Experiences with the 2006 IPCC Guidelines

Engineered CO_2 Capture, Transport and Storage (Volume 2 and 3)

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CARBON COUNTS

Some MRV milestones for sink enhancements

Kyoto Protocol

CDM A/R Modalities & Procedures

CDM CCS Modalities & Procedures

Paris Agreement

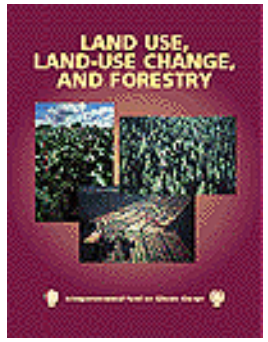
Enhanced Transparency Framework

Article 6 RMPs

2000

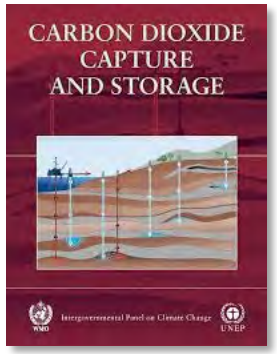
2010

2020

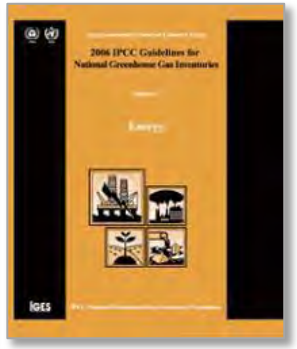


2000 SR LULUCF

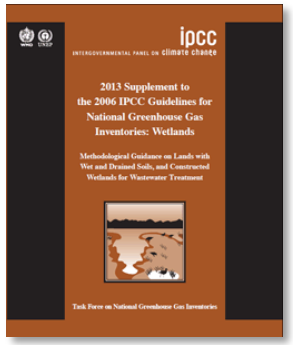
2003 GPGs LULUCF



2005 SR CCS



2006 GLs



2013 Wetlands

2019 GLs Refinement

2024 CDR Expert Meting etc…

2006 IPCC Methodological Basis | CO_2 capture

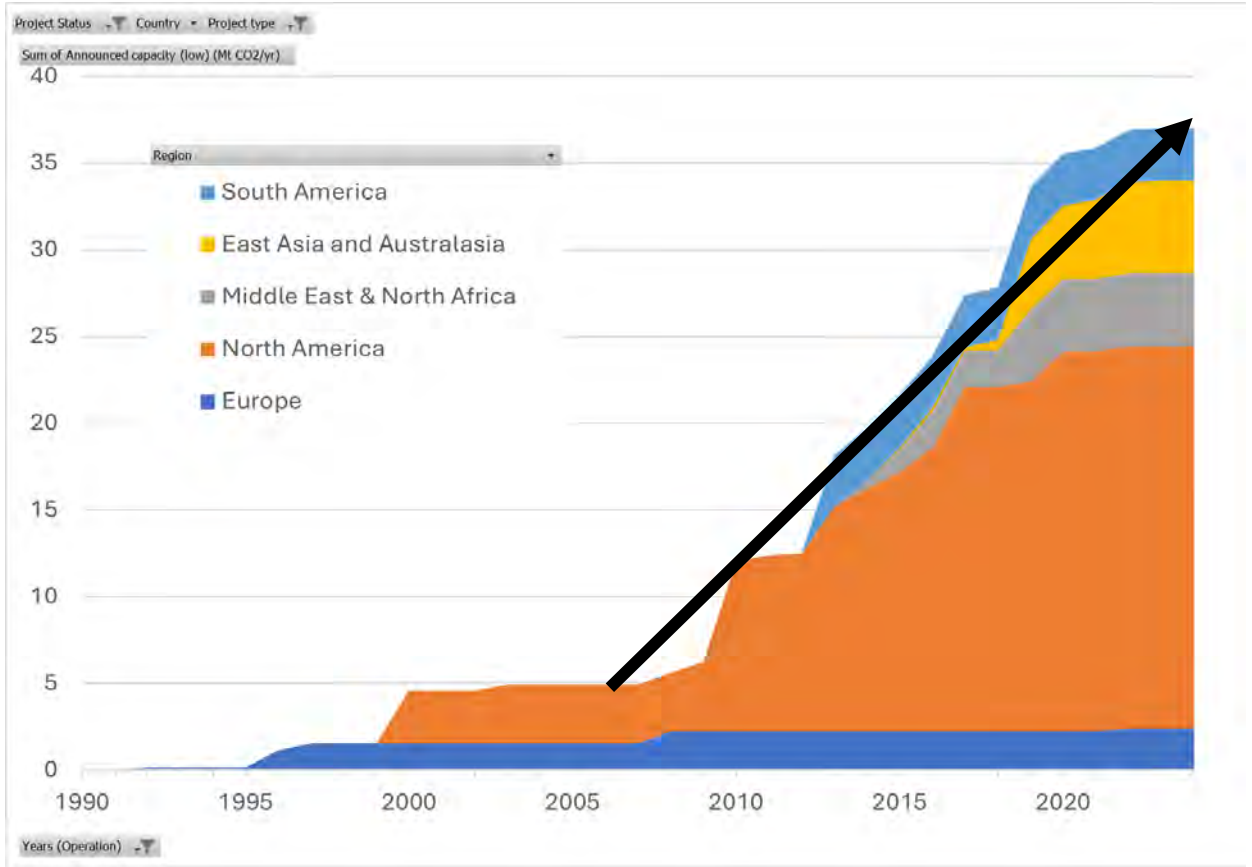
- **2006 IPCC Guidelines** first edition to cover CCS and monitoring of enhanced geological sinks
- **Volume 1, Chapter 1 (Introduction)**. General concepts for reporting:
  - CO_2 emissions from biomass combustion for energy are reported in AFOLU Sector as net changes in C stocks
  - Captured CO_2 should be allocated (i.e. reported as emitted) in the sector generating the CO_2 **unless** it can be shown that the CO_2 is stored in properly monitored geological storage sites as set out in Chapter 5, Volume 2.
- **Volume 2, Volume 3, (Energy; IPPU).** Allow for captured CO_2 to be deducted, per above proviso. For BECCS:
  - CO_2 emissions = zero (already in national totals in the AFOLU sector)
  - Subtraction of gas transferred to long-term storage may give negative emissions (in the Energy Sector).
  - Corollary: any subsequent CO_2 emissions (transport/injection/storage) counted in national total emissions, irrespective of whether the carbon originates from fossil sources or recent biomass production

2006 IPCC Methodological Basis | CO_2 transport

Type	Method
Truck and rail	Not covered
Pipelines	Default emission factors [**Tier 1**] are derived from the emission factors for transmission (pipeline transport) of natural gas.
Ship	Default emission factors [Tier 1] 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 [**Tier 3, mass balance**]
Intermediate storage	Tanks: fugitive emissions to be calculated using default factors [**Tier 1**] Geological reservoirs: emissions calculated as per storage [**Tier 3**]

2006 IPCC Methodological Basis | CO_2 Storage

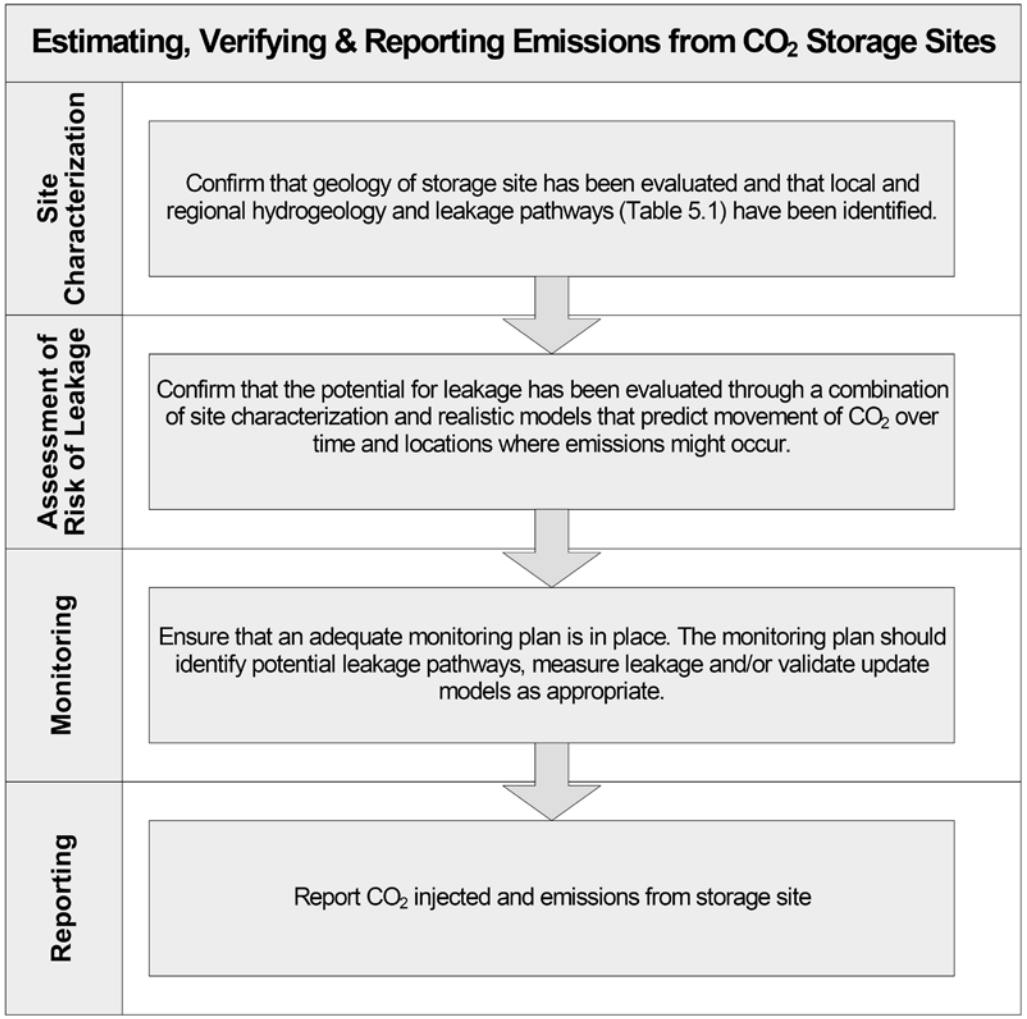
- Insufficient empirical evidence to produce emission factors that could be applied to leakage from geological storage reservoirs.
- Guidance therefore does not include Tier 1 or Tier 2 methodology. Possibility of developing such methodologies in the future, when more monitored storage sites are in operation and existing sites have been operating for a long time.
- A site-specific **Tier 3** approach can, however, be developed



Derived from IEA CCUS Projects Database

2006 IPCC Methodological Basis | CO_2 Storage

- Suitability and efficacy of monitoring tech influenced by the geology and potential emissions pathways at individual storage sites, so site-by-site approach
- Risk-based Tier 3 approach – fate of CO_2 determined through:
  1. Geological characterisation (build confidence of "no leakage")
  2. Modelling (prediction of future CO_2 behaviour)
  3. Monitoring (observed CO_2 behaviour)
  4. Model validation/calibration + update
- Inventory compiler can rely on regulatory framework, where present. Otherwise….



2006 IPCC Methodological Basis | CO_2 Storage

Inventory Compiler guidance (or achieved through appropriate regulatory body)

5.7.1 Methodological Procedure

Identify and document all geological storage operations in the jurisdiction

1. Determine whether an adequate geological site characterization report has been produced for each storage site
2. Determine whether the operator has assessed the potential for leakage at the storage site
3. Determine whether each site has a suitable monitoring plan
4. Collect and verify annual emissions from each site

5.10 Reporting and Documentation

Prior to start, obtain and archive the following:

- Report on the methods & results of the site characterization
- Report on the methods & results of modelling
- Proposed monitoring programme including appropriate background measurements
- Year in which CO_2 storage began or will begin
- Proposed sources of the CO_2 and the infra in the whole chain

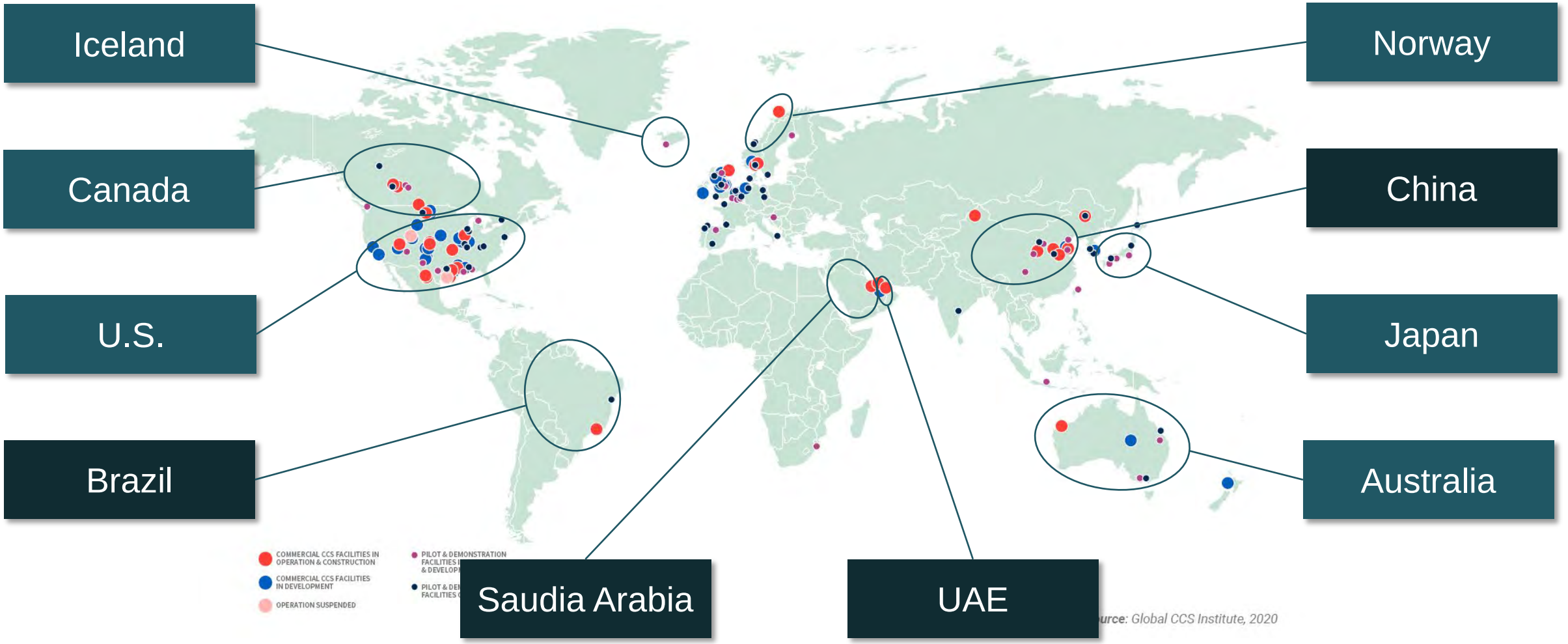
Annually from each site:

- Mass of CO_2 injected & stored
- Cumulative mass of CO_2 stored at the site
- Source (s) of the CO_2 and the infra in whole chain
- Report on rationale, methodology, monitoring frequency and results of the monitoring
- Report on any adjustment of the modelling and forward modelling in light of the monitoring results
- Mass of any fugitive emissions of CO_2 + other GHGs to atmosphere or seabed from the storage site
- Descriptions of the monitoring programmes and methods, frequency and results
- Results of 3rd party verification

2006 IPCC Methodological Basis | CO_2 Storage

- **Annex 5.1** contains substantial guidance on potential monitoring techniques:
  1. **Deep Subsurface** (2D/3D seismic; crosshole/vertical/micro seismic, well monitoring, gravity surveys)
  2. **Shallow Subsurface** (sparker seismic; towed boomer seismic; sidescan sonar etc)
  3. **Surface fluxes** (eddy covariance; accumulation chambers; gas analysis)
  4. **Raised CO_2 in soil and air** (open-path infrared gas analysis; soil gas; airborne infra-red laser etc)
  5. **Proxy measures** (satellite or airbore hyperspectral imaging; satellite interferometry/surface topography)
  6. **Sea water CO_2** (sediment gas analysis; sea water gas analysis)
- Reviewed in respect of: capabilities; detection limits; costs; limitations; current status

2006 IPCC Vol 2, Chapter 5 | Who should be doing this?



Source: Heidug, UNECE

2006 IPCC Vol 2, Chapter 5 | What are they reporting?

	Capture (avoided fossil)	Capture (-ve BECCS/DACS)	Transport (fugitive emissions)	Injection (fugitive emissions)	Storage (fug+performance)	Source
Iceland	Y / N Carbfix geotherm=Y / CRI=N	N Climeworks excluded	N	N	N	NIR, 2023
Canada	Y	n/a	Y 0.65 $ktCO_2$, T1 IPCC	Y From EOR under 1.B.2	N Refer to PTRC website	NIR, 2023
U.S.	N / Y Dakota export deducted	N	N	N	N	NIR, 2023
Brazil	N	n/a	N	N	N	BUR3, 2019 BUR4, 2021
Saudi Arabia	N	n/a	N	N	N	BUR1, 2018 BUR2, 2024
UAE	N	n/a	N	N	N	BUR1, 2023 NC5, 2023
Norway	Y Sleipner & Snohvit unvented	n/a	N T1 too high, so excluded	Y / N Only when shutdown	Y Extensive info on sites	NIR, 2023
China	N	n/a	N	N	N	NC4, 2023 BUR3, 2023
Japan	Y	n/a	N Too minor. Not estimated	N	N No info provided	NIR, 2023
Australia	Y 2.7Mt Gorgon unvented	n/a	Y Zero, T3 NGER data	Y 12 $ktCO_2$, T3 mass balance	N Refer to license+NGER	NIR, 2023

Report all as emitted

New IEAGHG report coming soon…

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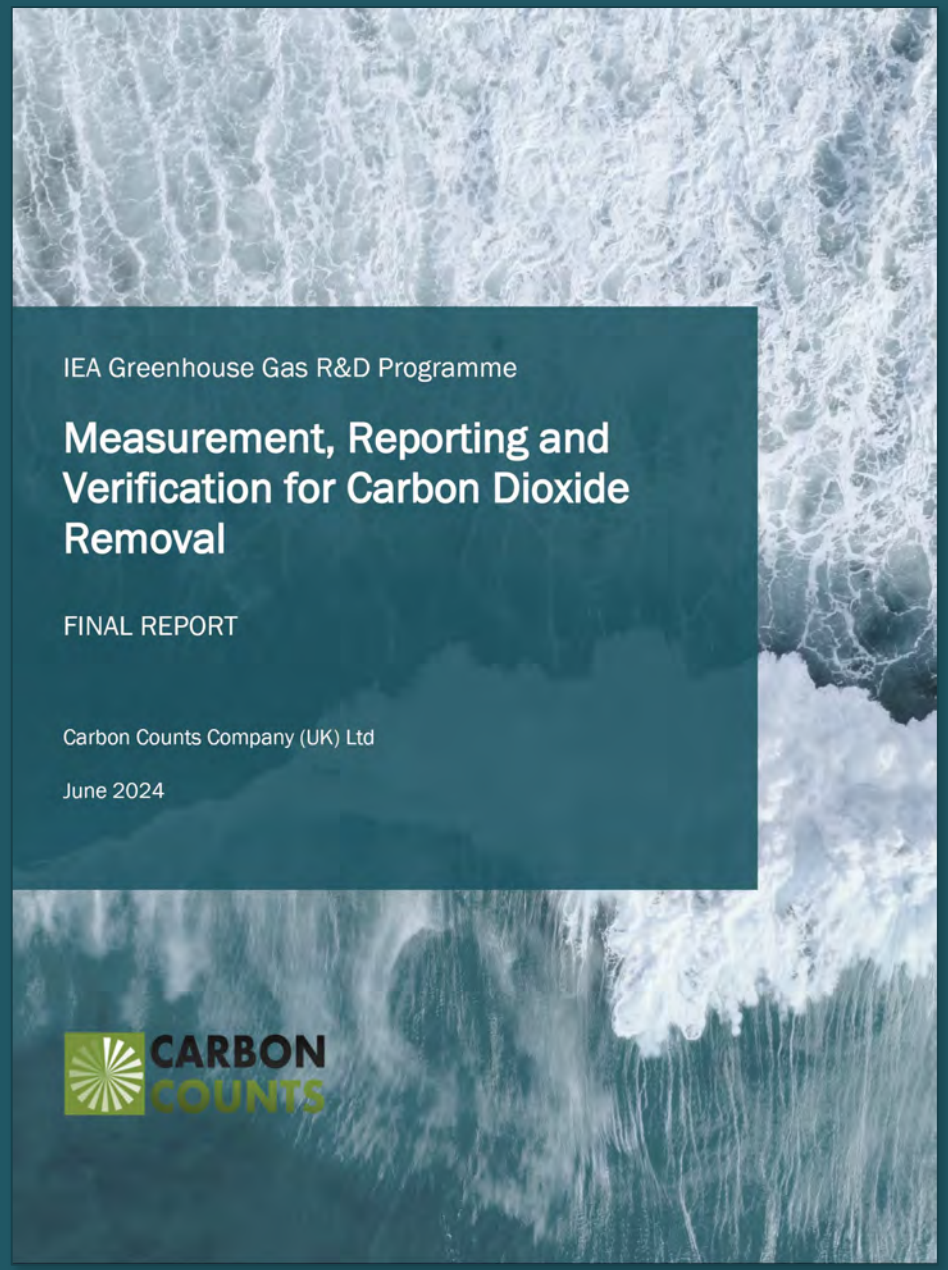

BACK UPs

CDR coverage of current IPCC Guidelines

- MRV guidance organised by sector (Energy; Industry; AFOLU; Waste)
- Nature-based CDR largely covered by Volume 4 (AFOLU) ✓

CDR method	Coverage	Applicable sections / comments	Publication
BECCS	✓	Volume 2:2 (Stationary combustion) Volume 3 (Various industrial sources) Volume 2:5 (CO_2 Transport and Storage)	2006 GLs
DACS + geostorage	~	Volume 2:5 (CO_2 Transport and Storage)	2006 GLs
DACS + mineral storage	✘	[explicitly excluded in Vol 2:5]	2006 GLs
Enhanced weathering**	~ / ✘	Volume 4:2.3.3.1 (advises Tier 3 approaches for soil inorganic carbon fluxes) [Freshwater and oceanic GHG fluxes not measured and reported]	2006 GLs
Biochar	~	Volume 1 (new guidance for mineral soils) Volume 4 (Biochar amendments to soil + Appendix 4)	2019 Refinement
Bio-oil storage	✘	[Parties could propose own methodology (probably Tier 3 only)]	n/a
Biomass burial	✘	[Parties could propose own methodology (probably Tier 3 only)]	n/a
Biomass sinking	✘	[Freshwater GHG fluxes not measured and reported]	n/a
Ocean alkalinity enhancement	✘	[Oceanic GHG fluxes not measured and reported]	n/a

2006 IPCC Vol 2, Chapter 5 | Treatment of storage

Iceland
The CarbFix project, located at the Hellisheiði Power Station, has been pioneering CO2 capture and reinjection on site into the basaltic subsurface, and has proven rapid and complete reaction to calcium carbonate precipitate. Emissions utilised at the George Olah Plant are not subtracted from the total emissions of the geothermal power plant in *Svartsengi*. Reporting of activities at Climeworks, an experimental Direct Air Capture (DAC) plant at the site of the CarbFix reinjection site (see also Chapter 3.4.1.2) is currently being investigated
Canada
Table A10-3 (Annex 10) presents details of CO2 capture volumes consistent with the origin of the captured CO2 (an upgrading facility and coal power plant) and these volumes are subtracted from emissions reported under Mining and Upstream Oil and Gas Production, and Public Electricity and Heat Production, in Alberta and Saskatchewan. CO2 flooding started in 2000 at the Weyburn site and in 2005 at the Midale site…In addition to being a CO2 EOR operation, Weyburn is also the site of a full-scale geological CO2 storage research program led by the IEAGHG with the support of various industries, research organizations and governments. Modelling and simulation results from the first phase (2000 to 2004) of the IEAGHG's CO2 monitoring and storage project, managed by the Petroleum Technology Research Centre (PTRC), indicate that after EOR operations are completed, over 98% of CO2 will remain trapped in the Weyburn reservoir after 5000 years, with only 0.14% of the remainder released to the atmosphere (Mourits, 2008).
U.S.
Since October 2000, the Dakota Gasification Plant has been exporting CO2 produced in the coal gasification process to Canada by pipeline. Because this CO2 is not emitted to the atmosphere in the United States, the associated fossil fuel (lignite coal) that is gasified to create the exported CO2 is subtracted from EIA (2022c) coal consumption statistics. For EOR CO2, as noted in the 2006 IPCC Guidelines, "At the Tier 1 or 2 methodology levels [EOR CO2 is] indistinguishable from fugitive greenhouse gas emissions by the associated oil and gas activities." In the U.S. estimates for oil and gas fugitive emissions, the Tier 2 emission factors for CO2 include CO2 that was originally injected and is emitted along with other gas from leak, venting, and flaring pathways, as measurement data used to develop those factors would not be able to distinguish between CO2 from EOR and CO2 occurring in the produced natural gas. Therefore, EOR CO2 emitted through those pathways is included in CO2 estimates in 1B2. …The quantity of CO2 captured and extracted is noted here for information purposes only; CO2 captured and extracted from industrial and commercial processes is generally assumed to be emitted and included in emissions totals from those processes. Several facilities are reporting under GHGRP Subpart RR… The quantity of CO2 sequestered and emitted is noted here for information purposes only; EPA is considering updates to its approach in the Inventory for this source for future Inventories.

2006 IPCC Vol 2, Chapter 5 | Treatment of storage

Brazil
No mention
Saudi Arabia
A number of research and development initiatives have been taken in the Kingdom to capture and store carbon dioxide emitted from industrial sources and other human-induced activities in an attempt to reduce the increasing rates of carbon dioxide emissions. Saudi Arabia was one of four countries signed up to the “Four Kingdoms”… The Kingdom has reported progress on two key projects: enhanced oil recovery (EOR) and CO2 to methanol and urea projects in its TNC and BUR1 reports. Jubail City is set to host one of the largest Carbon Capture and Storage (CCS) hubs globally, with an objective to capture 44 million tons of CO2 annually by 2035. This ambitious project involves a collaborative effort between Saudi Aramco, SLB, and Linde, and is expected to sequester up to 9 million tons of CO2 each year starting in 2027. Under the ‘reuse’ pillar, the Saudi Aramco Carbon Sequestration project in Uthmaniyah captures and stores 800,000 tons of CO2 a year and with United, a SABIC facility capturing and utilizing 500,000 tons worth of CO2 per year.
UAE
Reyadah is the region’s first commercial-scale CCUS facility, with an 800,000 tonnes per year of CO2 capture capacity. Al –Reyadah processes the CO2 captured from Emirates Steel Industries, which is then injected into UAE’s onshore oilfields to safely store the CO2 while enhancing oil recovery.
Norway
Venting and other emissions connected to CCS is reported in 1C. See Section 3.5 and Annex IV CO2 capture and storage at the oil and gas production field Sleipner Vest and Hammerfest LNG (Snøhvit gas-condensate field) for description of this source. By 31.12.2022, 19 million tonnes CO2 have been injected and stored in the Utsira Formation and 0.25 million tonnes CO2 have been vented. By 31.12.2022, 1 087 ktonnes CO2 have been injected into the Tubåen Formation, 6240 ktonnes have been injected into the Stø Formation, and 592 ktonnes CO2 have been vented (Table 3.40). CO2 venting occurs when the CO2 reinjection system must shut down.

2006 IPCC Vol 2, Chapter 5 | Treatment of storage

China
China has been advancing the technological research of carbon dioxide geological storage. The Roadmap for Carbon Capture, Utilization and Storage Technology Development in China (2019) was released. The potential of carbon dioxide geological utilization and storage in Qitai area, eastern Junggar Basin, Xinjiang, was evaluated, and the methods for evaluation of basin-scale carbon dioxide geological storage potential and storage engineering site selection in basins were optimized; the evaluation of carbon dioxide storage potential of the Junggar Basin and its suitability, as well as the atlas compilation, had been completed, making clear the matching conditions of carbon source and sink for carbon storage in the basin. A pioneering field test of CO2-EWR, which involved a filling of 1,010 tons of carbon dioxide was launched in Zhundong, Xinjiang, and verified that CO2-EWR is technologically feasible and geologically safe;
Japan
CO2 generated from an oil refinery plant was captured and stored from fiscal year 2004 to 2007 and 2016 through 2019, and it is reported under “CO2 amount captured” in liquid fuels of 1.A.1.b Petroleum refining of the CRF table 1.A(a). It is subtracted from the emissions estimated by the above formula. Please refer to section 3.4.4. for details. According to the interview to the entities of the projects shown in Table 3-97, the fugitive emissions in the stage of CO2 transport by pipeline do not occur basically or the amount is quite small even if the fugitive emissions occur. Especially in the case of Tomakomai injection site, the pipeline is structurally designed to allow no gas leaks, and the assurance of airtightness is confirmed by execution of airtightness test. …according to the interview to the entities of the projects shown in Table 3-97 (excluding the Tomakomai project), the fugitive emissions shown above do not occur basically or the amount is quite small even if the fugitive emissions occur. Second, the maximum amount of annual injection is about 6 kt-CO2. Therefore, the emissions from this category are reported as insignificant NE in the years CO2 injection were conducted in the projects other than Tomakomai.
Australia
In Australia, any CCS project is undertaken under a licence provided under state or commonwealth legislation depending on the jurisdiction the project in located in. Under these licenses, strict project specific condition for monitoring and reporting of leaks are given. Hence, for estimating leakage from the storage formation, the NGER scheme mirrors estimates made in accordance with the measurement, reporting, and verification (MRV) requirements of the licence. This is particularly important given the project-specific nature of monitoring and reporting requirements for CCS projects. Emissions from the Transport of CO2 are identified as Not Occurring on the basis that the pipelines at Gorgon are short and no leaks have been identified for inclusion in reporting to date.