Expert Meeting on Carbon Dioxide Removal Technologies and Carbon Dioxide Capture, Use and Storage

# The feasibility of developing new or updated IPCC default methods (and default emission factors) for various emerging technologies

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### Key considerations for new methods

- Expected Significance (future importance)
- Technological Readiness Level
- Evidence and data: Potential, costs, current implementation
- Feasibility of higher tier methods
- Globally representative
- Reportable in IPCC Emissions Factor Database (EFDB)
  - 1. Robust
  - 2. Applicable
  - 3. Documented

#### **Emerging CDR Technologies**

Technological readiness and expected significance: Mitigation pathways in AR6 focused on AR, BECCS and DACCS



Source: Authors' illustration using data from Technical Summary AR6 WGIII report, trl: technology readiness level; tech: CDR technology

Legend: AR: Afforestation/ reforestation; BC: Biochar; BECCS: Bioenergy with carbon capture and storage; DACCS: Direct Air carbon capture and storage; SCS: Soil Carbon Sequestration

### **Emerging CDR Technologies**

#### **Current Implementation of emerging CDR technologies**



Amount of carbon dioxide removal (CDR) is the sum of conventional CDR (2013-2022) and novel CDR (2023)

Source: Smith et al (eds.) The State of Carbon Dioxide Removal 2024 - 2nd Edition. DOI 10.17605/OSF.IO/F85QJ (2024)

- Around 99.9% of the current implementation of CDRs is through conventional routes like afforestation/reforestation
- Emerging CDR technologies like BECCS, DACCS and Enhanced Rock Weathering are growing more rapidly that conventional methods
- Only 0.6 out of the 1.3 million tonnes of CO<sub>2</sub> from emerging technologies was stored in geological reserves

#### BECCS – case of biomass cofiring in coal power plants



Figure Source: Yang, B., Wei, Y. M., Liu, L. C., Hou, Y. B., Zhang, K., Yang, L., & Feng, Y. (2021). Life cycle cost assessment of biomass cofiring power plants with CO2 capture and storage considering multiple incentives. *Energy Economics*, *96*, 105173.

- How to measure CDR from biomass co-fired coal power plant? Type of CO<sub>2</sub> capture? post-, pre- or oxy-fuel combustion?
- Fugitive emissions from pellet production and biomass to liquid and biomass to gas conversion (Appendix 4A.2 and 4A.3 in the 2019 Refinement to the 2006 Guidelines)
- Tier 1 EF from biomass combustion
- Tier 3: modelling methodology (plant level)
- Sources of biomass (tier 2/3) managed forests, energy crops, waste and residues, 1<sup>st</sup> versus 2<sup>nd</sup> generation biomass
- Carbon neutrality of biomass
- Where and how to classify? Energy, AFOLU?

## BECCU/S – case of biomethane production



Schematic diagram for biogas with CCU and CCS

- Methods for CCU and CCS in biogas production systems
- 2006 and 2019 refinement guidelines already have some methods for bioenergy production
- Further expansion and mainstreaming of biomass to fuel conversion annexures from 2019 refinement to 2006 guidelines
- More representative emission factors measurement is required

#### BECCUS – case of bioenergy-CO2-EOR system



**Figure Source:** Patange, O. S., Garg, A., & Jayaswal, S. (2022). An integrated bottom-up optimization to investigate the role of BECCS in transitioning towards a net-zero energy system: A case study from Gujarat, India. *Energy*, *255*, 124508.

- Example of a net-zero energy system with CO<sub>2</sub> capture, utilization and storage connected to multiple sectors
- Methods and measurement guidelines for CCUS based netzero systems
- How to report emissions and CDR across Energy, IPPU, AFOLU and Waste sectors?

## Soil Carbon Sequestration (SCS)



## • Mature technology, methodological and measurement guidelines available

- Forestry and agriculture soil organic carbon emission factor
- Representativeness of the emission factors
- Uncertainty assessment would be important
- Measurement in different types of soils

## Other anthropogenic mineral and biological CDRs

- Afforestation/Reforestation, agroforestry, improved forestry management – mature technologies/practices, mature guidelines
- Biochar mature technology, possibility of developing default removal factors?
- Blue carbon management nascent technology, low potential and expected significance, candidate for tier 3?
- Enhanced Weathering nascent technology, candidate for tier 3, draw reference from biochar?
- Ocean Alkalization nascent technology, candidate for tier 3?

### Direct Air Capture (DAC) – case of net-zero aviation fuels

#### DAC with CCS



**Figure Source:** Becattini, V., Gabrielli, P., & Mazzotti, M. (2021). Role of carbon capture, storage, and utilization to enable a net-zero-CO2-emissions aviation sector. *Industrial & Engineering Chemistry Research*, *60*(18), 6848-6862.

- Two prevalent technologies Emission factors measurement
- What EF to measure?
  - EFDB criteria
- Where to report?
- How to classify? Energy, IPPU?
- Few plants exist in the world, applicability? – tier 3 approach?

#### Direct Air Capture (DAC) – case of net-zero aviation fuels

#### DAC with CCU



Figure Source: Becattini, V., Gabrielli, P., & Mazzotti, M. (2021). Role of carbon capture, storage, and utilization to enable a net-zero-CO2-emissions aviation sector. *Industrial & Engineering Chemistry Research*, 60(18), 6848-6862.

#### • What to measure?

- Leakage factor,
- Energy penalty of conversion,
- Efficiency of conversion
- Byproducts
- Documentation of FT synthesis and hydrogen
- Measurement of Emission factors for Green Hydrogen production (share of renewables versus batteries)
- Country representativeness?





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