In the case of DACCU, no CO_2 removal would be reported for direct air capture, and emissions from the use of short-lived CCU products would not be reported (or possibly zero-rated / reported as a memo item like CO_2 emissions from biomass).

In the **downstream approach**, CO_2 emissions would be reported in the category where CO_2 from the combustion or use of the CCU products would actually be released into the atmosphere, while CO_2 capture would be reported in the category where the CO_2 was first generated (in case of capture from fossil or biogenic off-gases) or CO_2 removal would be reported for DAC in the case of DACCU.

CO_2 recovery / capture for use in products according to the ***downstream approach*** has been widely reported in GHG inventories for urea production, in line with the explicit guidance provided by the 2006 IPCC guidelines for ammonia production, category 2.B.1, where CO_2 recovery for urea production usually takes place. For CO_2 from urea use, downstream emissions are usually reported in IPPU for the use of urea in selective catalytic reduction or in Agriculture/AFOLU for use as fertiliser. Another example for the downstream approach applied in some national GHG inventories is CO_2 recovery for melamine production; downstream emissions of the captured CO_2 would be reported under waste incineration (usually in energy the energy sector, 1.A).

Well known short-term CO_2 use cases usually covered by the **upstream approach** in national GHG inventories are CO_2 recovery for e.g. carbonation of drinks, for use in refrigeration equipment or for dry ice. Thus, no recovery is reported for activities where CO_2 is captured and no respective product use categories are reported in IPPU. We note, however, that Japan has applied the downstream approach for such uses in its 2024 GHG inventory[2].

While both approaches in principle result in sound balances and avoid gaps or double-counting, the national total of the reporting party is affected in case of net exports or net imports of the short-lived CCU product.

New relevance for the decision 'upstream vs. downstream approach' is to be expected in particular for the use-case of synthetic fuels / e-fuels which are being discussed in climate mitigation policies as a means for de-fossilisation of the transport sector, in particular for aviation. Given the high energy demand to produce synthetic fuels, and internationally diverging costs for clean energy for 'sustainable' synthetic fuels, substantial international trade of such synthetic fuels may be expected.

In contrast to other short-lived CCU use cases mentioned above, production and trade of synthetic fuels should be expected to be covered in respective energy statistics. A distinction of carbon sources with respect to fossil, biogenic or atmospheric origin in statistics would probably be more difficult, but not necessarily needed for an application of the downstream approach.

[2] National Greenhouse Gas Inventory Document of Japan 2024, https://unfccc.int/documents/637879

In the absence of more explicit IPCC guidance (and/or respective decisions taken by Parties to the Paris Agreement under the UNFCCC), net exporters of synthetic fuels might be tempted to systematically opt for the downstream approach to 'optimise' national GHG inventory totals, while net importers might prefer the upstream approach, as they might wish to reflect synthetic fuels as 'sustainable' and thus zero-rated. Such a situation would lead to an under-estimation of CO_2 emissions in the international aggregation of GHG inventory data.

The expected IPCC methodology report could therefore expand its guidance with respect to the CCU reporting approach, in particular for synthetic fuels, possibly clarify which reporting approach is good practice, and/or enhance proposed reporting tables for more transparency[3].

3 Quantification methodologies for removals from the atmosphere

3.1 Direct air capture

The IPCC methodology report could contain:

- Quantification methodologies for carbon captured and related default factors
- Guidance with respect to capture for short-term vs. long-term storage, consistent with guidance related to upstream/downstream CCU reporting (see section 2.2)
- Identification of a suggested inventory category
- Amending the IPCC tabular format to allow for appropriate reporting of removals for long-term and/or short-term storage

3.2 Enhanced rock weathering

The IPCC methodology report could contain:

- Quantification methodologies for carbon captured and related default factors
- Identification of a suggested inventory category
- Amending the IPCC tabular format to allow for appropriate reporting of removals

3.3 Ocean alkalinisation

The IPCC methodology report could contain:

[3] An explicit identification of synthetic fuels for use in international transport could be considered in this context. as emissions from international bunkers are reported outside the scope of national totals.

- Quantification methodologies for carbon captured and related default factors, including a discussion / explanation how such ocean alkalinisation activities would coincide with the territorial scope[4] of the reporting party
- Identification of a suggested inventory category
- Amending the IPCC tabular format to allow for appropriate reporting of removals

3.4 Concrete carbonation under atmospheric conditions

The carbonation of concrete structures in the built environment under atmospheric conditions is a slow process removing CO_2 from the atmosphere. (For industrial processes where captured CO_2 is fixed as carbonate in building materials at significantly higher reaction rates and speed, see section 4.3).

The IPCC methodology report could contain quantification methodologies for direct removals by means of carbonation of concrete structures in the built environment under atmospheric conditions[5], identification of a suggested inventory category, and enhancing the IPCC tabular format to allow appropriate reporting of removals. The methodology report could also review uncertainties of available quantification approaches and consider guidance with respect to uncertainty thresholds for methodologies to be applied in GHG inventories.

4 Quantification methodologies for carbon captured from off-gases

4.1 Capture of biogenic CO_2 in agriculture and waste sectors

Biogenic CO_2 may be captured for use or long-term storage while processing biogas produced in agriculture, or while processing biogas, landfill gas or sewage gas produced in the waste sector. Unlike the energy and IPPU sectors, respective reporting is presently not facilitated in the tabular format.

The IPCC methodology report could thus contain an amendment to the IPCC tabular format to allow appropriate reporting of the capture of biogenic carbon in the agriculture and waste sectors.

4.2 Reporting of carbon captured during international navigation

The option to capture carbon from fuel combustion on-board of large ships is being discussed.

[4] Similar clarifications with respect to the territorial scope of inventories could also be made in respect to other ocean-based CDR options like direct ocean carbon capture, ocean fertilisation or artificial upwelling in case those were discussed in the upcoming IPCC methodology report.

[5] We note that such carbonation under atmospheric conditions should not be considered a 'novel CDR' option unless techniques would be developed in the construction industry to enhance CO_2 removal under atmospheric conditions.

The IPCC methodology report could provide guidance whether/how carbon capture on ships involved in international navigation should be reported.

4.3 Concrete carbonation using captured CO_2

Industrial processes are being developed[6] where captured CO_2 is fixed as carbonate in building materials at significantly higher reaction rates and speed. These processes include concrete curing for new material and carbonation of concrete demolition waste. For other carbonate products generated using captured CO_2, re-emission of this CO_2 is to be expected at short- to medium term (e.g. precipitated calcium carbonate used in paper products and released during combustion).

The IPCC methodology report could contain:

- Quantification methodologies for captured carbon permanently stored in building material to be considered for reporting of the CO_2 capture for the upstream activity of first CO_2 generation (see section 2.2), possibly considering consistency with approaches developed for quantifying carbonation of the built environment (see section 3.4).
- Quantification methodologies for fugitive emissions during the industrial carbonation process of CO_2 previously captured, identification of a suggested inventory category, and enhancing the IPCC tabular format to allow appropriate reporting of emissions.

5 Quantification methodologies for emissions from CCU products

5.1 Synthetic fuels

For the reporting of CO_2 emissions from the combustion of synthetic fuels, identification of default emission factors would be helpful.

5.2 Biomass definition with respect to CCU

The IPCC methodology report should clarify whether or not CCU products (e.g. synthetic fuels) where the carbon content is stemming from captured biogenic CO_2 (BioCC) are subject to the biomass definition of the IPCC guidelines: "*Organic matter consisting of or recently derived from living organisms (especially regarded as fuel) excluding peat. Includes products, by-products and waste derived from such material.*" (2006 IPCC Guidelines Glossary, page G.3)

Such a clarification is relevant to decide whether such synthetic fuels[7] should be considered biomass fuels under a downstream CCU reporting approach (see section 2.2) and hence be zero-rated for national totals.

[6] We note that Japan reports on such carbonisation such uses in its 2024 GHG inventory (2024 National Inventory Document of Japan, https://unfccc.int/documents/637879).

[7] Another example would apply to waste incineration of plastics that are produced using captured biogenic CO_2 as a feedstock.

Under the application of an ***upstream*** CCU reporting approach (see section 2.2) a classification of BioCC-based synthetic fuels would not matter, as the combustion of any synthetic fuels would be zero-rated, anyway. However, under a ***downstream*** CCU reporting approach a classification of such fuels as zero-rated biomass would lead to an underestimation of national totals, as carbon capture of biogenic CO_2 for fuel production would be reported as a negative contribution to national totals.

As the main purpose of biomass combustion or fermentation, preceding CO_2 recovery for such fuel production, is direct energy or feedstock use rather than the generation of CO_2, we consider that synthetic fuels containing carbon from BioCC do NOT meet the inventory definition for biomass. However, we are aware of an opposite interpretation by inventory experts and suggest that consensus should be explored.

5.3 Reporting of fugitive CO_2 emissions from international CO_2 transport

The IPCC methodology report could explain whether/how fugitive emissions from internationally transported CO_2 should be reported. This may apply to CO_2 transport by ship or by pipeline.

6 Quantification methodologies related to biogenic carbon pools

6.1 Reporting biogenic CO_2 in energy and IPPU sectors

The IPCC methodology report could review the present IPCC tabular format and explicitly clarify for the various sectors and sub-sectors where CO_2 from biomass should be reported/included and where the capture of biogenic CO_2 should be reported.

Furthermore, the methodology report could explain how CO_2 from biofuels in international transport should be reported.

6.2 Non-wood biomass storage products

The use of non-wood biomass in construction is gaining attention, e.g. the use of hemp as insulation material. Under the European Union's certification framework for permanent carbon removals, carbon farming, and carbon storage in products (CRCF) such carbon storage exceeding 50 years may soon be eligible for certification. For GHG inventories, however, methodologies for carbon pools in products are so far available only for harvested wood products (HWP).

The IPCC methodology report could discuss the quantification methodologies for non-wood biomass storage products following the example of HWP methodologies, identification of an inventory category and enhancement of the IPCC tabular format to allow for appropriate reporting of involved additions to and losses from such a carbon pool (interpreted as gross emissions and gross removals).

6.3 Biomass dumping

Under-water dumping or under-ground burying of biomass is being discussed as CDR options, in analogy to biochar.

The IPCC methodology report could discuss the definition of a carbon pool covering dumped or buried biomass, respective quantification methodologies, identification of inventory categories and enhancement of the IPCC tabular format to allow for appropriate reporting of involved additions to and losses from such a carbon pool (interpreted as gross emissions and gross removals).

6.4 Biochar beyond application to soils

The major application discussed for biochar is its application to soil. Guidance for the quantification and reporting of an increase in soil carbon (interpreted as a gross 'removal') is available in the 2019 refinement to the 2006 IPCC guidelines. However, respective guidance is not available with respect to other biochar use options involving long-term storage that are being explored, e.g. the addition to building materials as cement additive[8].

The IPCC methodology report could contain quantification methodologies for biochar permanently stored in long-lasting materials, the identification of a suggested inventory category and an enhancement of the IPCC tabular format to allow for appropriate reporting of involved negative emissions / removals / increases of the carbon pool.

[8] We note that Japan reports on such carbon storage in its 2024 GHG inventory (2024 National Inventory Document of Japan, https://unfccc.int/documents/637879).