Existing guidance and need for updating on carbon dioxide capture in Volume 2 of the IPCC Guidelines

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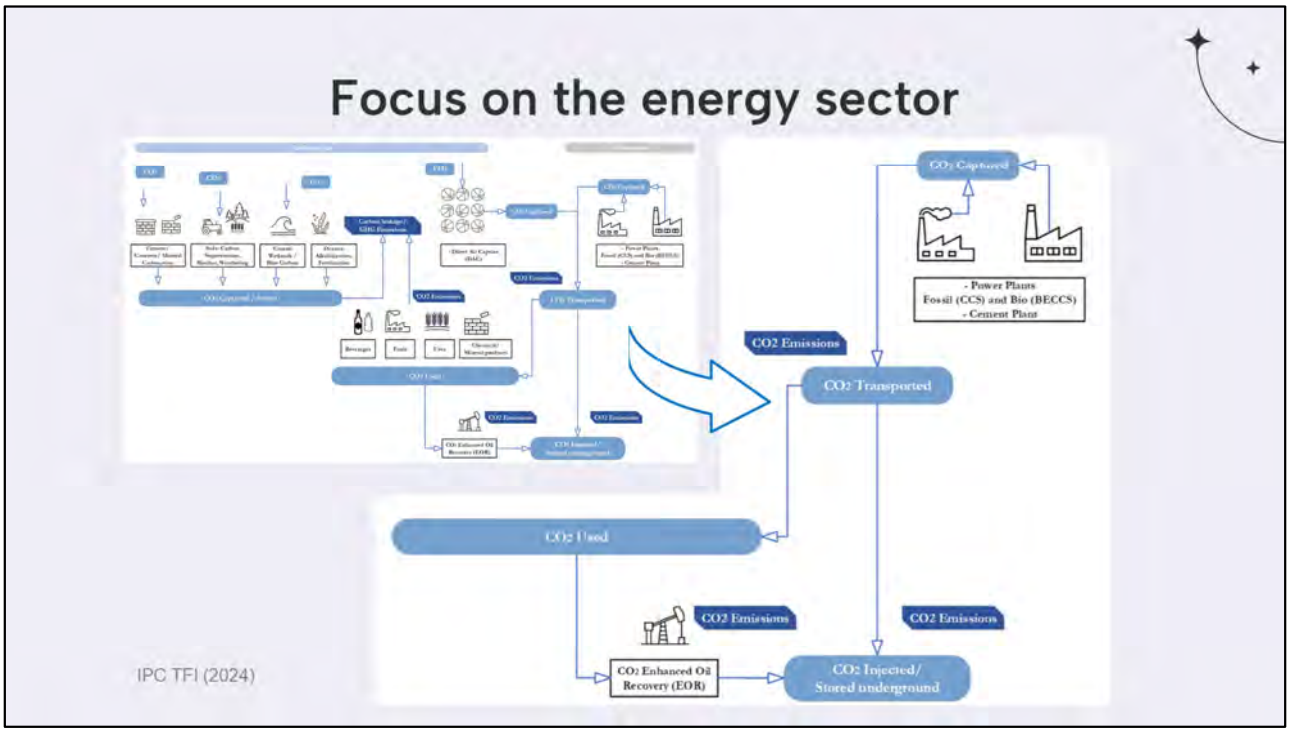
Scope

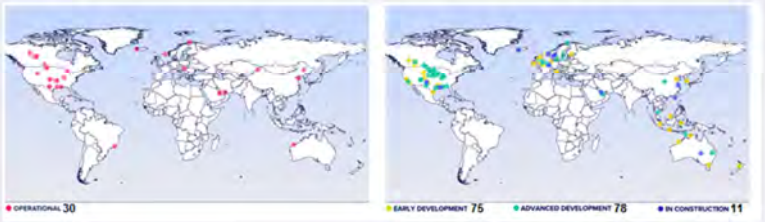
Energy sector
Status of CCS worldwide



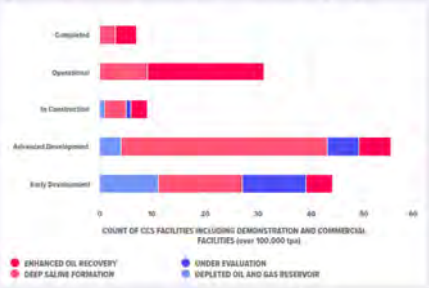
This talk focuses on the South East part of Figure 1 (Conceptual pathways of carbon dioxide removals, generation, capture and storage) of the Background Paper prepared by the TSU for this meeting. This sector do the figure corresponds to the emissions and removals of CO_2 that are estimated and reported in the energy sector of the national GHG emission inventories.

Status of CCS facilities worldwide

- CCS facilities



- Full value chain CCS: single CO_2 capture plant with its own dedicated compression, transport and storage systems.
- CCS networks: shared transport and storage infrastructure, are becoming the predominant method of deployment.
- Transboundary transportation of CO_2 for geological storage: in addition to pipelines, shipping is emerging as an essential transport vector when CO_2 sources and storage sites are too far away.
- Average injection rate per project is increasing: from > 1 Mt year^{-1} to 5 Mt year^{-1} in the CCS networks in development.
- Potential and current CO_2 stored across storage types and deployment status



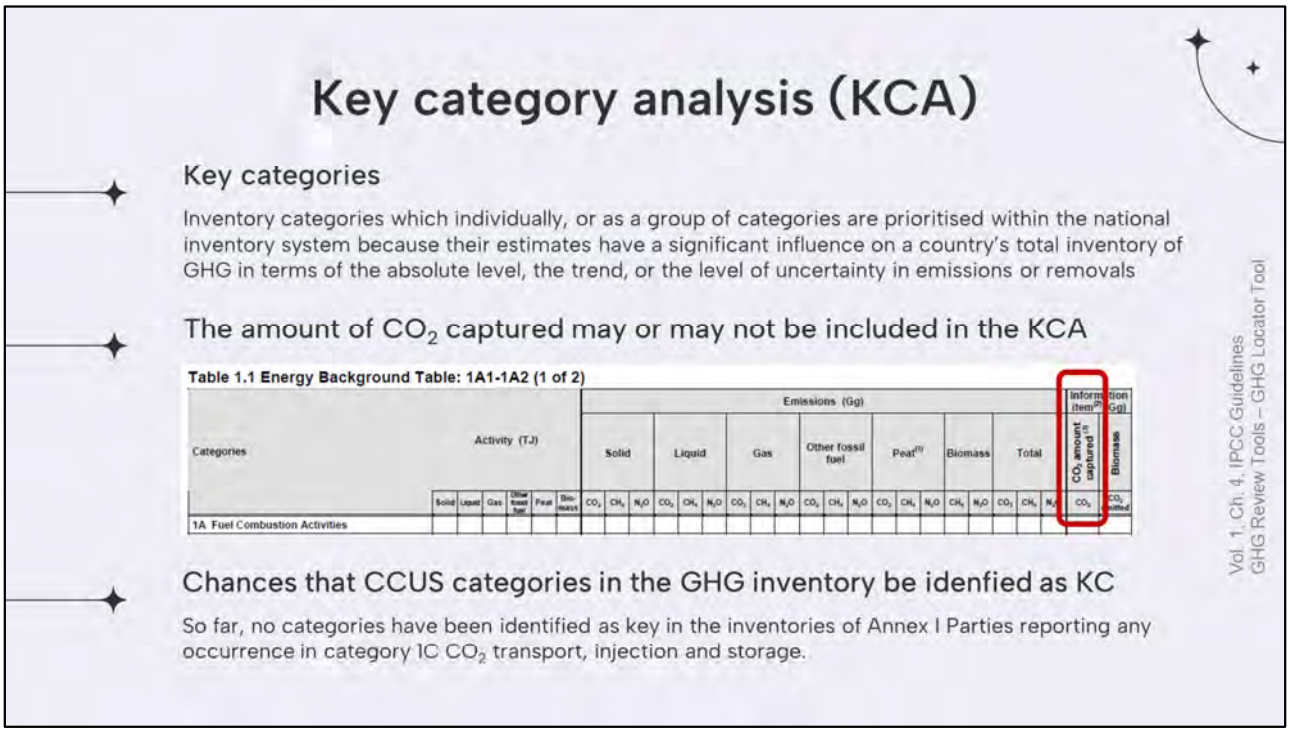
Global CCS Institute (2022)

Selected topics from the "Global Status of CCS 2022" report showing current facilities and trends in CO_2 capture, transport, injection and storage, which are expected to be taken into account when preparing the new IPCC Methodological Report for the preparation of national greenhouse gas inventories on CCS activities.

2

Key categories

Generalized decision tree for fuel combustion
Methodological choice

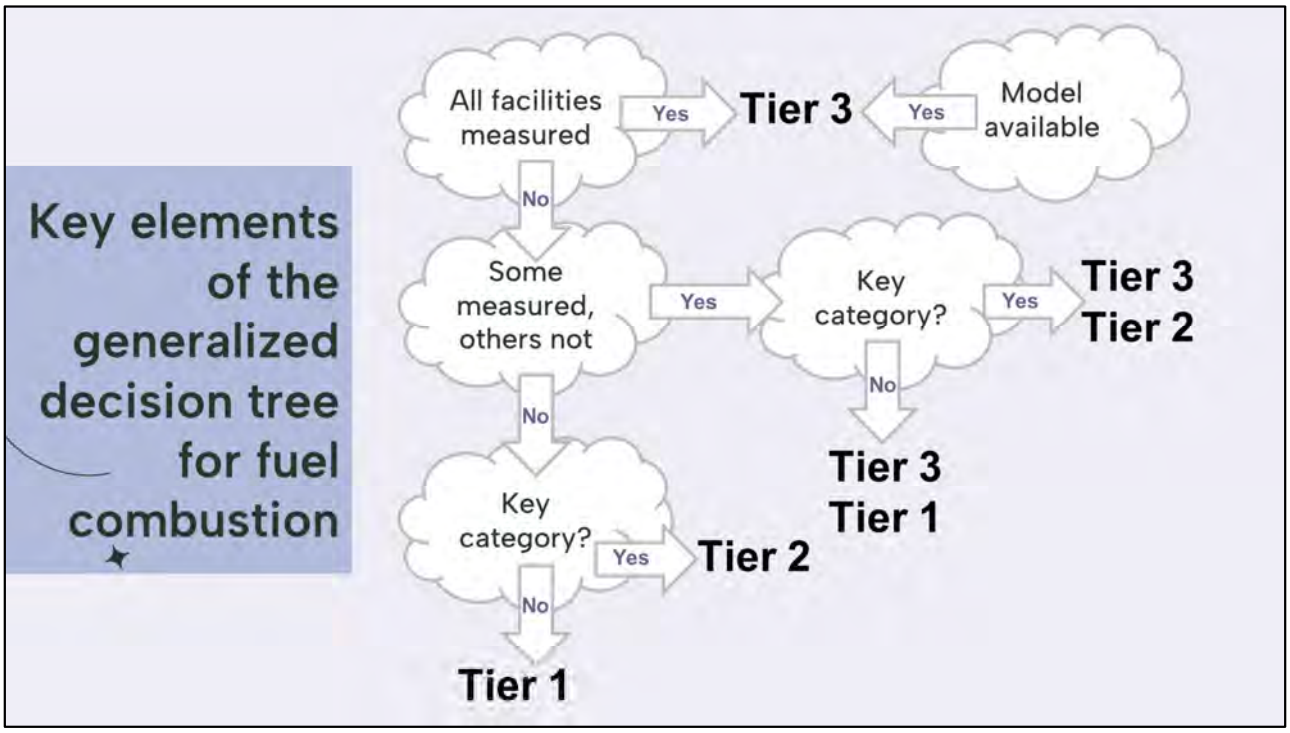


With the exception of pipeline transport, the 2006 IPCC Guidelines only provide tier 3 methods for the other components of a CCS system. The choice of estimation method depends on the available information and whether or not CO_2 emissions/removals from the activity in question have been identified as a key category.

Identification of key categories is used to prioritize the limited resources available for preparing inventories. It is good practice to allocate enough resources to improve data and methods for key categories. More detailed higher-tier methods should be used for key categories.

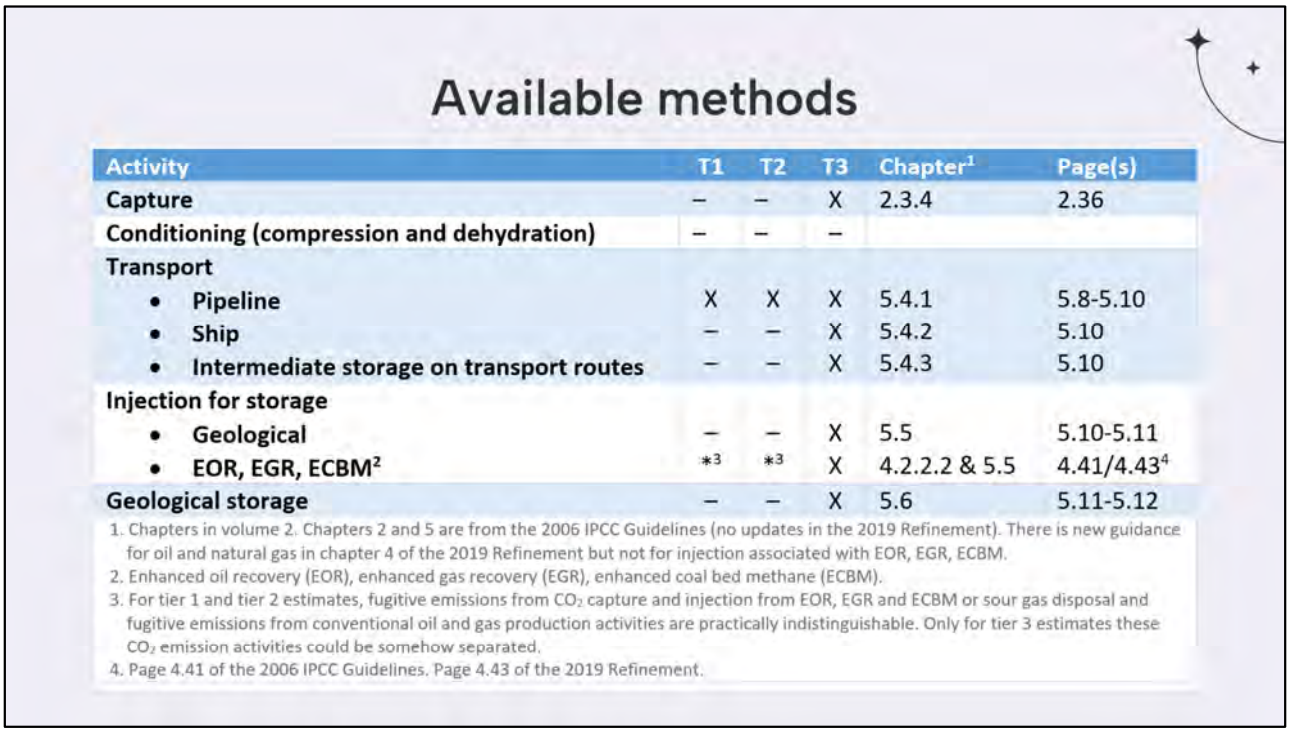
KCA should be performed at the level of categories or subcategories at which the IPCC methods are applied in the inventory. All direct GHGs should be included in the key category analysis. Generally, each greenhouse gas emitted from each category should be considered separately. If data are available, the key category analysis should be performed for emissions and removals separately within a given category.

The corresponding KCA results from the six Annex I Parties (Australia, Canada, Iceland, Japan, Norway and the USA) that include CO_2 transport, injection and storage in their respective national GHG inventories did not identify any CCS activities as key.



This is a simplified version of the generalized decision tree for estimating emissions from fuel combustion (Vol. 2, Ch. 1 of the 2006 IPCC Guidelines).

It describes the spirit behind good practice in estimating GHG emissions and removals in national inventories. In essence, the idea is to select higher tier methods based on the availability of information, with the lower tier 1 being acceptable only when estimating emissions or removals from a non-key category.



Available methods

Activity	T1	T2	T3	Chapter[1]	Page(s)
Capture	–	–	X	2.3.4	2.36
Conditioning (compression and dehydration)	–	–	–		
Transport					
• **Pipeline**	X	X	X	5.4.1	5.8-5.10
• **Ship**	–	–	X	5.4.2	5.10
• **Intermediate storage on transport routes**	–	–	X	5.4.3	5.10
Injection for storage					
• **Geological**	–	–	X	5.5	5.10-5.11
• **EOR, EGR, ECBM[2]**	*[3]	*[3]	X	4.2.2.2 & 5.5	4.41/4.43[4]
Geological storage	–	–	X	5.6	5.11-5.12

1. Chapters in volume 2. Chapters 2 and 5 are from the 2006 IPCC Guidelines (no updates in the 2019 Refinement). There is new guidance for oil and natural gas in chapter 4 of the 2019 Refinement but not for injection associated with EOR, EGR, ECBM.
2. Enhanced oil recovery (EOR), enhanced gas recovery (EGR), enhanced coal bed methane (ECBM).
3. For tier 1 and tier 2 estimates, fugitive emissions from CO_2 capture and injection from EOR, EGR and ECBM or sour gas disposal and fugitive emissions from conventional oil and gas production activities are practically indistinguishable. Only for tier 3 estimates these CO_2 emission activities could be somehow separated.
4. Page 4.41 of the 2006 IPCC Guidelines. Page 4.43 of the 2019 Refinement.

Methods in the 2006 IPCC Guidelines for CCS.

EOR, EGR, ECBM (in the IPCC Guidelines)
"Oil and gas projects that involve CO_2 injection as a means of enhancing production (…) or as a disposal option (…) should distinguish between the CO_2 capture, transport, injection and sequestering part of the project, and the oil and gas production portion of the project. The net amount of CO_2 sequestered and the fugitive emissions from the CO_2 systems should be determined based on the criteria specified in Chapter 5 for CO_2 capture and storage." (Vol. 2, Ch. 2, Section 4.2.2.2 of 2006 IPCC Guidelines and the 2019 Refinement).

"Emissions from underground storage reservoirs at EOR, EGR and ECBM sites are classified as emissions from geological storage sites and Section 5.7 of this Chapter provides guidance on estimating these emissions." (Vol. 2, Ch. 5, Section 5.2 of the 2006 IPCC Guidelines).

CO_2-EOR and CCS (some views from recent references)
"The historic dominance of CO_2 stored through EOR is understandable given the CCS industry was born out of EOR in the US. These facilities showed that million-tonne CO_2 injection rates at multimillion-tonne storage sites were possible. Importantly, monitoring confirms that all the CO_2 injected is ultimately stored." (Global CCS Institute, 2022).

"The scientific literature shows that there could be overlaps between monitoring at both CO_2-EOR and dedicated CO_2 storage sites. (…) Leakage from storage sites is an aspect of monitoring that is included in some articles (…). Leakage of CO_2 could have a negative impact on climate change mitigation measures. According to Thorne et al. (2020), the amount of leakage in CO_2-EOR processes is uncertain (…) (Rodriguez 2023).

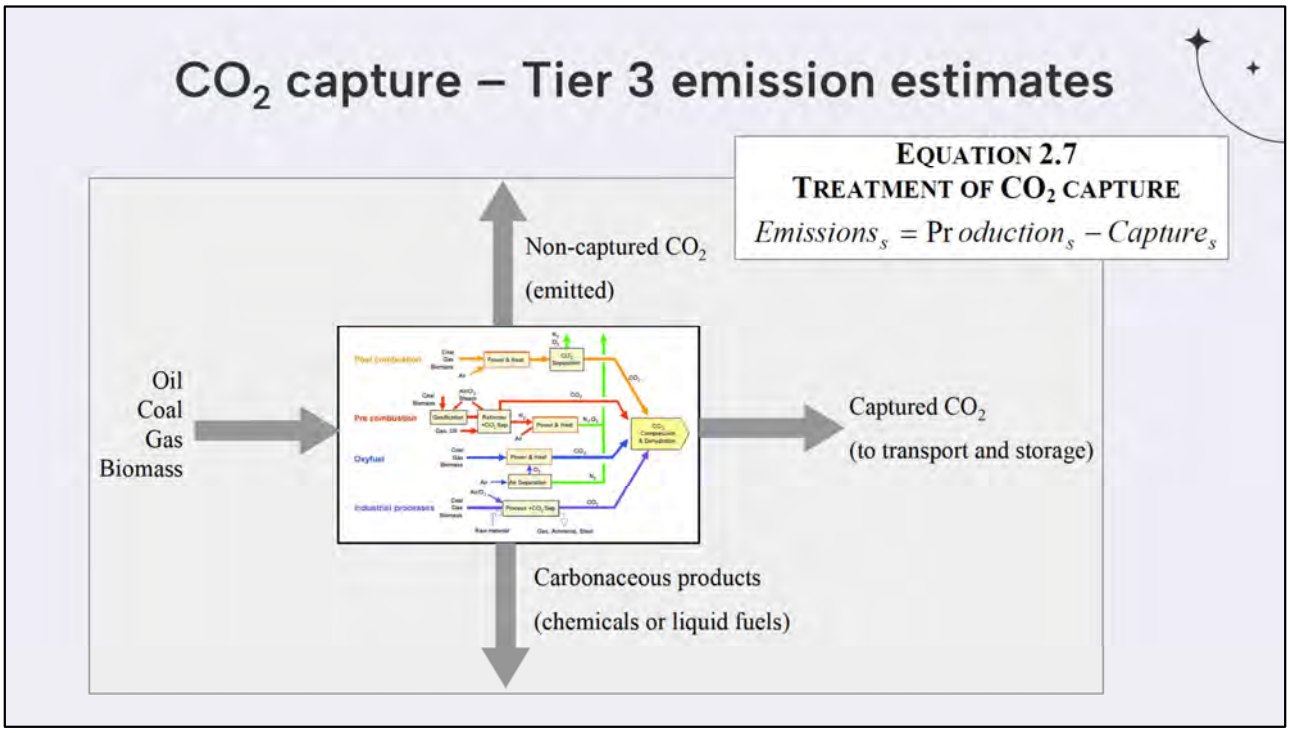
"Monitoring to document storage efficiency and to provide assurance of CO_2 containment during and after project operation is likely to become more important over the coming years".

(Eide et al., 2019).

3

Engineered CO_2 capture

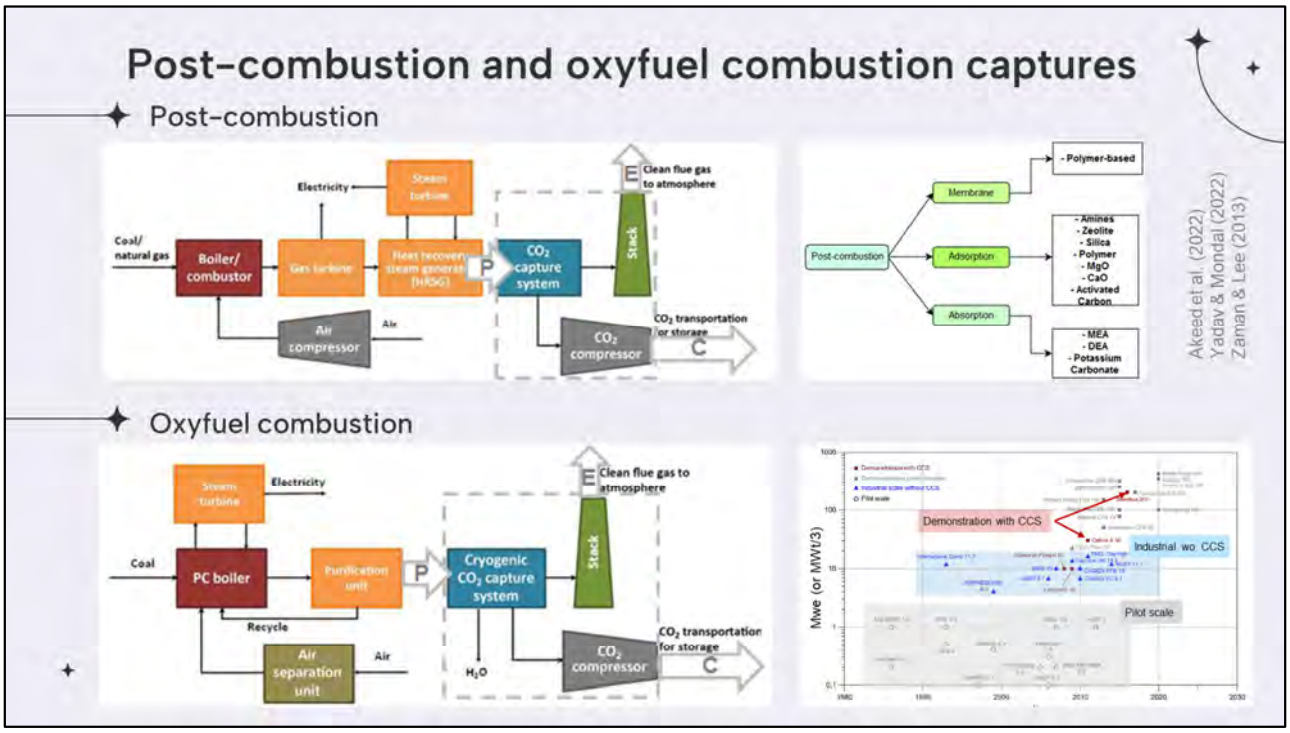
Post and oxyfuel combustion
Pre combustion



The slide combines selected points in Vol. 2 of the 2006 IPCC Guidelines relative to CO_2 capture:

- Outer (gray) diagram: Figure 2.6 - Carbon flows in and out of the system boundary for a CO_2 capture system associated with stationary combustion processes (ch. 2, section 2.3.4).
- Inner (color) diagram: Figure 5.2 - CO_2 capture systems (After the IPCC Special Report on Carbon Dioxide Capture and Storage) (ch. 5, section 5.3).
- Equation 2.7 to estimate CO_2 emissions from the non-captured CO_2
  - *s* = source category or subcategory where capture takes place
  - $Capture_s$ = Amount captured.
  - $Production_s$ = Estimated emissions, using these guidelines assuming no capture
  - $Emissions_s$ = Reported emission for the source category or sub-category

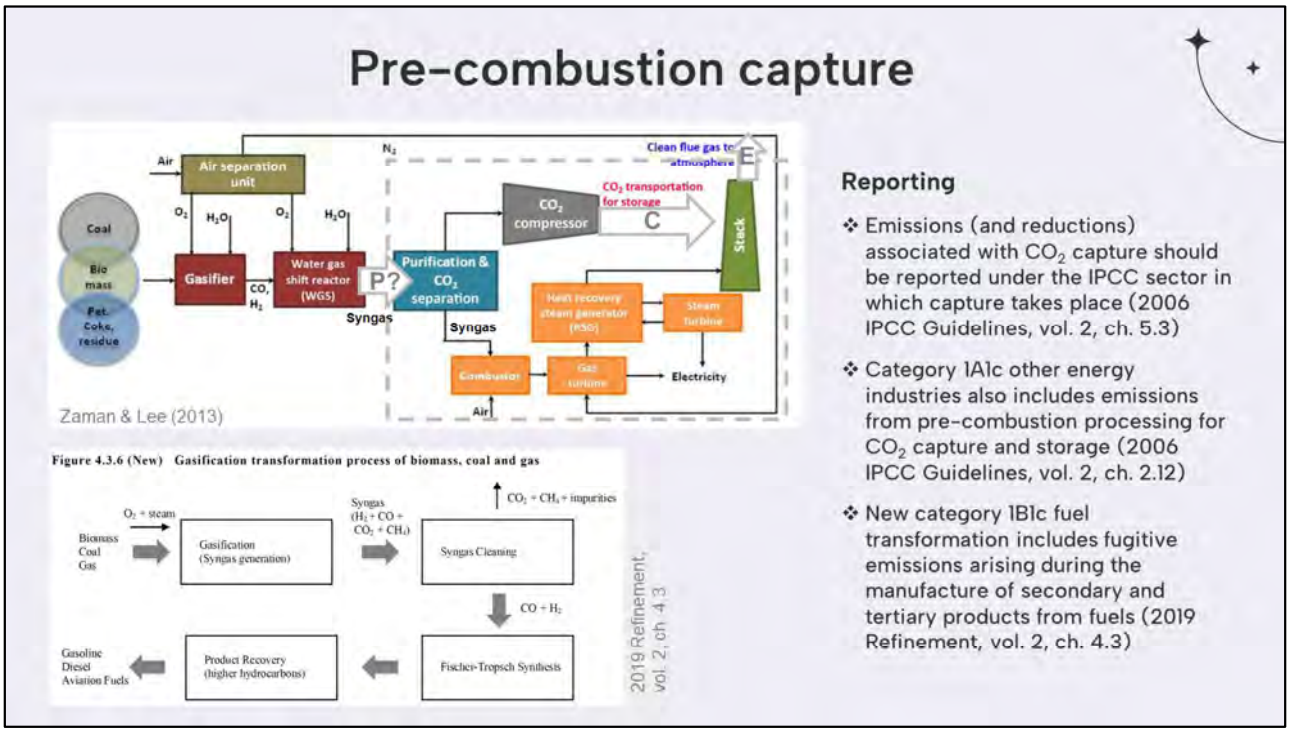
According to how $Production_s$ was estimated there may exist double counting of the non-CO_2 gases from combustion emissions (e.g., CH_4, CO, NMVOC)



The post-combustion and oxyfuel combustion capture schemes were taken from the review article by Zaman & Lee (2013). The carbon flows in Fig. 2.6 of the 2006 IPCC Guidelines were superimposed for ease of reference. Equation 2.7 can be readily applied to both capture schemes.

The figure on the upper right, taken from the review article by Akeeb et al. (2022), shows the various technologies available for post-combustion capture, with amine-based absorption being the leading option.

The figure on the lower right, taken from the review article by Yadav & Mondal (2022), depicts the historical progression of oxy-fuel combustion technology development from the lab to commercial deployment. The commercial feasibility of this technique depends on the verification of theories and observations of the bench and laboratory-scale facilities through pilot-scale and industrial demonstration projects for oxy-fuel combustion. Almost all operating pilot and demonstration projects have a capacity of less than 100 MWth.



The pre-combustion scheme, also taken from Zaman & Lee (2013), allows to visualize the main differences between the pre-combustion and the post-combustion and oxyfuel combustion schemes.

The first step in pre-combustion capture is a fuel transformation process similar to the gasification processes in the new fugitive emissions subcategory 1B1C-fuel transformation in the 2019 Refinement. In this regard, what is the *Production*$_s$ stream needed to apply Eq. 2.7?

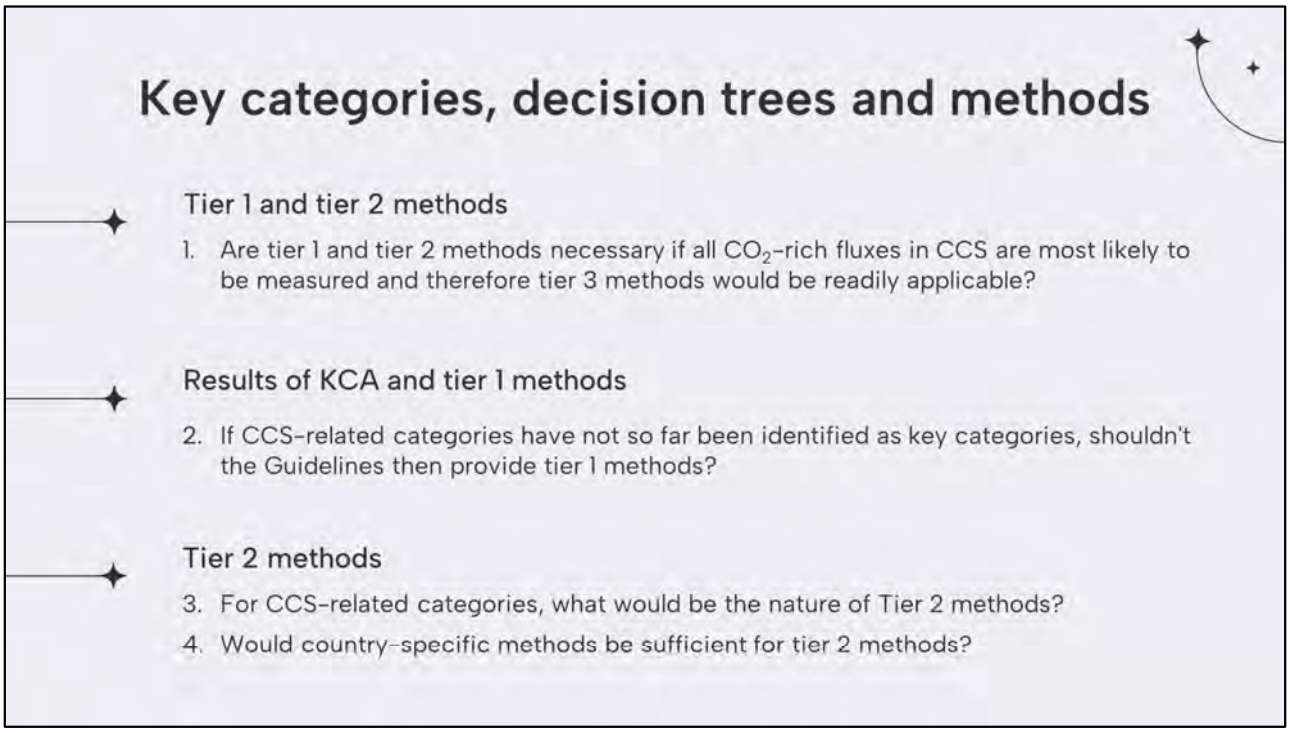
Regarding the allocation of emissions and removals, the IPCC guidance indicates that they should be reported under the IPCC sector where the capture takes place, the energy sector in this case.

- Emissions from combustion associated with the heat required for the fuel transformation process should be reported under 1A1c other energy industries.
- Where should the fugitive emissions from the fuel transformation process be allocated?

4

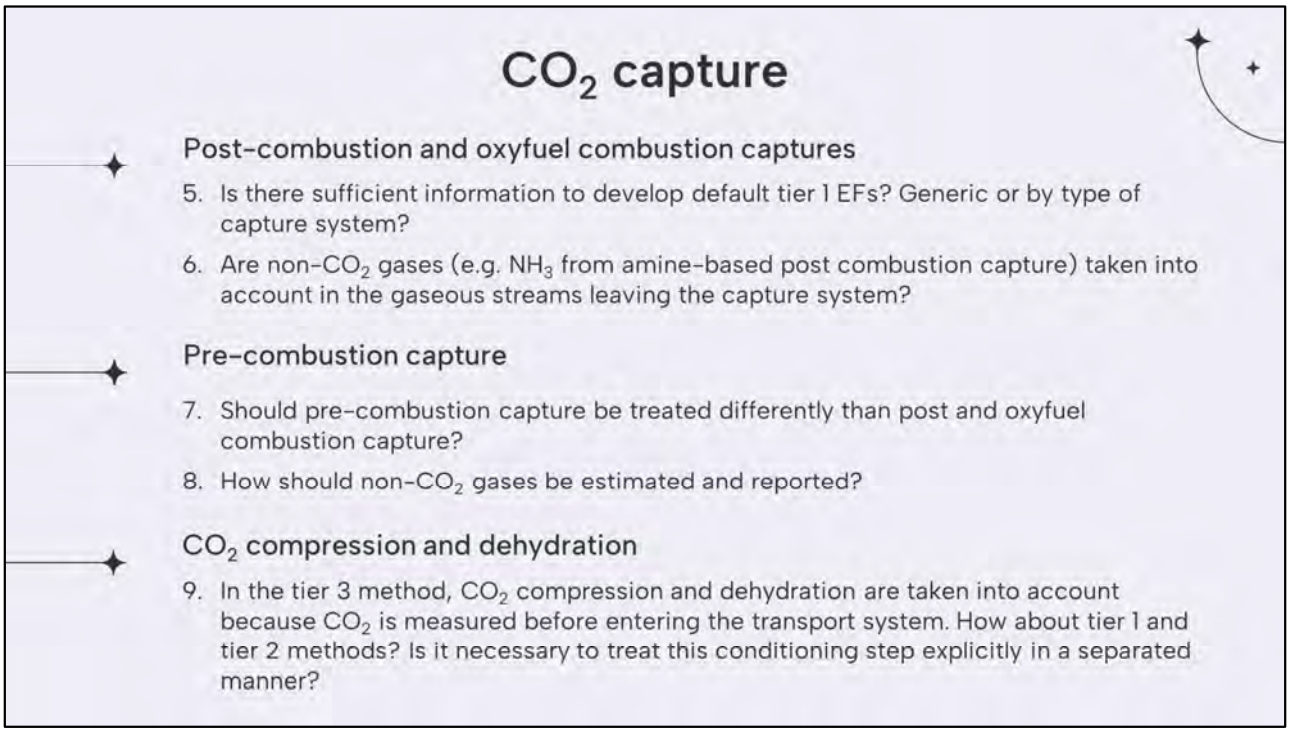
12 Questions

Possible topics for discussion at BOG 1

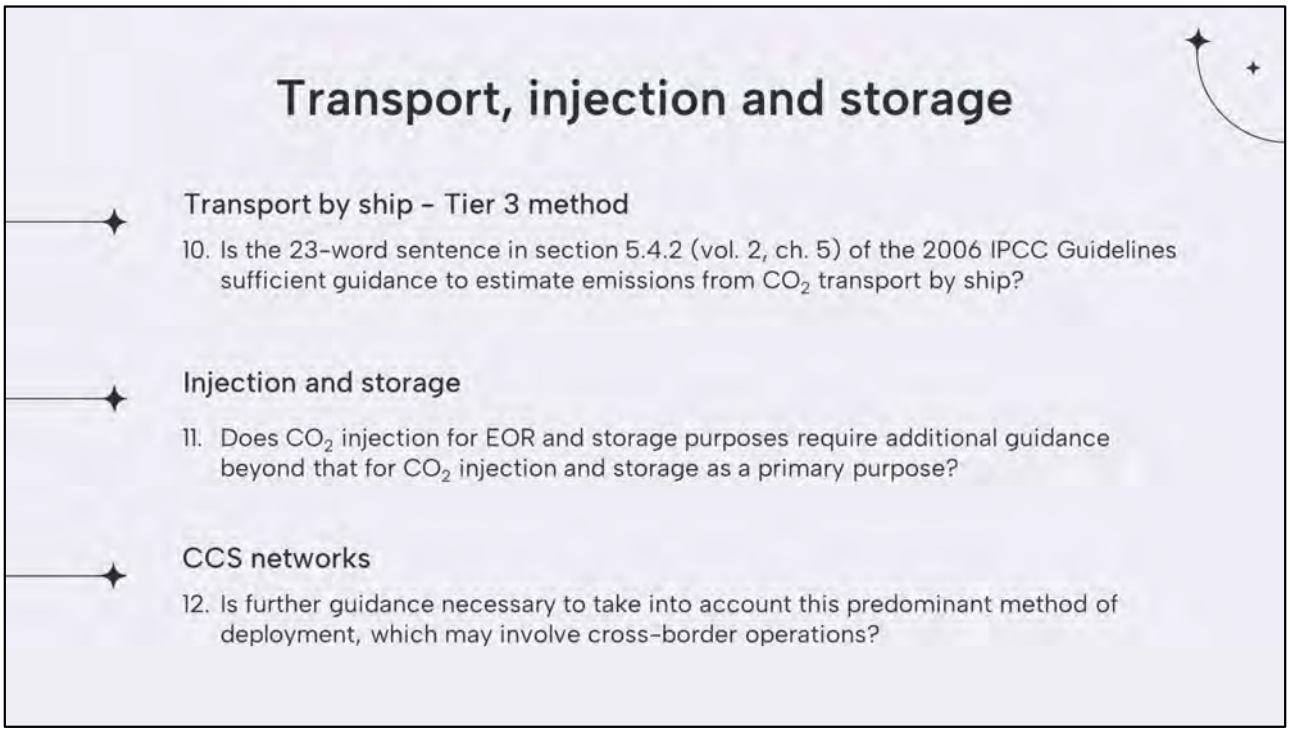


1. If the answer to this question is yes, it will only be necessary to slightly update the existing guidance.
2. If a CCS activity has not been identified as a key category and neither measurements nor models are available, a tier 1 approach would be desirable. In addition, the results of a tier 1 method would be useful for comparison with the results of higher tier approaches.

3-4. In the energy sector tier 2 methods are in general country-specific, although there are exceptions such as road transport, for which the tier 2 approach uses fuel-based emission factors specific to vehicle subcategories, aviation, which is based on the number of landing/take-off cycles (LTOs) and fuel use, or coal mining and handling, for which the tier 2 method is country- or basin-specific.



5. For post-combustion capture, there appears to be sufficient information to develop Tier 1 emission or removal factors for the main amine-based absorption technology. It would be interesting to identify possible default parameters for other technologies. For oxyfuel combustion capture, the review by Yadav & Mondal (2022) seems to indicate that further studies are needed to typify the performance of this technology. However, it is not for this meeting to decide whether or not a Tier 1 method could be developed in the near future.
6. Section 2.3.4 (Vol.2) of the 2006 IPCC Guidelines indicates that in those processes associated with post-combustion and oxyfuel combustion capture systems, no carbonaceous coproducts are typically produced. Because of the boundary selected for the treatment of CO_2 capture, it is implicit that all non-CO_2 gases from combustion leave in the $Production_s$ stream. However, according to the capture technology other gases may me generated, being NH_3, a short-lived climate forcer, emitted from amine-based absorption.
7. In post-combustion capture and oxyfuel combustion capture the fuel for electricity and heat production is directly combusted while in pre-combustion capture, the fuel is firstly transformed to the fuel that is finally combusted.
8. The fuel transformation system at the beginning of the pre-combustion system generate fugitive emissions. Are these emissions to be also included under the corresponding stationary combustion category, typically 1A1 energy industries?
9. No additional comment.



10. "Default emission factors for fugitive emissions from CO_2 transport by ship are not available. The amounts of gas should be metered during loading and discharge using flow metering and losses reported as fugitive emissions of CO_2 resulting from transport by ship under category 1C1 b."
11. The 2006 IPCC Guidelines indicate that the guidance for geological storage also covers the emissions from underground storage reservoirs at EOR, EGR and ECBM. Recent literature discusses that there could be overlaps between monitoring at both CO_2 -EOR and dedicated CO_2 storage sites. However, it is worth considering whether CO_2 storage associated with EOR, EGR and ECBM merits special treatment in the future Guidelines.
12. Given that CS systems are evolving from full value chain CCS (single CO_2 capture plant with its own dedicated compression, transport and storage systems) to CCS networks (shared transport and storage infrastructure) it is advisable to consider whether additional guidance is needed to consider the latter method of deployment.

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¡Thank you!

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