IPCC Scoping Meeting
for a
Methodology Report
on
Carbon Dioxide Removal Technologies, Carbon Capture Utilization and Storage

Report of the IPCC Scoping Meeting
14-16 October 2024, Copenhagen, Denmark

Task Force on National Greenhouse Gas Inventories

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INTERGOVERNMENTAL PANEL ON climate change
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The IPCC Scoping Meeting on a Methodology Report on Carbon Dioxide Removal Technologies, Carbon Capture Utilization and Storage was organized by the IPCC Task Force on National Greenhouse Gas Inventories (TFI) with support from the Government of Denmark. It was held on 14-16 October 2024 in Copenhagen, Denmark.

This meeting report was prepared by the Co-Chairs of the IPCC TFI (Takeshi Enoki and Mazhar Hayat) and the TFI Technical Support Unit (TSU) and subjected to review by the meeting participants.

Supporting material prepared for consideration by the Intergovernmental Panel on Climate Change (IPCC). This supporting material has not been subject to formal IPCC review processes.

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Foreword

The IPCC Working Group III (WGIII) contribution to the Sixth Assessment Report (AR6) states that "The deployment of carbon dioxide removal (CDR) technologies to counterbalance hard-to-abate residual emissions is unavoidable if net zero CO_2 or GHG emissions are to be achieved".

With this context in mind, the IPCC Panel requested the Task Force on National Greenhouse Gas Inventories (TFI) to develop a Methodology Report for the preparation of national greenhouse gas inventories on Carbon Dioxide Removal Technologies, Carbon Capture Utilization and Storage (Dec. IPCC-LX- 9).

The *2006 IPCC Guidelines for National Greenhouse Gas Inventories (2006 IPCC Guidelines)* already provides methods for the estimation of emissions and removals from some of these CDR activities and also for activities relating to carbon capture, utilisation and storage (CCUS). After 20 years a review of these methods is timely, however, given the development of new science and empirical data and because of the emergence of new technologies for CDR.

IPCC Methodology Reports are prepared by the IPCC TFI and should not be conflated with IPCC Assessment Reports, which are the business of the IPCC Working Groups. This Methodology Report will be like other IPCC TFI Methodology Reports such as the *2006 IPCC Guidelines* and will be designed to ensure that the methodologies available to governments to estimate anthropogenic emissions and removals reflect the latest technological trends and the latest science.

Questions about the potential deployment, legal/social/environmental/sustainability impacts or challenges of implementation of CDRs will be addressed as per current practice through the work of the Assessment processes of the IPCC Working Groups. This TFI Methodology Report will make no judgement about the desirability or otherwise of these CDR technologies only that, should they be deployed, governments will estimate the associated emissions and removals applying methods and approaches that comply with IPCC TFI principles of transparency, accuracy, time series consistency, comparability and completeness.

The first step in the development of the Methodology Report on CDR technologies and CCUS has been to convene a Scoping Meeting to produce an outline of the Report in accordance with IPCC procedures.

The Scoping Meeting was held on 14-16 October 2024 in Copenhagen, Denmark.

As Co-Chairs of the IPCC TFI we are pleased to present this Meeting Report of that Scoping Meeting.

The recommendations in this Report will be considered by the IPCC in early 2025 and, following the decision of governments, a Methodology Report will be prepared through the course of four Lead Author Meetings with the final report to be considered by the IPCC by the end of 2027.

We would like to thank all those involved in the Scoping Meeting namely the experts, the members of TFB and the members of TSU for their contributions toward making this meeting a success.

In particular, we would like to express our sincere gratitude to the Government of Denmark and the Danish Meteorological Institute for their generous support in hosting this meeting.

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Executive Summary

The Intergovernmental Panel on Climate Change (IPCC) decided that the Task Force on National Greenhouse Gas Inventories (TFI) should produce an IPCC Methodology Report on Carbon Dioxide Removal Technologies, Carbon Capture Utilization and Storage at its 60th Session on 16-19 January 2024 in Istanbul, Türkiye (Decision IPCC-LX-9).

The first step in the development of a Methodology Report on Carbon Dioxide Removal Technologies Carbon Capture Utilization and Storage has been to convene the Scoping Meeting to produce an outline of the Methodology Report in accordance with the Appendix A to the Principles Governing IPCC Work, which contains the procedures for the preparation, review, acceptance, adoption, approval and publication of IPCC reports.

Preparation for the Scoping Meeting started in June 2024 with a call for nomination of experts issued to IPCC Member States and Observer Organizations by the IPCC Secretary. Invitees to the meeting were selected by the Bureau of TFI (TFB) from the nominations received on the basis of their expertise while addressing geographical representation and gender balance.

The participants of the Scoping Meeting recommend the title of the Report to be *2027 Methodology Report on Carbon Dioxide Removal Technologies, Carbon Capture, Utilization and Storage: (Supplement to the 2006 IPCC Guidelines)*.

Other elements of the outline for this Methodology Report are included in this Meeting Report as follows:

- Draft Terms of Reference for *2027 Methodology Report on* Carbon Dioxide Removal Technologies, Carbon Capture, Utilization and Storage is presented in **Appendix 1**;
- Draft Table of Contents is presented in **Appendix 2**;
- Draft Instructions to Experts and Authors is presented in **Appendix 3;** and
- The Work plan recommended by the TFB is presented in **Appendix 4**.

The recommendations and documents in Appendix 1 to Appendix 4 will constitute the basis of the TFI proposal for the outline for the *2027 Methodology Report on Carbon Dioxide Removal Technologies, Carbon Capture, Utilization and Storage: (Supplement to the 2006 IPCC Guidelines)* to be presented to the IPCC-62 in early 2025 for the consideration by governments.

A summary of Meeting discussions is included in sections 1-5 of this Report.

Table of Contents

Glossary

Removals - are the consequence of sink activities (*2006 IPCC Guidelines Glossary*).

Sink - means any process, activity or mechanism which removes a greenhouse gas, an aerosol or a precursor of a greenhouse gas from the atmosphere (*UNFCCC*)[1].

Reservoir - means a component or components of the climate system where a greenhouse gas or a precursor of a greenhouse gas is stored (*UNFCCC*)[2].

Emissions - means the release of greenhouse gases and/or their precursors into the atmosphere over a specified area and period of time (*UNFCCC*).

Source - means any process or activity which releases a greenhouse gas, an aerosol or a precursor of a greenhouse gas into the atmosphere (*UNFCCC*).

Anthropogenic emissions and removals - means that greenhouse gas emissions and removals included in national inventories are a result of human activities (*2019 Refinement to the 20006 IPCC Guidelines Vol 1.1.1 page 1.5*).

In the *AFOLU* sector, emissions and removals on managed land are taken as a proxy for anthropogenic emissions and removals **(Managed Land Proxy)** (*2019 Refinement to the 2006 IPCC Guidelines Vol 1.1.1 page 1.5*).

Managed land is land where human interventions and practices have been applied to perform production, ecological or social functions (*2006 IPCC Guidelines Vol 4.1.1 page 1.5*).

In the case of wetlands, the *2006 IPCC Guidelines* restricted managed wetlands to those lands where the water table is artificially changed (i.e. lowered or raised). Further, the Wetlands Supplement extends this coverage also to include wetlands created (e.g. constructed), or where emissions and removals from coastal wetlands are attributed to specified human activities. *(IPCC 2013 Wetlands Supplement O.8*).

National Greenhouse Gas Inventories - a greenhouse gas inventory includes a set of standard reporting tables covering all relevant gases, categories and years (*2019 Refinement to the 2006 IPCC Guidelines, Vol 1.1.1 page 1.6*).

TSU Note: **Coverage: sources and sinks –** Inventories should be a complete account of anthropogenic sources and sinks consistent with the UNFCCC definitions and generally include, as a minimum, estimates of the anthropogenic sources and sinks identified by the *IPCC Guidelines*.

Coverage: territorial - National inventories should include anthropogenic greenhouse gas emissions and removals taking place within national territory and offshore areas over which the country has jurisdiction (*2019 Refinement to the 2006 IPCC Guidelines, Vol 1.1.1 page 1.6*).

Coastal wetlands may extend to the landward extent of tidal inundation and may extend seaward to the maximum depth of vascular plant vegetation (*IPCC 2013 Wetlands Supplement 4.1.1 page 4.6*).

Changes in soil carbon stocks combines the change in soil organic C stocks for mineral soils and CO_2 emissions from organic soils; and stock changes associated with soil inorganic C pools[3] *(2019 Refinement to the 2006 IPCC Guidelines Vol 4.2.3.3 page 2.29*.

IPCC classification system – greenhouse gas emission and removal estimates are divided into main sectors, which are groupings of related processes, sources and sinks.[4] High level categories include:

1. Energy
    - *A. Fuel Combustion*

[1] Examples of sink activities include Direct Air Capture technologies and photosynthesis.

[2] including terrestrial, coastal waters and ocean bodies, geological storage and storage in products.

[3] For Tier 3 only.

[4] According to type of process.

- *B. Fugitive Emissions from fossil fuel extraction and distribution;*
- *C. Carbon Dioxide Capture, Transport and Storage*

2. Industrial Processes and Product Use (IPPU)

3. *Agriculture, Forestry and Other Land Use* (*AFOLU*)

4. *Waste*

The *AFOLU* sector is sub-divided into estimation of non-CO_2 emissions from Agriculture (livestock and from soil management) and the mainly carbon stock changes occurring on managed lands:

- *Forest Land*
- *Cropland*
- *Grassland*
- *Wetlands*
- *Settlements*
- *Other land.*

TSU Note: This classification system is designed to assist national inventory compilers to enhance transparency and to report anthropogenic emissions and removals **when and where** they occur.

TSU Note: ***IPCC Guidelines*** should be taken to include the *2019 Refinement to the 2006 IPCC Guidelines* (IPCC 2019), the *2006 IPCC Guidelines for National Greenhouse Gas Inventories* and the *2013 Supplement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Wetlands.*

1. Introduction

The IPCC decided that the Task Force on National Greenhouse Gas Inventories (TFI) should produce an IPCC Methodology Report on Carbon Dioxide Removal Technologies, Carbon Capture Utilization and Storage (CDR CCUS) at its 60th Session on 16-19 January 2024 in Istanbul, Türkiye (Decision IPCC-LX-9).

The Scoping Meeting to make recommendations for an outline for this Methodology Report on CDR and CCUS was held on 14-16 October 2024 in Copenhagen, Denmark.

The nomination letter for the Scoping Meeting was sent by IPCC Secretariat to the IPCC Focal Points and Observer Organisations on 14 June 2024 and 612 nominations were received. The selection of invitees was implemented by the IPCC TFI TFB, in consultation with representatives from the IPCC Bureau. Invitations were issued by the TFI Co-Chairs from 13 August 2024.

The Scoping Meeting was attended by 78 experts including 8 members of the IPCC TFB (the list of participants is provided in **Appendix 6)**.

The Meeting was tasked with considering the title and format of the Methodology Report and to prepare draft Terms of Reference (ToR), draft Table of Contents (ToC) and draft Instructions to Experts and Authors for the Methodology Report.

- ***Terms of Reference (ToR)*** *- The ToR sets out the background, the scope and coverage, the approach and a work plan for the production of the Methodology Report;*
- ***Table of Contents (ToC)*** *– The ToC sets the aggregated outline for chapters of the Methodology Report;*
- ***Draft Instructions to Experts and Authors*** *- These instructions to experts and authors are intended to ensure a consistent and coherent approach across all methodologies, volumes and chapters, including the use of common terminology; and*
- ***Draft Work Plan*** *– the Workplan shows the timeline for production of the Methodology Report.*

Working drafts of these documents were prepared by the Technical Support Unit (TSU) to support the work of participants based on the report of an IPCC Expert Meeting on CDR and CCUS held in Vienna, Austria on 1-3 July 2024 and on scoping documentation for previous TFI Methodology Reports.

The Report of that Expert Meeting, along with presentations by experts, has been published on the TFI website at: CDR_CCUS_EM_Report (iges.or.jp).

The adopted agenda for the Scoping Meeting is presented in **Appendix 5.** The Scoping Meeting was organized into three Plenary sessions and parallel work in two Break-Out Groups (BOGs). The first Plenary session introduced the background and objectives of the meeting; the second Plenary session was aimed at taking stock of the progress of the work of the BOGs and to discuss cross-BOG issues; and the final Plenary session concluded on the title and format and on the documents: ToR, ToC, Instructions to Experts and Authors.

The following two Break Out Groups (BOGs) were organized to facilitate detailed discussions amongst participants:

1. BOG 1 – topics mainly related to the removal and/or capture of carbon dioxide and its storage and other topics outside of Agriculture, Forestry and Other Land Use (*AFOLU*); and
2. BOG 2 – *AFOLU* topics mainly related to the removal of carbon dioxide and storage in soils and water.

Discussions and conclusions of the meeting are summarized in this Report while the draft Outline documents are presented in **Appendixes 1-4.**

The Scoping Meeting presentations (from TSU and BOGs) are available together with this report at https://www.ipcc-nggip.iges.or.jp/public/mtdocs/2410_CDR_CCUS_Scoping.html

2. Meeting Discussions

The Meeting participants considered IPCC Guideline concepts presented on Day 1 by the IPCC TFI TSU, drawing from the Background paper made available to participants.

2.1 Specific conceptual considerations

The Meeting considered key definitional issues including the meaning of 'removals', 'anthropogenic removals', 'technologies', 'negative emissions' and 'storage' as well 'anthropogenic removals on land'.

Definition of removals

From the glossary, a sink is any activity that removes carbon dioxide ***from the atmosphere***[5]. It follows that a removal is the consequence of sink activities[6].

Technologies that generate direct air capture will constitute a sink activity because they remove carbon dioxide ***from the atmosphere*** (like a tree).

This case is distinguished from the case where carbon dioxide is captured from an on-site stream of carbon dioxide generated by human activity (for example, capturing a stream of carbon dioxide from the stack of a power plant or from a fossil fuel extraction facility). These activities do not constitute removal activities because they do not remove carbon dioxide ***from*** the atmosphere, although they are nevertheless also valuable because they reduce emissions ***to*** the atmosphere.

The application of these definitions was a source of debate in the Meeting. The participants agreed this issue should be carefully considered by the authors of this Report.

The relevant definitions included in the glossary in this Report are taken from the definitions in the UN Framework Convention on Climate Change (sink) and from the glossary of the *2006 IPCC Guidelines* (removals).

Definition of anthropogenic removals

From the glossary, anthropogenic removals and emissions means that greenhouse gas emissions and removals included in national inventories are a result of human activities.

It was noted that the IPCC will develop a glossary of definitions for the IPCC Seventh Assessment Report cycle, including definitions for anthropogenic removals and emissions. The need for a coordinated glossary across IPCC working groups/task force was raised. The participants agreed this issue should be carefully considered by the authors of this Report as well as those of the WGs Assessment Reports.

Meaning of technologies

In Meeting discussions, 'Technologies' was not explicitly defined by participants but was implicitly taken to mean human activities that result in removals or emissions that should be included in national greenhouse gas inventories.

Estimation of anthropogenic removals on land

According to the *IPCC Guidelines*, anthropogenic removals and emissions on land are ***estimated*** using the managed land proxy – that is, all estimated carbon dioxide removals and emissions on 'managed land' are considered anthropogenic (except for removals and emissions associated with natural disturbances[7]).

[5] The UNFCCC definition is used in the IPCC Guidelines.

[6] 2006 IPCC Guidelines.

[7] Natural disturbances in the context of the *AFOLU* sector are non-anthropogenic events or non-anthropogenic circumstances that cause significant emissions and are beyond the control of, and not materially influenced by a country. These include wildfires, insect and disease infestations, extreme weather events and/or geological disturbances, beyond the control of, and not materially influenced by a country. Natural disturbances exclude human activities such as harvesting, prescribed burning and fires associated with activities such as slash and burn (2019 Refinement Vol 4.2.6.1.2 page. 2.69).

Background note: The origins of the managed land proxy concept included in the glossary to this Report can be traced back to the IPCC 2003. The key rationale for this approach is that the preponderance of anthropogenic effects occurs on managed lands. By definition, all direct human-induced effects on greenhouse gas emissions and removals occur on managed lands only. While it is recognized that no area of the Earth's surface is entirely free of human influence (e.g., CO_2 fertilization), many indirect human influences on greenhouse gases (e.g., increased N deposition, accidental fire) will be manifested predominately on managed lands, where human activities are concentrated. Finally, while local and short-term variability in emissions and removals due to natural causes can be substantial (e.g., emissions from fire), the natural 'background' of greenhouse gas emissions and removals by sinks tends to average out over time and space. This leaves the greenhouse gas emissions and removals from managed lands as the dominant result of human activity (*2006 IPCC Guidelines*, Volume 1.1 page 1.5). In the report of a recent IPCC TFI Expert Meeting on Reconciling Anthropogenic Emissions from Land Use:

> ..countries - by following the *IPCC Guidelines* for NGHGIs (IPCC 2006, 2019) and its 'managed land proxy' - consider a large part of the land sink to be anthropogenic …. This is because, especially in areas where land-use changes do not occur (e.g., forests that remain unchanged), it is often not possible to factor out direct and indirect effects using the observational data typically available from NGHGI and used for managing land resources, such as forest inventories (Canadell et al 2007 , IPCC 2009). This approach by NGHGI is what Parties of the Paris Agreement are required to follow under the Enhanced Transparency Framework.
>
> IPCC Expert Meeting on Reconciling Anthropogenic Land Use Emissions, 9-11 July 2024, Ispra, Italy

The negative CO_2 emissions artefact

It was also noted that the notion of 'negative CO_2 emissions' is not defined by the *IPCC Guidelines*, being a term used in one instance when aggregating a number of processes into a particular narrative (Bioenergy with carbon capture and storage, BECCS).

In that single case, its function was to record an artificial 'negative CO_2 emission' in the *Energy* sector for one part of this BECCS process to cancel the artificial CO_2 emission reported in the *AFOLU* sector resulting not from an actual emission process but from the transfer of carbon out of the biomass or HWP pool.

In this case, the function of the negative emissions term was to offset the over-estimation of net emissions recorded in the *AFOLU* sector and should not be conflated with an actual removal from the atmosphere at the point of capture and storage.

Another example occurs in the case of carbon dioxide captured from a process gas stream such as in a smoke stack at a power station. Here the IPCC methods indicate a deduction is recorded for the amount of carbon dioxide captured from the estimated potential emissions – commonly based on analysis of fuel inputs - which, if unadjusted, would result in an overestimation of net emissions. If these emissions had instead been estimated using end-of-pipe direct measurement techniques, then the amount of captured carbon dioxide would have been irrelevant to the estimate of emissions at that facility.

In this case, the function of the deduction for the amount of carbon dioxide captured is to offset the over-estimation of emissions caused by the IPCC estimation method and it does not count for an actual removal from the atmosphere.

Treatment of captured and stored CO_2

Currently, the *IPCC Guidelines* only allows for subtraction of captured CO_2 at the source against estimated potential emissions, as in the example above, if the captured CO_2 is for a long-term storage or otherwise included in the inventory.

The concepts of 'storage' or 'long term storage' are not explicitly defined in the *IPCC Guidelines*. They may need to be reviewed which could have implications for the structure of the inventory if, for example, the concept of storage was extended to include captured CO_2 used in products with short lifetimes (such as fuels or beverages). The application of storage concepts was a source of debate in the Meeting. The participants agreed this issue should be carefully considered by the authors of this Report.

2.2 Introduction to general inventory concepts in the *IPCC Guidelines*

The Meeting considered the nature of the *IPCC Guidelines* presented on Day 1 by the IPCC TFI TSU, drawing from the Background paper made available to participants.

The main application of the *IPCC Guidelines* is for users to create GHG inventories for international reporting (for example, to the UN Framework Convention on Climate Change (UNFCCC)).

The *IPCC Guidelines* aim to help countries accurately estimate and report anthropogenic GHG emissions and removals reliably and to provide methods and tools for the consistent compilation of GHG inventories over time and across countries.

The *IPCC Guidelines* do not assess the potential of emission reduction measures or mitigation strategies and are not focused on policy recommendations.

The IPCC Guidelines offer practical guidance

The *2006 IPCC Guidelines* achieve their purpose by offering practical guidance to help compilers estimate greenhouse gas emissions and removals.

Individual sectoral chapters of the *2006 IPCC guidelines* offer detailed sections like overview, introduction, and category descriptions to help identify emission sources and removal sinks:

- Clear definitions of emission sources and removal sinks by sector;
- Explanation of how emissions or removals are produced (combustion, chemical, biological, etc.);
- Identification of expected GHGs for each source;
- Sector splits and activity breakdowns for accurate categorization; and
- Cross-references to other sectors to prevent double-counting.

IPCC Guidance is provided as *good practice,* rather than as standardized rules and is flexible, adaptable to each country's national circumstances and encourages continuous improvement.

The Guidelines focus on the best practical estimate, avoids biases and aims to minimize uncertainties, and supports global comparability of inventories even across countries with different data levels.

Flexibility is provided to inventory compilers in the selection of emission or removal estimation methods through the tiered approach, with detailed sections offering methods for different data availability levels:

- Tier 1: Basic methods using default data.
- Tier 2: Intermediate methods with more specific national data.
- Tier 3: Detailed, country-specific methods using complex models and datasets.

Decision trees guide compilers in the selection of the appropriate tier based on significance, data quality and data availability.

Importance of transparency

The IPCC Guidance supports the building of trust in inventories through transparency requiring clear documentation of methods, data, and assumptions. To support the production of inventories that are reliable and transparent, the *2006 IPCC Guidelines* provide the following tools and procedures for GHG's Inventory compilers:

- Tools for identifying all emission sources, sectors and gases, and cross-checks to avoid omissions or double-counting.
- Methods for ensuring consistent datasets and GHG estimates and recalculating past years when methods or data change.
- Guidelines for quantifying uncertainties in activity data, emission factors and GHG estimates, improving reliability.
- Structured QA/QC procedures, including checklists for data reviews and external validations.
- Templates and guidance for reporting GHG estimates and documenting methodologies, assumptions, and recalculations for transparency.

The IPCC Guidelines should be read in conjunction with the UNFCCC

The *IPCC Guidelines* already support the reporting of removals from direct air capture.

This is because the Guidelines should be read in conjunction with the UNFCCC, which provides for the reporting of anthropogenic sinks from ***any*** process, activity or mechanism which removes a greenhouse gas from the atmosphere - this includes direct air capture technologies, for example, or the passive carbonation of cement.

The Guidelines support this UNFCCC sink definition by providing for any estimated removal from a previously undescribed CDR technology to be reported under the generic 'other' category provided in the IPCC classification system for all sectors and for a number of categories.

The role of the default estimation methodologies described in the *IPCC Guidelines*, therefore, is better understood as underpinning the scope of a set of minimum anthropogenic emissions and removals that should be reported by inventory compilers – but those do not limit what additional sinks and sources compilers can estimate and report.

The provision of IPCC methodologies for these CDR technologies is intended to underpin the routine reporting of removals from these technologies in national inventories in future.

Debate on this topic was well noted by participants to the Meeting.

2.3 Technologies under consideration

The IPCC Working Group III (WGIII) contribution to the Sixth Assessment Report (AR6) provides a summary of the role for CDR technologies in future mitigation pathways (Table TS.7).

The IPCC WGIII identified 12 CDR technologies of importance for the delivery of these pathways. Some of these technologies, like afforestation/reforestation, have been well reviewed for previous updates of the *IPCC Guidelines* and were not considered further.

Table 1: List of CDR Technologies and CCUS processes under consideration

CDR and CCUS processes
1. Direct air capture
2. Carbonation:
(i) Cement
(ii) Industry slags and wastes
(iii) Alkalinization of water bodies
(iv) Enhanced weathering
3. Direct removal of CO_2 from water bodies
4. Enhanced oil, gas or coalbed methane recovery
5. Production of CO_2 containing products
6. Consumption & use of CO_2 containing products
7. Biochar
8. Enhancing biomass in coastal waters/wetlands
9. Other durable biomass products
10. Wastewater based CDR/CCUS
11. Open ocean fertilization and alkalinization
12. Other

Source: TSU opening presentation, derived from IPCC (2024). IPCC Expert Meeting on Carbon Dioxide Removal Technologies and Carbon Capture, Utilization and Storage Eds: Enoki, T., Hayat, M., Report of the IPCC Expert Meeting, Pub. IGES, Japan.

The participants to the Scoping Meeting considered the list of technologies in Table 1, which was the IPCC WGIII list but amended in light of discussions at the IPCC Expert Meeting held in Vienna, Austria, on 1-3 July 2024. This list of technologies was also added to during the course of the Scoping Meeting.

2.4 Assessment Criteria for new source or removal categories

Participants assessed and evaluated CDR technologies (and CCUS processes) and associated potential sinks or source processes for inclusion in the *IPCC Guidelines*, or update of the existing Guidelines, using the following criteria (which draw on the criteria used for the *2019 Refinement of the 2006 IPCC Guidelines)*:

1. Gaps in the IPCC Guidance or need for updates

Participants considered the identification of gaps in the existing *IPCC Guidelines* for specific anthropogenic sinks or sources; and the identification of relevant existing sources and sinks where an update of the Guidelines was considered necessary or desirable.

2. Delineation of the sink or source

Participants considered the delineation of anthropogenic sinks and sources within territorial boundaries as part of the process of considering the feasibility of being able to specify estimation methodologies.

3. Current and expected significance of the sink or source

Participants considered the data requirements to be imposed on inventory compilers since the development of methods for sources or sinks that are expected to be of only minor consequence in future will not have great utility.

4. Capacity to generalize tier 1 default values

Participants considered whether the scientific and empirical evidence exists to parameterise a tier 1 and, in some cases, tier 2 estimation method with confidence and in order to meet the IPCC Tier 1 methodology stipulation that it should be applicable under any national circumstances:

Background note:

There should be availability of the necessary activity data to implement the methods (readily available national or international statistics); and there should be ability to specify tier 1 default values: sufficient availability of data to calculate a global (at least) value from a sample large enough to have it as a central value; and which should be expected to produce unbiased estimates, so far as can be judged. There is no quantitative threshold for the number of empirical studies required to support the establishment of a default factor.

Instances of non-specification of tier 1 method

In some instances, where no global default values can be produced by authors according to the relevant criteria, the *IPCC Guidelines* provides the methodology only as a higher order method. Examples include for carbon capture and storage, soil inorganic carbon and for biochar (the *2006 IPCC Guidelines* Vol 2: 5.7 page 5.13 , *2006 IPCC Guidelines* Vol 4: page 2.37 and *2019 Refinement to the 2006 IPCC Guidelines* Vol 2: Annex 2.A page 2.82).

Instances of methods assigned to appendices

Once a drafting process is launched authors may still conclude, after due consideration, that the emissions or removals remain poorly understood and that there is insufficient information available to develop reliable, globally applicable, default methods and emission factors for a particular source or sink. This drafted text may not be lost but placed in appendices in the *IPCC Guidelines* as basis for future methodological development.

A national inventory can be considered complete without the inclusion of estimates for these sources in the appendices, although countries may use appendices as a basis for estimation of GHG emissions, if country specific data are available.

Examples from past drafting processes of methods that were ultimately not included in the main chapters of the Guidelines, but in appendices include Fugitive emissions from wood pellet production; Fugitive emissions from biomass to liquid and biomass to gas conversion; Fluorinated compounds emissions from textile, carpet, leather and paper Industries, and Organic and dissolved inorganic carbon loss from peatlands and drained organic soils.

These methods may be subject to further consideration at future iterations of methodological work.

5. Feasibility of being able to specify higher tier methods

Participants considered the feasibility of being able to specify higher tier methods for identified CDR technologies and CCUS activities.

6. Feasibility of verification activities

Participants considered the possibility of guidance being provided for inventory compilers as to how they may be able to devise appropriate **verification** activities to strengthen the robustness confidence of the estimated emissions and removals.

3. Sectoral Discussions

The Table of Contents (TOC) structure set out in Appendix 2 provides for two new IPCC Sectors:

- *IPCC Sector 5: Carbon Dioxide Capture, Transport, Utilization and Storage;* and
- *IPCC Sector 6: Direct Removal of CO_2 from Waterbodies. Alkalinity Enhancement of Waterbodies*.

The creation of *IPCC Sector 5, Carbon Dioxide Capture, Transport, Utilization and Storage* brings together methods that cover the chain of activities for capture, transport, utilization and storage of carbon dioxide into one new IPCC Sector. Methods for direct air capture – a removal - (chapter 3) and carbon capture from process gas streams – a reduction in emissions - (chapter 2) are specified separately but with a recognition that, once carbon dioxide is captured, methods used to describe emission processes for transport, utilisation and storage should be identical.

Elements relating to carbon dioxide capture from process streams, transport, injection and storage are not new but have been relocated from the *IPCC Sector 1.C (Energy)* and also will be updated. Participants agreed that since carbon dioxide may be captured from sources in other IPCC Sectors – such as from *Industrial Processes and Product Use (IPPU)* or from *Waste* – that it was no longer appropriate to allocate emissions from carbon dioxide capture, transport, injection and storage to the *Energy Sector* alone.

The creation of *IPCC Sector 6: Direct Removal of CO_2 from Waterbodies. Alkalinity Enhancement of Waterbodies* incudes new CDR technologies that are explicitly designed to influence the carbon stock reservoirs in the waterbodies and consequently in the atmosphere.

3.1 Carbon capture, utilization and geological storage and IPPU issues

BOG1: Co-facilitators: Zhu Songli (China) and Ole-Kenneth Nielsen (Denmark)

Rapporteur: Joni Jupesta (Indonesia)

BOG 1 initially considered issues including Direct Air Capture, carbon capture, utilisation and storage, carbonation processes (cement, metal industry wastes and slag), removal of CO_2 from water bodies, cross-boundary issues.

Participants evaluated relevant CDR technologies against the assessment criteria set out in Section 2.4.

Listing of new technologies

Elements listed by participants under the new IPCC Sector 5 *Carbon Dioxide Capture, Transport, Utilization and Storage* include:

- Carbon dioxide capture from process gases
- Direct air capture
- Carbon dioxide utilization
- Carbon dioxide transport; and
- Carbon dioxide injection and geological storage.

'Direct Air Capture (DAC)' refers to a technological process of removing carbon dioxide from the atmosphere.

In relation to Direct Air Capture, participants recognized a gap in the current *IPCC Guidelines* for Greenhouse Gas Inventories, which do not yet provide guidance on this technology. DAC is projected to play a more significant role in future carbon removal strategies, though participants noted the challenges of developing a generalized Tier 1 approach due to technological complexity. Instead, the development of higher-tier methods may be more feasible and provide greater accuracy. Verification activities,

essential for tracking effectiveness, would need to be defined through standardized monitoring plans to support DAC's inclusion

Evidence assembled from empirical literature to support the assessments in relation to Direct Air Capture is provided in Section 4 Technology 1.

The participants recommended that new guidance be developed in *IPCC Sector 5, Volume 6, Chapter 3 Direct Air Capture.*

'Carbon dioxide capture from process gases' refers to capture of carbon dioxide from anthropogenic sources such as process gases.

In relation to Carbon dioxide capture from process gases, participants noted that existing guidance in the *2006 IPCC Guidelines* addresses aspects of CCS, though further updates are warranted to reflect advances in technology and usage. Developing new Tier 1 approaches is challenging due to the specialized nature of CCS and CCU; higher-tier methods may be more appropriate to achieve reliable estimates. Participants highlighted the need for robust verification activities supported by well-defined monitoring plans which would help enhance the reliability of emissions data for CCS and CCU.

Evidence assembled from empirical literature to support the assessments in relation to Carbon dioxide capture from process gases' is provided in Section 4 carbon capture, utilization, and storage.

The participants recommended that updated guidance be developed for a re-located category in IPCC Sector 5, Volume 6, Chapter 2 Carbon capture from process gases.

Once captured, the carbon dioxide captured under DAC or carbon capture from process gases would be subject to the methods for utilization, transport, injection and storage listed in the TOC as Volume 6 chapters 4, 5 and 6.

'Carbon dioxide utilization' refers to possible ways of CO_2 utilization, e.g. enforced carbonation of industrial and mining wastes, critical mineral extraction, mineralisation (surface), synthetic fuels. It also refers to tracking of captured CO_2, national carbon dioxide balance matrix (sources of captured CO_2 vs. final use and short- and long-term storage).

Evidence assembled from empirical literature to support the assessments in relation to the utilization of carbon dioxide in the mining industry is provided in Section 4 Technology 2 (ii).

The participants recommended that new and updated guidance be developed for a category in IPCC Sector 5, Volume 6, Chapter 4 Carbonation dioxide utilization.

In addition, the participants recommended that updated guidance be developed for a re-located category in IPCC Sector 5, Volume 6, Chapter 5 Carbon dioxide transport and Chapter 6 Carbon dioxide injection and geological *storage.*

'Carbonation of cement' (Table 1 Technology 2 (i)) refers to the passive carbonation of cement.

In considering this technology, participants considered that there was a gap in the Guidelines and that the delineation of the category could be broadened to include passive carbonation of lime-based structures. The category could be broadened to include all life stages from initial curing to construction to final disposal of the cement or lime-based structure (as wastes).

Not included in this category would be enforced or catalysed carbonation processes such as occur in the mining industry as these are covered in the new IPCC Sector 5 (carbon dioxide utilization (Volume 6, chapter 4).

Participants considered the feasibility of methods and verification. While some research exists to support the development of a Tier 1 approach, higher-tier methodologies may offer improved accuracy and applicability. Verification should be implemented through monitoring plans to track carbonation efficiency and durability

Evidence assembled from empirical literature to support the assessments is provided in Section 4 Technology 2 (i).

The participants recommended that new and updated guidance be developed for a category in IPCC Sector 2, Volume 3, Chapter 11 Carbonation of cement and lime-based struc*tures*.

Updated or additional guidance

Production of CO_2 containing products (Table 1 Technology 5) refers to the production of products containing carbon dioxide, for example, synthetic e-fuels. These production processes include the use of carbon dioxide.

In considering the production of CO_2 containing products, participants noted that these processes, such as the synthesis of e-fuels, present a unique pathway for utilizing captured carbon. The current *IPCC Guidelines* allow for the subtraction of captured CO_2 at the source only if it is intended for long-term storage or otherwise accounted for in the inventory. Expanding guidance to include CO_2 used in products with shorter lifetimes, such as fuels and beverages, could significantly impact inventory sectors like *Energy* and *Industrial Processes and Product Use*. This may necessitate additional guidance to manage cross-sectoral impacts and ensure accurate accounting.

Evidence assembled from empirical literature to support the assessments is provided in Section 4 Technology 5 and Technology 6.

The participants recommended that new and updated guidance in relation to the production of products containing or derived from captured CO_2 in IPCC Sector 2, Volume 3, Chapter 3 Chemical Industry IPCC Sector 1, Volume 2, Chapter 2, Stationary Combustion and Chapter 5 Fugitive Emissions be developed.

In addition, participants recommended that new guidance in relation to the consumption of products containing or derived from captured CO_2 in IPCC Sector 2, Volume 3, Chapter 9 Consumption and use of CO_2 containing products be developed, depending on decisions made in relation to Carbon Capture and Utilization (in volume 6).

Further consideration will be also required by authors as to the treatment of CO_2 containing products which may impact the current guidance offered for production of industrial products (IPPU); production and combustion of synthetic fuels (*Energy*) or disposal of CO_2 containing products (Waste).

Evaluation of omitted or referred technologies

In relation to the removal of CO_2 from waterbodies, participants acknowledged that this technology is not covered in the current *IPCC Guidelines* but shows potential as a novel CO_2 removal approach. 'Removal of CO_2 from waterbodies' was considered further by BOG 2.

3.2 *Agriculture, Forestry and Other Land Use (AFOLU)* and related Issues

BOG 2: Co-facilitators: Stephen Ogle (United States of America) and Jongikhaya Witi (South Africa). Rapporteur: Dan Zwartz (Australia).

BOG 2 considered *AFOLU* chapters and issues relating to soils and water bodies: Soils (biochar, enhanced weathering and inorganic carbon, other), biomass products other than Harvested Wood Products; coastal wetlands (seagrass, tidal marshes, macro algae, enhanced alkalinization); wastewater-based CDR/CCUS; cross-boundary issues and open water bodies (ocean fertilization, enhanced alkalinization).

Participants evaluated relevant CDR technologies against the assessment criteria set out in Section 2.4.

Listing of new technologies

Elements that BOG 2 listed under the new IPCC Sector 6 Direct Removal of CO_2 from Waterbodies, Alkalinity Enhancement of Waterbodies include:

- Direct Removal of CO_2 from Waterbodies; and
- Alkalinity Enhancement of Waterbodies.

'Direct Removal of CO_2 from waterbodies' (Table 1, Technology 3) refers to a technological process composed by three parts (i) extraction of carbon dioxide from water bodies (ii) indirect removals of carbon dioxide by those water bodies because of their increased capacity to absorb additional carbon dioxide from the atmosphere and (iii) a requirement that the carbon dioxide extracted under part (i) is stored and either transferred and injected into permanent storage or utilised.

In relation to Direct Removal of CO_2 from waterbodies participants noted that there was a gap in the *IPCC Guidelines*; that the activity could be significant; that higher tier methods would be feasible but that it was unlikely to be feasible to derive a Tier 1 methodology and more information was required to determine whether it was feasible to derive verification activities.

Evidence assembled from empirical literature to support the assessments is provided in Section 4 Technology 3.

The participants recommended that new guidance be developed in a new *IPCC Sector 6, Volume 7, Chapter 2 Direct Removal of CO_2 from Waterbodies*.

'Alkalinity enhancement of waterbodies' (Table 1, Technology 2 (iii)) refers to a process composed by two parts (i) adding alkalinity to the surface within territorial waters to bind dissolved CO_2 in long-lasting precipitates, so enhancing the capacity of waterbodies to store dissolved CO_2; (ii) *indirect removals of carbon dioxide by those water bodies because of their increased capacity to absorb additional carbon dioxide from the atmosphere.*

In relation to alkalinity enhancement of waterbodies the participants noted that there was a gap in the *IPCC Guidelines*; that the activity could be significant; that higher tier methods would be feasible but that more information was required to determine whether it was feasible to derive a tier 1 method and verification activities. Participants also agreed that alkalinity enhancement may consider wastewater effluent and brine from desalinization processes and restoration of coastal wetlands.

Evidence assembled from empirical literature to support the assessments is provided in Section 4 Technology 2 (iii).

The participants recommended that new guidance be developed in a new IPCC Sector 6 Volume 7, Chapter 3 Alkalinity Enhancement of Waterbodies.

Updated or additional guidance

Enhanced Rock Weathering (ERW) (Table 1, Technology 2 (iv)) refers to a process composed by three parts (i) adding mineral components to the soil to speed up the chemical reaction between CO2 dissolved in soil waters, and mineral components in the soils which results in (ii) additional precipitation of CO_2 in mineral components residing, across time, in the soil, in the terrestrial waters and eventually into the ocean (iii) the lower carbon content of terrestrial waters allows waterbodies to increase their capacity to *absorb additional carbon dioxide from the atmosphere*.

In relation to enhanced weathering, the participants noted that the soil inorganic carbon is a component included in existing *IPCC Guidelines* as a tier 3 method while liming, which involves similar processes, is already covered as a CO_2 source. A gap exists, however, regarding other rock amendments (such as silicate rock as a soil amendment). Significance of this activity is small currently but could grow significantly for CDR. A Tier 1 methodology already exists for liming; although there may not be enough information to develop Tier 1 methodology, including emissions factors, to encompass all other rock/mineral additions to soils as well as the interaction with the natural rock weathering considering the small but growing literature. However, the development of Tier 3 methods was considered feasible,

although associated with verification measurements, mainly consisting of analysis of inorganic C content in soils and in the circulating water.

The CDR Technology of biochar (Table 1, Technology 7) refers to the application of biochar to agricultural soils, and the related impacts on the responsiveness of soil carbon stock changes to various management activities.

In relation to biochar, the participants noted that the gap in the *IPCC Guidelines* related to the lack of Tier 1 EFs, although there is material in appendix 4 of chapter 2, Volume 4 of the *2019 Refinement of the 2006 IPCC Guidelines* that could be used as a basis for the development of Tier 1 EFs. There was a need to consider the range of available biochar feedstocks, processes of carbonification of feedstocks, non-soil uses of biochar and relationship between biochar and methods for harvested wood products, including for trade, and methods for nitrous oxide emissions from fertilizer use as well as for methane emissions from rice cultivation. The process was likely to be significant in the future, given recent market growth, and the update of the methods contained in the 2019 Refinement as well as the provision of Tier 1 EFs were considered to be feasible.

Background Note: Biochar refers to a solid material generated by heating biomass to a temperature in excess of 350 °C under conditions of controlled and limited oxidant concentrations to prevent combustion….using processes that can be classified as either pyrolysis ..or gasification.. (IPCC 2019 Refinement). Methods for the estimation of emissions from the production of biochar are already provided in Volume 2, Chapter 4.3 of the 2019 Refinement of the *2006 IPCC Guidelines*.

Biochar is less reactive to the atmosphere than biomass. As in the case explained in section 2.3, this provides for a benefit of slowing of expected emission release and which, because of the IPCC estimation processes deployed, the production of Biochar may require counting in the *AFOLU* sector. This may require the transfer of the C stocks from the biomass C pool, including annual biomass, to a long-lasting C pool, and its subsequent trade, if any, and its use as soil amendment, which requires its transfer to soils organic matter C pool, or its alternative use as a product – for example, for construction, CO_2 capture, feedstock in industrial processes, or feed integrate-(see also "Other Biomass durable products).

Evidence assembled from empirical literature to support the assessments is provided in Section 4 Technology 2 (iv) and Technology 7.

Participants recommended that updated guidance be developed for the existing chapters:

- Chapters 2, 4 ,5, 6, 7, 8 and 9 Volume 4 the *2019 Refinement of the 2006 IPCC Guidelines* - Generic Methodologies Applicable to Multiple Land-Use Categories, Forest Land, Cropland, Grassland, Wetlands, Settlements, Other Land
    - in order to address enhancing soil carbon sinks in croplands and grasslands for CDR: Update in relation to reference stocks and default factors for soil organic carbon estimates and enhancing soil carbon sinks on managed land for CDR: Update to add enhanced weathering into the Tier 3 soil inorganic carbon and relationship to soil organic carbon; update biochar application in soils to develop a Tier 1 method and update of the Tier 2 & 3 methods

- Chapter 4 Volume 4 the *2006 IPCC Guidelines* – Cropland [Rice Cultivation]
    - Enhancement of soil carbon for biochar amendments: Update Tier 1 default factors to estimate impact of biochar amendments on methane emissions from rice cultivation and provide guidance for Tier 2 and Tier 3.

- Chapter 11 Volume 4 the *2006 IPCC Guidelines* – N_2O Emissions from Managed Soils, and
- CO_2 Emissions from Lime and Urea Application

- Enhancement of soil carbon for biochar amendments: Update Tier 1 default factors to estimate impact of biochar amendments on soil N_2O emissions from N inputs in managed soils, and provide guidance for Tier 2 and Tier 3.

Enhancing biomass in coastal waters/wetlands (Table 1, Technology 8) refers to the enhancement of carbon sinks for CDR mainly through revegetation or enhanced sedimentation in coastal waters/wetlands.

In relation to the enhancement of carbon sinks in coastal wetlands the participants noted that there were either gaps in the *IPCC Guidelines* or need for updates including for the restoration/revegetation of additional coastal wetlands ecosystems (e.g. seagrass, mangroves, tidal marshes, coastal sabkhas and other tidal wetlands) as well as for seaweeds (macro-algae); that the category could be well delineated; that the enhancement activity could be significant; that Tier 1 and higher tier methods would be feasible and that verification activities could be designed, for example, using satellite technologies.

Evidence assembled from empirical literature to support the assessments is provided in Section 4 Technology 8.

The participants recommended that new and updated guidance be developed for the existing Chapter 4 of the Wetlands Supplement – Coastal Wetlands for the existing activities that result in carbon dioxide removals - as an update of factors in relation to mangroves, tidal marshes and seagrass in coastal waters - and new guidance for activities that result in carbon dioxide removals in other coastal wetland types not yet covered by IPCC guidance.

In addition, new guidance on carbon export from organic soils for the existing Chapters 2, 3, and 4 of the Wetlands Supplement was recommended.

Other durable biomass products (Table 1, Technology 9) refer to the treatment of biomass products not currently considered to be covered by the methods provided for harvested wood products but, as HWP, to store their carbon stocks longer than for a single year.

In relation to durable biomass products the participants noted that an update in relation to other durable biomass products for CDR could include the development of factors for other durable products (e.g., biochar products) and guidance for the trade and for higher tier methods, and transfers from other pools.

Evidence assembled from empirical literature to support the assessments is provided in Section 4 Technology 9.

The participants recommended that new and updated guidance be developed for Chapter 12 Volume 4 the *2006 IPCC Guidelines* – HWP and other durable biomass products.

Evaluation of omitted technologies

BOG 2 concluded that it was premature to list the following technologies in the Table of Contents:

- Wastewater based CDR/CCUS (including biomass uptake on constructed wetlands for wastewater and CO_2 capture).
- Ocean fertilisation.

In relation to biomass uptake in constructed wetlands for wastewater treatment (Table 1, Technology 10), while the participants acknowledged that there was a gap in the *IPCC Guidelines*, they concluded that the activity was not significant and that more information was required to determine whether it was feasible to derive a tier 1 method, higher tier methods, and verification activities.

In relation to direct capture of CO_2 at wastewater plants (Table 1, Technology 10), while the participants acknowledged that there was a gap in the *IPCC Guidelines*, they concluded that the activity is just a subset of the activities included in new Sector 6.

In relation to ocean fertilisation (Table 1, Technology 11), while the participants acknowledged that there was a gap in the *IPCC Guidelines*, they concluded that it was not clear whether the category could be

delineated consistent with the principles of national inventories. They also concluded that research results indicated that the activity does not result in significant carbon storage across time. Activity data was not available to determine a Tier 1 method and that more information was required to determine whether it was feasible to derive higher tier methods and verification activities.

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Technology 6: Consumption of CO_2 containing products

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5. Conclusions

The objective of this Scoping Meeting was to produce the outline of a Methodology Report on Carbon Dioxide Removal Technologies, Carbon Capture, Utilization and Storage in accordance with the Appendix A to the Principles Governing IPCC Work, which contains the procedures for the preparation, review, acceptance, adoption, approval and publication of IPCC reports.

The following outcomes of the Scoping Meeting, as recommended to be used by the TFB for its submission for an outline of a Methodology Report on Carbon Dioxide Removal Technologies, Carbon Capture, Utilization and Storage to the IPCC Panel, were produced:

- The title:

  2027 Methodology Report on Carbon Dioxide Removal Technologies, Carbon Capture, Utilization and Storage: (Supplement to the 2006 IPCC Guidelines)*

- Draft Terms of Reference for *2027 Methodology Report on* Carbon Dioxide Removal Technologies, Carbon Capture, Utilization and Storage is presented in **Appendix 1**;

- Draft Table of Contents is presented in **Appendix 2**;

- Draft Instructions to Experts and Authors is presented in **Appendix 3;** and

- The Work plan is presented in **Appendix 4**.

The recommendations and documents in Appendix 1 to Appendix 4 will constitute the basis of the TFI proposal for the outline for the *2027 Methodology Report on Carbon Dioxide Removal Technologies, Carbon Capture, Utilization and Storage: (Supplement to the 2006 IPCC Guidelines*)* to be presented to the IPCC-62 in early 2025 for the consideration by governments.

Appendices

Appendix 1. Terms of Reference (ToR)

Draft Terms of Reference

2027 Methodology Report on Carbon Dioxide Removal Technologies, Carbon Capture, Utilization and Storage (Supplement to the 2006 *IPCC Guidelines)**

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*The reference to the 2006 *IPCC Guidelines* for National Greenhouse Gas Inventories, and thus the notation *2006 IPCC Guidelines*, includes the following three methodological reports:

- *2006 IPCC Guidelines for National Greenhouse Gas Inventories (2006 IPCC Guidelines)*
- *2013 Supplement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Wetlands (Wetlands Supplement)*
- *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories (2019 Refinement*).

Background

1. At the 60th Session (IPCC-60) held in January 2024 (Istanbul, Türkiye) the IPCC decided that the Task Force on National Greenhouse Gas Inventories (TFI) will hold an Expert Meeting on Carbon Dioxide Removal Technologies, Carbon Capture Utilization and Storage and provide a Methodology Report on these by the end of 2027 (Decision IPCC-LX- 9).

2. IPCC TFI held the Expert Meeting in July 2024 (Vienna, Austria) and the Scoping Meeting in October 2024 (Copenhagen, Denmark). These meetings considered Carbon Dioxide Removal (CDR) methods mentioned in the AR6 WGIII Report as a starting point for discussion and noted that several CDR activities have been already covered by the existing *IPCC Guidelines*.

3. The Scoping Meeting produced the draft Table of Contents of the new Methodology Report, which is outlined in Annex 1.

Scope

4. *The IPCC Guidelines* already cover issues related to Afforestation/Reforestation, Soil carbon sequestration in croplands and grasslands, Peatland and coastal wetland restoration, Agroforestry, Improved Forest Management, Biochar amendments, Carbon Capture and Storage from process gases.

5. The aim of the new Methodology Report is to provide an updated and sound scientific basis for supporting the preparation and continuous improvement of national greenhouse gas inventories in relation to estimation and reporting of carbon dioxide removal technologies, carbon capture, utilization and storage. In order to achieve the overall aim, the new Methodology report will:

- provide new methodological guidance for carbon dioxide removal technologies, carbon capture utilization only where currently there are gaps in the existing guidelines or where new removal technologies have emerged that could provide scientifically sound and empirically robust methods, activity data, removal factors and other parameters;

- provide, where needed, updated guidance and information of the existing guidance in the *2006 IPCC Guidelines* in relation to carbon dioxide removal technologies, carbon capture and storage.

6. This work will not revise the *2006 IPCC Guidelines* but will update and provide new guidance for the *2006 IPCC Guidelines* where gaps or out-of-date science have been identified. The Methodology Report will not replace the *2006 IPCC Guidelines*, but will be used in conjunction with the *2006 IPCC Guidelines*.

7. Generally, national inventories should include greenhouse gas emissions and removals taking place within national territory and offshore areas over which the country has jurisdiction [*2006 IPCC Guidelines*, Volume I, Chapter 8.2.1]

Approach

8. The result of this work will be an IPCC Methodology Report "*2027 Methodology Report on Carbon Dioxide Removal Technologies, Carbon Capture, Utilization and Storage (Supplement to the 2006 IPCC Guidelines*)".

9. The authors will follow Annex 2 "Instructions to Experts and Authors" to ensure a consistent and coherent approach across all the volumes or chapters, including the use of common terminology.

10. Annex 3 provides the timetable for this task. Literature will be considered up to a cut-off date at the start of the Government/Expert Review.

Appendix 2. Table of Contents (ToC)

Draft Table of Contents

2027 Methodology Report on Carbon Dioxide Removal Technologies, Carbon Capture, Utilization and Storage (Supplement to the 2006 IPCC Guidelines)

Introductory Note

2027 Methodology Report on Carbon Dioxide Removal Technologies, Carbon Capture, Utilization and Storage (Supplement to the 2006 IPCC Guidelines) will be a single Methodology Report comprising an Overview Chapter and seven volumes following the format of the *2006 IPCC Guidelines for National Greenhouse Gas Inventories (2006 IPCC Guidelines*).

Overview Chapter
Volume 1: General Guidance and Reporting
Volume 2: Energy
Volume 3: Industrial Processes and Product Use
Volume 4: Agriculture, Forestry and Other Land Use
Volume 5: Waste
Volume 6: Carbon Dioxide Capture, Transport, Utilization and Storage
Volume 7: Direct Removal of CO2 from Waterbodies. Alkalinity Enhancement of Waterbodies

The structure of the Methodology Report is the same as that of the 2006 IPCC Guidelines so as to make it easier for inventory compilers to use this Methodology Report with the 2006 IPCC Guidelines.
For those Chapters where update or new guidance is expected, a description is provided below.
Also, authors should develop modifications for Chapters, if deemed necessary to ensure consistency with the updates or new guidance made in the other Chapters.
In addition, authors should develop updates or produce new Worksheets, where necessary.

Overview Chapter

Glossary

Volume 1: General Guidance and Reporting (Update)

Chapter 1 Introduction

- *Consequential updates based on the new/updated guidance*

Chapter 4 Methodological Choice and Identification of Key Categories

- *Consequential updates based on the new/updated guidance*

Chapter 8 Reporting Guidance and Tables

- *Update in relation to categorization of new source/sink categories or recategorization of existing (e.g. 1.C). Update of all reporting tables, clarifying that the CO_2 emissions are adjusted by CO_2 capture (negative quantities) to derive net CO_2, explanations to reporting*

tables: fugitive emissions during international CO_2 transport; CO_2 from biomass fuels in international transport, CO_2 from CCU-products/e-fuels I international transport, CO_2 captured during international transport, CO_2 from biomass in IPCC sectors 1B & 2, 3A and 4, how to report carbon capture in all sectors, differentiating fossil/CCU; biomass & atmospheric origins

Volume 2: Energy (Update)

Chapter 2 Stationary Combustion & Chapter 3 Mobile Combustion

- *Placeholder: Depending on the decisions made in relation to CCU, there might be a need for additional guidance in these chapters, e.g. in relation to new emission factors for combustion of fuels based on captured CO_2.*

Chapter 4 Volume 2 of the 2006 IPCC Guidelines – Fugitive Emissions
Chapter 4 Volume 2 of the 2019 Refinement to the 2006 IPCC Guidelines – Fugitive Emissions

- *Clarification in relation to the emissions from transport, injection and sequestering of CO_2 in relation to enhanced oil, gas, and coal-bed methane recovery*
- *Placeholder: Depending on the decisions made in relation to CCU, there might be a need for additional guidance in this chapter, e.g. in relation to new emission factors for the production of fuels based on captured CO_2*

Volume 3: Industrial Processes and Product Use (New and Update)

Chapter 3 of the 2006 IPCC Guidelines – Chemical Industry
Chapter 3 of the 2019 Refinement of the 2006 IPCC Guidelines – Chemical Industry (Update)

- *Guidance in relation to the production of products containing or derived from captured CO_2.*

Chapter 9 of the 2006 IPCC Guidelines – Consumption and Use of CO2 containing products
Chapter 9 of the 2019 Refinement of the 2006 IPCC Guidelines – Consumption and Use of CO2 containing products
(New)

- *Placeholder: Depending on the decisions made in relation to CCU (in Volume 6), there might be a need for additional guidance on emissions arising from the consumption and use of CO_2 containing products*

Chapter 10 Carbonation of cement and lime based structures

Covering all life stages. Excluding enforced carbonation (covered in Volume 6)

Volume 4: Agriculture, Forestry and Other Land Use (Update and New)

Chapters 2, 4 ,5, 6, 7, 8 and 9 Volume 4 the 2019 Refinement of the 2006 IPCC Guidelines - Generic Methodologies Applicable to Multiple Land-Use Categories, Forest Land, Cropland, Grassland, Wetlands, Settlements, Other Land
(Update)

- *Enhancing soil carbon sinks in croplands and grasslands for CDR: Update in relation to reference stocks and default factors for soil organic carbon estimates.*
- *Enhancing soil carbon sinks on managed land for CDR: Update to add enhanced weathering into the Tier 3 soil inorganic carbon and relationship to soil organic carbon; update biochar application in soils to develop a Tier 1 method and update of the Tier 2 & 3 methods.*

Chapter 4 Volume 4 the 2006 IPCC Guidelines – Cropland [Rice Cultivation] (Update)

- *Enhancement of soil carbon for biochar amendments: Update Tier 1 default factors to estimate impact of biochar amendments on methane emissions from rice cultivation, and provide guidance for Tier 2 and Tier 3.*

Chapter 11 Volume 4 the 2006 IPCC Guidelines – N_2O Emissions from Managed Soils, and CO_2 Emissions from Lime and Urea Application (Update)

- *Enhancement of soil carbon for biochar amendments: Update Tier 1 default factors to estimate impact of biochar amendments on soil N2O emissions from N inputs in managed soils, and provide guidance for Tier 2 and Tier 3.*

Chapters 2, 3, 4 of the Wetlands Supplement (New)

- *Enhancement of carbon stocks in organic soils for CDR: new guidance on carbon export from organic soils.*

Chapter 4 of the Wetlands Supplement – Coastal Wetlands (Update and New)

- *Enhancement of carbon sinks for CDR: Update factors in relation to mangroves, tidal marshes and seagrass in coastal waters.*
- *New guidance on other coastal wetland types not in previous IPCC Guidelines.*

Chapter 12 Volume 4 the 2006 IPCC Guidelines – HWP and other durable biomass products (New and Update)

- *Update in relation to other durable biomass products for CDR: Develop factors for other durable products (e.g., biochar products) and guidance for higher tier methods, and transfers from other pools.*

Volume 5: Waste (Update)

Chapter 5 Volume 5 the 2006 IPCC Guidelines - Incineration and Open Burning of Waste (Update)

- *Placeholder: Depending on the decisions made in relation to CCU (in Volume 6), there might be a need for additional guidance on emissions arising from incineration of CO_2 containing products*

Volume 6 Carbon Dioxide Capture, Transport, Utilization and Storage (IPCC Sector 5) (New and Update)

Chapter 1. Introduction (New)

- *The basic concepts and terms and definitions related to CCUS should be addressed inter alia: technology, removal, short- and long-term storage, "negative" emissions.*

Chapter 2 Carbon Dioxide Capture from process gases (Update)

Chapter 3 Direct Air Capture (New)

Chapter 4. Carbon Dioxide Utilization (New)

- *Possible ways of CO_2 utilization, e.g. enforced carbonation of industrial and mining wastes, critical mineral extraction, mineralisation (surface), synthetic fuels*
- *Tracking of captured CO_2, national carbon dioxide balance matrix (sources of captured CO_2 vs. final use and short- and long-term storage).*

Chapter 5. Carbon Dioxide Transport (Update)

- *Update in relation to all sub-categories (CO_2 transport (ship/rail/pipeline/truck) and cross-border transfers)*

Chapter 6. Carbon Dioxide Injection and Geological Storage (Update)

- *Update in relation to all sub-categories (injection, long term storage, other)*
- *Mineralisation (subsurface)*

Volume 7. Direct Removal of CO_2 from Waterbodies. Alkalinity Enhancement of Waterbodies (IPCC Sector 6) (New)

Chapter 1. Introduction

Chapter 2. Direct Removal of CO_2 from Waterbodies

- *New guidance on enhancing carbon sinks by capture of CO2 from water with durable storage or other utilization.*

Chapter 3. Alkalinity Enhancement of Waterbodies

- *New guidance on enhancing carbon sinks by increasing alkalinity in waterbodies.*

Appendix 3. Instructions to Experts and Authors

Instructions to Experts and Authors

2027 Methodology Report on Carbon Dioxide Removal Technologies, Carbon Capture, Utilization and Storage (Supplement to the 2006 IPCC Guidelines)

1. Work on a Methodology Report will be guided by the IPCC procedures for the Preparation, Review, Acceptance, Adoption, Approval and Publication of the IPCC Reports (Appendix A to the Principles Governing the IPCC Work[8]). This document is consistent with the IPCC procedures and applies to all experts engaged in the production of a new Methodology Report.
2. In this document the term "experts" covers Co-Chairs, members of the TFI Bureau (TFB), technical support unit (TSU) Staff, Coordinating Lead Authors (CLAs), Lead Authors (LAs), and Review Editors (REs) as well as Contributing Authors (CAs) and Expert Reviewers.
3. These notes are intended as guidance to experts contributing to a new Methodology Report. They are intended to ensure a consistent and coherent approach across all the volumes or chapters and to promote common terms used.

Confidentiality

4. Authors meetings are closed meetings. Any discussions are confidential except for any published report of the meeting. This is to ensure that experts participating in the meetings can express themselves and discuss issues freely and openly.
5. The IPCC considers the drafts of a new Methodology Report, prior to acceptance, to be pre-decisional, provided in confidence to reviewers, and not for public distribution, quotation or citation.
6. The TSU will keep drafts of a new Methodology Report sent for the IPCC review, any comments received on them and the responses by authors. All written expert and government review comments will be made available to reviewers on request. These will be made available on the IPCC website as soon as possible after the acceptance by the Panel and the finalisation of the report.

Conflict of Interest

7. It is important that all experts involved in the IPCC activities avoid any conflict of interest or the direct and substantial appearance of a conflict of interest. It is recognised that many experts in Emission Inventories are employed by, or funded by, parties with some interest in the outcome (e.g. most inventory compilers are funded by national governments or industry). It is therefore important to be open and transparent about financial and other interests.
8. The IPCC implements a Conflict of Interest (COI) Policy[9] that applies to all individuals directly involved in the preparation of IPCC reports, including senior IPCC leadership (IPCC Chair and Vice-Chairs), other Bureau and Task Force Bureau members, authors with responsibilities for report content (CLAs, LAs), Review Editors and staff of the TSU. The overall purpose of this policy is to protect the legitimacy, integrity, trust, and credibility of the IPCC and of those directly involved in the preparation of reports, and its activities.
9. Before an individual is appointed as a CLA, LA and RE for a new Methodology Report, the TFB will request the individual to complete a Conflict of Interest Disclosure Form ("the COI Form") contained in Annex B to the COI Policy which will be submitted to the TSU. The TFB will then evaluate the form to determine whether the individual has a conflict of interest that cannot be resolved.
10. All CLAs, LAs and REs will inform the TSU annually of any changes in the information provided in their previously submitted COI Form. The TFB will evaluate the revised information.

[8] https://www.ipcc.ch/site/assets/uploads/2018/09/ipcc-principles-appendix-a-final.pdf
[9] https://www.ipcc.ch/site/assets/uploads/2018/09/ipcc-conflict-of-interest-2016.pdf

11. All COI Forms and any records of the deliberations of the COI Expert Advisory Group, deliberations and/or decisions of the COI Committee in relation to conflict of interest issues in respect of specific individuals and any information disclosed by individuals for the purposes of the COI Policy will be transferred to the Secretariat after they have been reviewed and will be securely archived by the Secretariat and retained for a period of five years after the end of the assessment cycle during which the relevant individual contributed, after which the information will be destroyed. Subject to requirement to notify the existence of a conflict of interest to others, the information referred to above will be considered confidential and will not be used for any purpose other than consideration of conflict of interest issues under these Implementation Procedures without the express consent of the individual providing the information.

Responsibilities of authors and other experts

12. The role of authors is to impartially assess ALL the available literature and to describe the best methodologies available. Experts should be impartial. Authors should review all literature available up to a cut-off date to be decided by the TFB as part of the agreed work plan.
13. After drafting the report authors will be asked to consider all comments received on the drafts and to adjust and revise the text accordingly. They should document their responses. If they do not accept a comment this should be explained. Review Editors should check whether the accepted changes were fully incorporated in the revised text.
14. Responsibilities and duties of authors and other experts are currently explained in more detail in the IPCC procedures for the Preparation, Review, Acceptance, Adoption, Approval and Publication of the IPCC Reports (Appendix A to the Principles Governing the IPCC Work).

Literature

15. The use of literature should be open and transparent. In the drafting process, emphasis is to be placed on the assurance of the quality of all cited literature. Priority should be given to peer-reviewed scientific, technical and socio-economic literature if available.
16. It is recognized that other sources provide crucial information for IPCC Reports. These sources may include reports from governments, industry, and research institutions, international and other organizations, or conference proceedings. Use of this literature brings with it an extra responsibility for the author teams to ensure the quality and validity of cited sources and information as well as providing an electronic copy. In general, newspapers and magazines are not valid sources of scientific information. Blogs, social networking sites, and broadcast media are not acceptable sources of information for IPCC Reports. Personal communications of scientific results are also not acceptable sources.
17. For any sources written in a language other than English, an executive summary or abstract in English is required.
18. All sources will be integrated into a reference section of an IPCC Report.
19. For more details of the procedure on the use and referencing of literature in IPCC Reports, see Annex 2 to the IPCC procedures for the Preparation, Review, Acceptance, Adoption, Approval and Publication of the IPCC Reports (Appendix A to the Principles Governing the IPCC Work).

Principles of the new Methodology Report

20. Guidance in the new Methodology Report should be understandable and easy to implement. Lead authors should make efforts to balance the need to produce a comprehensive self-contained report with reasonable limits to the length and detail of the guidance. In particular:
    a. The guidance should follow a cookbook approach by providing clear step by step instructions. It should not try to be a textbook. Detailed background information on emission processes, scientific studies, etc. is generally referenced rather than included.
    b. Lead authors must consider relevant scientific developments and national methods used by countries in their inventories.
    c. Authors should bear in mind that the target audience is a diverse group of readers who are primarily concerned with the elaboration of national inventories. For this reason, the

emphasis should be on ensuring clear communication of practical and understandable guidance.

21. This work aims to cover all IPCC inventory sectors with categories where the science is considered to be robust enough to provide guidance for a Tier 1 methodological approach and have a relative[10] contribution to the global/regional emissions of the species, using the significance and prioritization criteria as shown below.

Significance and prioritization criteria

- Significance of the category and the species within the sector on a global/regional scale. Categories significant only for a limited number of particular countries, currently or in the foreseeable future, may not meet this criterion.
- Sufficient data availability and maturity of scientific advances to provide a basis for methodological development, including:
  - Ability to develop default emission and removal factors and parameters
  - Feasibility of obtaining the necessary data to implement the methods
- Relevant for IPCC emissions scenarios and pathways to net zero emissions

22. The general structure, approach and definitions used in the *2006 IPCC Guidelines*, such as tiered approach and decision trees will be followed. Annexes may be used where necessary to contain additional data to support the methodologies, although large numbers of annexes will probably not be necessary. Appendices are not ruled out where scientific knowledge is insufficient for countries to agree full methodologies, but please avoid as far as possible work on areas that have to be relegated to an appendix. Appendices should be sub-titled by "Basis for future methodological development".
23. The general structure should include the following elements: Methodological issues (Choice of method, Choice of emission factors, Choice of activity data), Completeness, Developing a consistent time series and Recalculations, Uncertainty assessment, Quality Assurance/Quality Control (QA/QC) and Reporting and Documentation, Worksheets.
24. Only Chapters identified in the draft Table of Contents are to be updated or new guidance should be provided, as proposed. However, authors should develop modifications for those Chapters, if deemed necessary to ensure consistency with updates or new guidance made in the other Chapters.

Definitions

25. The following terms will be used throughout the new Methodology Report, and it is essential that all Lead Authors have a common understanding of their meaning and relevance.
26. Tier A - Tier refers to a description of the overall complexity of a methodology and its data requirements. Higher tier methods are generally more complex and data-intensive than lower tier methods. The guidance for each category should contain at least a Tier 1 method, and in many cases there will be a Tier 2 and Tier 3. The general expectation is that Tier 2 and Tier 3 methods will both be consistent with good practice guidance for key categories, although in some cases Tier 3 will be preferred.
27. Tier 1 approaches are simple methods that can be applied by all countries in all circumstances. Default values for the emission and removal factors and any other parameters needed must be supplied (see below for documentation needed).
28. Tier 2 methods should in principle follow the same methodological approach as Tier 1 but allow for higher resolution country specific emission and removal factors and activity data. In some categories, this may not be the case. These methods should better replicate the parameters

[10] i.e. not insignificant

affecting the emissions. Country specific emission and removal factors are needed and possibly more parameters will also be needed.

29. Tier 3 methods give flexibility either for country specific methods including modelling or direct measurement approaches, or for a higher level of disaggregation, or both. This is a more complex method, often involving a model. This will replicate many features of nation emissions and require specific parameters for each country.
30. Default information is data that is appropriate for use where there is no better detailed, country specific information. If appropriate, authors may specify regional default data. Users of the guidelines should be encouraged to try to find better country specific data. Default data are appropriate for Tier 1 methods and the guidelines should contain all the default values needed. Emission and removal factors for higher tiers need not be specified because it is a function of higher tier methods to find data reflecting national circumstances. Default information is included primarily to provide users with a starting point from which they can develop their own national assumptions and data. Indeed, national assumptions and data are always preferred because the default assumptions and data may not always be appropriate for specific national contexts. In general, therefore, default assumptions and data should be used only when national assumptions and data are not available.
31. Decision Trees. A decision tree is a graphical tool to assist countries in selecting from the IPCC methods.
32. Key categories are inventory categories which individually, or as a group of categories (for which a common method, emission and removal factors and activity data are applied) are prioritised within the national inventory system because their estimates have a significant influence on a country's total inventory in terms of the absolute level, the trend, or the level of uncertainty in emissions. Key category analysis should be performed species by species. The appropriate threshold to define key categories should be considered by authors.
33. Sector refers to the sectors of the guidelines, these are divided into categories and subcategories.
    a. Sector 1
    b. Category 1.A
    c. Sub-category 1st order 1.A.1
    d. Sub-category 2nd order 1.A.1.a
    e. Sub-category 3rd order, 1.A.1.a.i
34. Worksheets. These will be printed versions of spreadsheet tables, that, when filled in, enable the user to perform the emission estimation. They should contain all the calculations and written text with any formulae. Additional worksheets may be required to compile the results of the worksheets into the reporting tables.
35. Reporting Tables are tables that present the calculated emission inventory and sufficient detail of other data used to prepare the inventories for others to understand the emission estimates.
36. Usage:
    a. "Good Practice" is defined in the 2019 Refinement as follows: "a key concept for inventory compilers to follow in preparing national greenhouse gas inventories. The key concept does not change in the 2019 Refinement. The term "good practice" has been defined, since 2000 when this concept was introduced, as "a set of procedures intended to ensure that greenhouse gas inventories are accurate in the sense that they are systematically neither over- nor underestimates so far as can be judged, and that uncertainties are reduced so far as practicable". This definition has gained general acceptance amongst countries as the basis for inventory development and its centrality has been retained for the 2019 Refinement. Certain terms in the definition have been updated based on feedback from the statistics community, such that this definition can be also understood as "a set of procedures intended to ensure that greenhouse gas inventories are accurate in the sense that they are systematically neither over- nor underestimates so far as can be judged, and that they are precise so far as practicable" in the context of refinement of Chapter 3 of Volume 1".

The concept mentioned above should be applied to all species dealt with in this report.

b. Good Practice covers choice of estimation methods appropriate to national circumstances, quality assurance and quality control at the national level, quantification of uncertainties and data archiving and reporting to promote transparency.

c. "Shall" should not be used. Either say "Good Practice is…" or say what needs to be done or what should be done. These all indicate what needs to be done to comply with Good Practice.

d. "Be encouraged to" indicates a step or activity that will lead to higher quality inventory but are not required for ensuring consistency with the *IPCC Guidelines*.

e. "Recommend" should not be used. In the GPG2000, the word "recommend" was avoided and "Suggested" was used instead.

f. "Inventory agency" is the body responsible for actually compiling the inventory, perhaps from contributions from a number of other bodies while "inventory compiler" is the person actually compiling the inventory,

Reporting Tables and worksheets

37. Worksheets reflect the application of tier 1 methods only, due to the varied implementation of higher tier methods by countries. Lead authors should stress the importance of documentation and archiving of particular types of information of relevance to each category, although advice may be given of what needs to be reported for transparency at higher Tiers.

Emission and Removal factors and methods

38. Authors should provide default emission or removal factors and parameters. In doing this work, they should draw on the widest possible range of available literature, scientific articles and country reports. Where default values for emission and removal factors or ancillary parameters cannot be provided for a robust methodology set to be a Tier 1 method, authors may decide to add the methodology as a higher tier method rather than Tier 1 setting the good practice for inventory compiler to use their own data.

39. All data reported in the guidance as IPCC default values shall be justified by authors by providing TSU with all background data used, and the source of those data, as well as all information on the method applied to derive the default values from the background data, as needed to replicate the calculation, in a timely manner as drafts are being developed. Background data should be compiled in the attached form (Appendix 1) to facilitate the upload in the Emission Factor Database (EFDB). Lead authors should be familiar with the draft cross-cutting guidance on data collection in Volume 1 and the guidance on cross-cutting issues in this note on terms, data types, data demands of methods and stratification requirements. Default data should also meet the EFDB evaluation criteria – robustness, documentation, and applicability[11].

40. Authors should develop guidance to provide additional information on rationale, references and background information on parameters used for estimating of default values where such information is available (similar to Annexes in Chapter 10, Volume 4, of the 2019 Refinement), with a view to enhancing the transparency and applicability of default values presented in the new Methodology Report.

41. Single IPCC default emission and removal factors might not be ideal for any one country, but they can be recommended provided that regional factors are unavailable, and the defaults are representative of typical conditions as far as can be determined. It may be necessary or appropriate to provide a range of default emission and removal factors along with clear guidance about how countries should select from within the range. Lead authors may also provide multiple default emission and removal factors, disaggregated by region, technology (including abatement and removal technologies), or another relevant classification scheme.

42. It is important to provide more default emission and removal factors that reflect the unique conditions of developing countries. In general, default emission and removal factors for Tier 1

[11] EFDB evaluation criteria: https://www.ipcc-nggip.iges.or.jp/EFDB/documents/EFDB_criteria.pdf

should represent emissions without category-specific mitigation measures, as well as relevant abatement technologies for which data are available.

43. Users of the guidelines should be encouraged to develop and use country specific data. Emission and removal factors for higher tiers need not be specified in the Methodology Report. Default information is included primarily to provide users with a starting point from which they can develop their own national assumptions and data. Indeed, national assumptions and data are always preferred because the default assumptions and data may not always be appropriate for specific national contexts.
44. The basic principle concerning national methods will continue to apply – countries are encouraged to use national data or methods so long as they are consistent with the *IPCC Guidelines*.
45. Authors should consider consistency in treatment by the exporting and the importing country on reporting of national total net emission when imported biomass is used in BECCS, biochar and other biomass products taking into consideration avoidance of double counting and completeness
46. Authors should exclude natural background when estimating GHG emissions/removals that are not carbon stock changes in C pools listed in Table 1.1 (Volume 4, *AFOLU*) and in the HWP pool.
47. Methods and emission factors for direct CO_2 removal and alkalinity enhancement will need to specify waterbodies, such as rivers, lakes, oceans, and others.
48. Alkalinity enhancement may consider wastewater effluent and brine from desalinization processes.
49. Methods and emission factors for direct CO_2 removal from water bodies, increased alkalinity and enhanced weathering should consider downstream storage of inorganic carbon.
50. Examples of coastal wetland systems that have not yet been considered in previous *IPCC Guidelines* are Tidal flats; tidal marsh-coastal sabkhas, seaweeds (macro-algae), subtidal sediments, and clarify definitions with consideration of Ramsar classes.
51. Coastal and inland wetlands guidance may consider management for CDR including restoration and other activities.
52. Enhanced weathering may include adding rock, mine tailings and other alkaline materials to land.
53. Consider including carbonate lime additions in soils in the updated guidance on enhanced weathering for soil inorganic carbon.

Boxes

54.Consistent with the *2006 IPCC Guidelines*, the new Methodology Report may contain Boxes, which should not be used to provide methodological guidance, but for information purposes or providing examples.

Decision trees

55.Consistent with the format and structure of the *2006 IPCC Guidelines*, the new Methodology Report may contain a decision tree for some sub-categories to assist countries in selecting from the IPCC methods. These decision trees link the choice of IPCC methods to national circumstances via specific questions about data availability and status as a key category[12].

56.To ensure consistency in decision tree logic and format across categories, lead authors should adhere to the following requirements:

a. The decision trees should be based on a series of questions with clear yes/no answers, and two subsequent branches along yes/no paths.
b. The decision trees should start with assessing data availability for the highest tier method, and then direct countries step-wise towards lower tier methods if activity data, emission and removal factors or other parameters are not available.
c. The decision tree should indicate the lowest tier method that is judged to be appropriate for

[12] The most appropriate choice of estimation method (or tier) may also depend on national circumstances, including the availability of resources and advice on this will be given in the cross-cutting volume.

estimating emissions from a key category.

d. If data are not available for the method referred to in c, the 'No' response should direct the reader to the question "Is this a key category?" If the answer to this is 'Yes', the decision tree should recommend that the country collect the necessary data to implement a higher tier method. If the answer is 'No', then the decision tree can recommend a lower tier method. There is no need to deal with the case for a key category where a country does not have the resources to gather additional data needed to implement higher Tier methods. This is dealt with in Volume 1 of the *2006 IPCC Guidelines.*

e. The branches of the decision trees should end in 'out-boxes' that correspond to specific tiers identified in the guidance for that category and are labelled by Tier. Lead authors may also recommend out-boxes for hybrid tiers.

f. Lead authors may develop separate decision trees for different sub-categories. Alternatively, they may include decision tree options for selecting different tiers for different sub-categories. This second option is appropriate if it is advantageous to recommend a higher tier method only for significant sub-categories rather than for the entire category. Decision trees that use the 'significance' criterion must include the "25-30% rule"[13], as reassessed by authors.

57.Additional Formatting Guidelines (see example):

Decision trees should be drafted in separate files. The TSU will integrate these files into the main text at a later date.

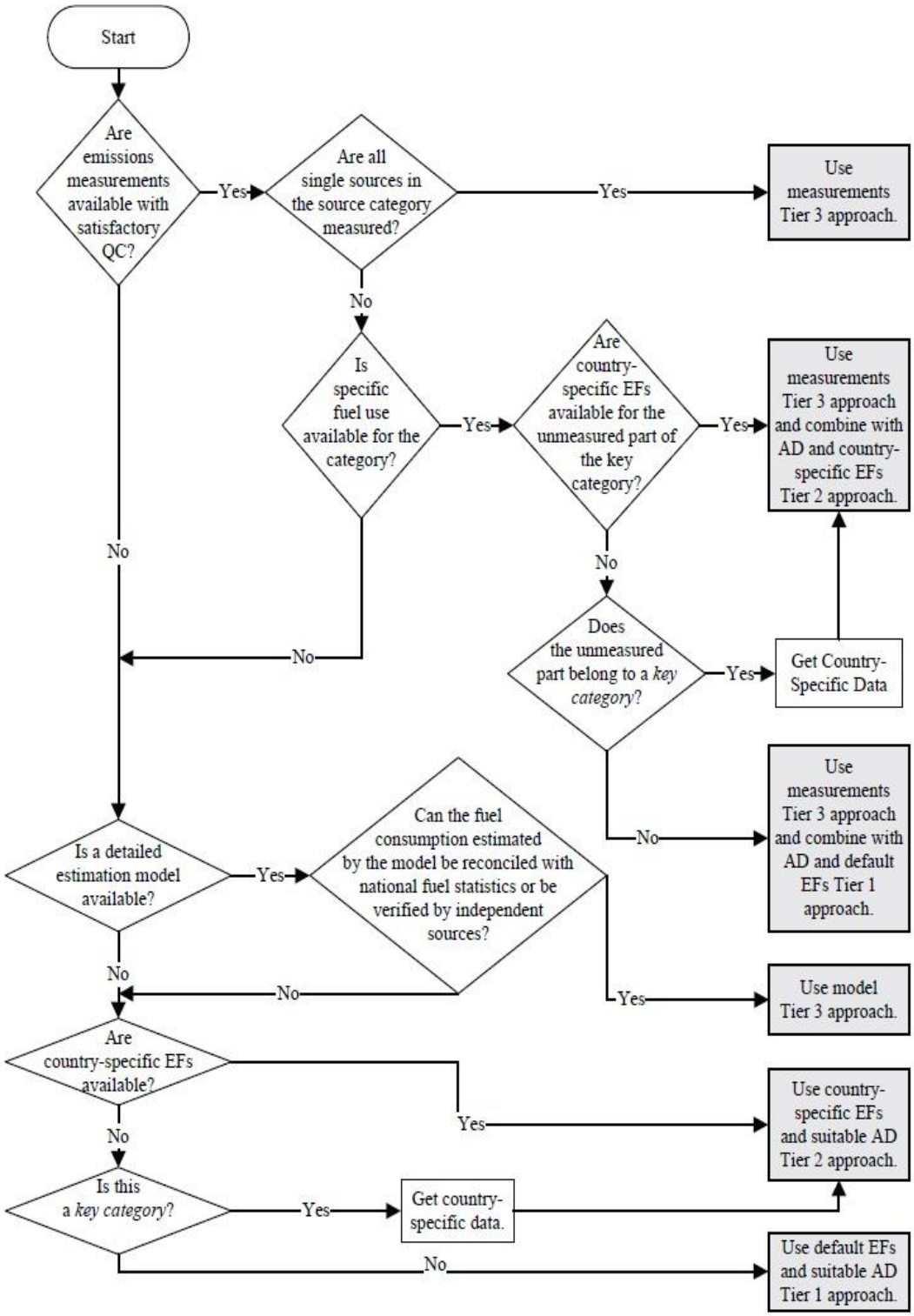
Decision trees should NOT ask the question: "Does this source occur in the country?" This is because decision trees will only be used for sources which occur.

There should be a "START" box. "Diamonds" should be used for questions/decisions. "Squares" should be used for all other information. The out-boxes should be individually numbered. The text font should be Times New Roman 10pt. Text should be centered within the boxes.

[13] As defined in the 2019 Refinement (i.e., a significant sub-category is one that makes up more than 25-30% of emissions from a category).

Example. Decision tree for estimating emissions from fuel combustion

Figure 1.2 Generalised decision tree for estimating emissions from fuel combustion



Note: See Volume 1 Chapter 4, "Methodological Choice and Key Categories" (noting section 4.1.2 on limited resources) for discussion of *key categories* and use of decision trees.

Units

58.SI units shall be used throughout: in text, equations, worksheets and tables. Emissions have to be expressed in mass units and units have to be used consistently within each sector. When similar activity data is used for different sectors same units need to be used (CLAs have to take care about such harmonisation). Conversion factors have to be provided (for example to estimate N_2O from N_2). Where input data available may not be in SI units conversions should be provided.

59.Standard abbreviations for units and chemical compounds should be used.

Standard equivalents

1 tonne of oil equivalent (toe)	1 x 10^{10} calories
10^3 toe	41.868 TJ
1 short ton	0.9072 tonne
1 tonne	1.1023 short tons
1 tonne	1 megagram
1 kilotonne	1 gigagram
1 megatonne	1 teragram
1 gigatonne	1 petagram
1 kilogram	2.2046 lbs
1 hectare	10^4 m^2
1 $calorie_{IT}$	4.1868 joule
1 atmosphere	101.325 kPa

Appendix 4. Workplan

Workplan

2027 Methodology Report on Carbon Dioxide Removal Technologies, Carbon Capture, Utilization and Storage (Supplement to the 2006 IPCC Guidelines)

Date	Action	Comments
October 2024	Scoping Meeting	Prepare ToR, ToC, Workplan and Guidance to authors
October 2024	TFB36 Meeting	Adoption of Outcomes of the Scoping Meeting and Submission to IPCC
1st half 2025	IPCC-62	IPCC Plenary approves ToR, ToC, Workplan and Guidance to authors
1st half 2025	Call for Nomination of Authors and Review Editors	IPCC invites nominations from governments and international organizations
1st half 2025	Establishment of the Steering Committee	TFB select members to join TFI Co-Chairs in the Steering Group *(to ensure consistency across all the volumes and continuity with the earlier IPCC inventory reports)*
1st half 2025	Selection of Coordinating Lead Authors, Lead Authors and Review Editors	Selection by TFB considering expertise and geographical and gender balance
2nd half 2025	1st Lead Author Meetings	LAM1 to develop zero order draft (ZOD)
2nd half 2025	2nd Lead Author Meeting	To develop first order draft (FOD) for review
Jan-Feb 2026 (8 weeks)	Expert Review	8 weeks review by experts
2026	Science Meeting	A small meeting of CLAs and some LAs to discuss specific issues that require intensive discussion to reinforce the writing process
March 2026	3rd Lead Author Meeting	To consider comments and produce second order draft (SOD) for review
July 2026	Literature cut-off date (one week before SOD Review)	Peer-reviewed papers accepted by the cut-off date (even if not yet published) will be considered. Non-peer-reviewed documents which are made publicly available by the cut-off date.
August-September 2026 (8 weeks)	Government & Expert Review	8 weeks review by governments and experts
December 2026	4th Lead Author Meeting	To consider comments and produce final draft (FD)
March-April-May 2027	Government Review	Distribute to governments for their consideration prior to approval (at least 4 weeks prior to the Panel)

July 2027	Adoption/acceptance by IPCC	Final draft submitted to IPCC Panel for adoption/acceptance
2nd half 2027	Publication	Electronic means

Appendix 5. Agenda of the Scoping Meeting

IPCC Scoping Meeting
Methodology Report on Carbon Dioxide Removal Technologies, Carbon Capture Utilization and Storage

Moltkes Palæ
Dronningens Tværgade 2, 1302 København K,
Copenhagen, Denmark
14-16 October 2024

Preliminary Agenda

Day 1	9:00 - 9:30	Registration
	9:30 - 10:00	Welcome - Marianne Thyrring, Director General of the Danish Meteorological Institute, Government of Denmark - IPCC TFI Co-Chairs (Takeshi Enoki and Mazhar Hayat)
	10:00 - 13:00	**Plenary session 1** **<u>Presentations and discussion</u>** 1. Introduction Objectives of the Meeting / Background (Rob Sturgiss, TSU) 2. Introduction to IPCC Guidance (Andre Amaro, TSU) 3. Expected outcome of the Scoping Meeting (Pavel Shermanau, TSU) Recommendation on the title and format of the Methodology Report Draft Terms of Reference (TOR) Draft Table of Contents (TOC) Draft Instructions to Experts and Authors *(Outcomes of the meeting will be included in the meeting report and will be considered by the TFB to make a proposal to IPCC-62)* Q&A
	13:00 - 14:30	*Lunch break*
	14:30 – 18:00	**Break-out group (BOG) session** **<u>Consideration of the Table of Contents</u>** **BOG1:** Direct air capture, carbon capture, utilisation and storage, carbonation processes (cement, metal industry wastes and slag), removal of CO_2 from oceans, cross-boundary issues. **BOG2:** *AFOLU* Chapters: Soils (biochar, enhanced weathering and inorganic carbon, other), biomass products other than HWP; coastal wetlands (seagrass, tidal marshes, macro algae, enhanced alkalinization); wastewater-based CDR/CCUS;

		cross-boundary issues and open water bodies (ocean fertilization, enhanced alkalinization). Given the number and diversity of issues under consideration, BOG chairs may decide to establish sub-BOGs.

18:00: Reception hosted by the Government of Denmark.

Day 2	09:30 - 13:00	**BOG session (*continuation*)** • BOG1, BOG2 and any sub BOGs
	13:00 - 14:30	*Lunch break*
	14:30 - 18:00	**Plenary Session 2** **<u>Reports from BOGs, Cross-cutting issues, Formal docs</u>** - Report from BOGs on ToC - Discussion of cross-BOG issues - Discussion of TOR, Instruction to Experts and Authors, Workplan
Day 3	09:30 - 13:00	**BOG session (*continuation*)** • BOG1, BOG2 and any sub BOGs
	13:00 - 14:30	*Lunch break*
	14:30 – 18:00	**Plenary session 3** **<u>Finalization of docs & wrap-up</u>** • Discussion and finalization of the documents to be recommended to the Task Force Bureau • Closing remarks

Coffee break: 11:00 – 11:30 and 15:30 – 16:00 every day

Appendix 6. List of Participants

IPCC Scoping Meeting
Methodology Report on Carbon Dioxide Removals and Carbon Capture, Utilization and Storage
2027 Supplement to the 2006 IPCC Guidelines

Copenhagen, Denmark
14-16 October 2024

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Appendix 7. List of Acronyms and Abbreviations

AD	Activity Data
AFOLU	Agriculture, Forestry and Other Land Use
AR	IPCC Assessment Cycle
BOG	Break-out Group
EF	Emission Factor
EMEP	European Monitoring and Evaluation Programme
GHG	Greenhouse Gas
HWP	Harvested Wood Product
IPCC	Intergovernmental Panel on Climate Change
IPPU	*Industrial Processes and Product Use*
TFB	IPCC Task Force Bureau
TFI	Task Force on National Greenhouse Gas Inventories
ToC	Table of Contents
ToR	Terms of Reference
TSU	Technical Support Unit
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change