Technology Collaboration Programme
by IEA

Carbon dioxide removal (CDR)
An overview

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Who are we?

Our internationally recognised name is the IEA Greenhouse Gas R&D Programme (IEAGHG). We are a Technology Collaboration Programme (TCP) and are a part of the International Energy Agency's (IEA's) Energy Technology Network.

Disclaimer

The IEA Greenhouse Gas R&D Programme (IEAGHG) is organised under the auspices of the International Energy Agency (IEA) but is functionally and legally autonomous. Views, findings and publications of the IEA Greenhouse Gas R&D Programme do not necessarily represent the views or policies of the IEA Secretariat or its individual member countries.

IEA Greenhouse Gas R&D Programme (IEAGHG)

- A collaborative international programme founded in 1991 under the International Energy Agency (an IEA Technology Collaboration Programme)
- Aim: To provide information on the role that technology can play in reducing greenhouse gas emissions from use of fossil fuels and biomass, in power and industrial systems, other energy carriers and energy integrated systems.
- Focus is on Carbon Dioxide Capture, Utilisation and Storage (CCS/CCUS)
- Producing information that is:
  - ✓ Objective, impartial, independent
  - ✓ Policy relevant but NOT policy prescriptive
  - ✓ Reviewed by external Expert Reviewers

IEAGHG Primary Activities

- Funding research into development and deployment of CCUS technologies
- Technical Reports >356 reports published on all aspects of CCUS
- International Expert Networks

  Risk Management; Monitoring; Modelling; Environmental Research; High Temperature Solid Looping; Costs; Social Research
- Conferences
  - GHGT conferences (the largest global conference on CCS)
    - GHGT16 – 23-27 Oct 2022, Lyon France. Call for abstracts – Sep 2021
  - PCCC conferences - PCCC6, UKCCSRC, virtual, 19-21 Oct 2021
  - Negative CO_2 Emissions conference – 14-17 June 2022 Gothenburg
  - International CCS Summer Schools
  - Peer reviews of national programme and projects, eg US DOE

ghgt-16

16TH GREENHOUSE GAS CONTROL TECHNOLOGIES CONFERENCE

23 - 27 OCTOBER 2022

Hosted by Club CO_2 With ADEME brgm IFP Energies nouvelles TotalEnergies

- The leading conference for CCUS for more than 30 years returns for an 'in person' attendance. Hosted by Club CO2 in Lyon, France.
- Over 500 presentations expected in 71 sessions, 7 parallel streams, panel sessions, keynotes, plus social events
- Over 800 abstracts received.
- Refer to www.ghgt.info

IEAGHG Knowledge Transfer

Input to WPFE and CCUS Unit

United Nations Framework Convention on Climate Change

CCS Side Events at COP22, COP23, COP24, COP25, COP26

carbon sequestration leadership forum

CSLF Technical Group
GHG TCP inputs

INTERGOVERNMENTAL PANEL ON climate change

Expert Reviewers,
Accredited Observer
1.5SR, AR6 reviews

CLEAN ENERGY MINISTERIAL
Advancing Clean Energy Together

CCUS Initiative
GHG TCP inputs

ISO TC-265
GHG TCP inputs

Zep Zero emissions platform

IMO

London Convention:
Regular updates on CCS:
ROAD permit assessment, Offshore workshops
CO_2 Export Resolution 2019 – Report 2021-TR02

IEAGHG members

SOUTHERN COMPANY

Chevron

INSTITUT TEKNOLOGI BANDUNG 1920

TotalEnergies

J-POWER

CIAB

ExxonMobil

INSTITUTO DE INVESTIGACIONES ELECTRICAS

Evaluating technology options to mitigate greenhouse gas emissions

ieaghg

EPRI

JÜLICH FORSCHUNGSZENTRUM

equinor

SOTACARBO SUSTAINABLE ENERGY RESEARCH CENTRE

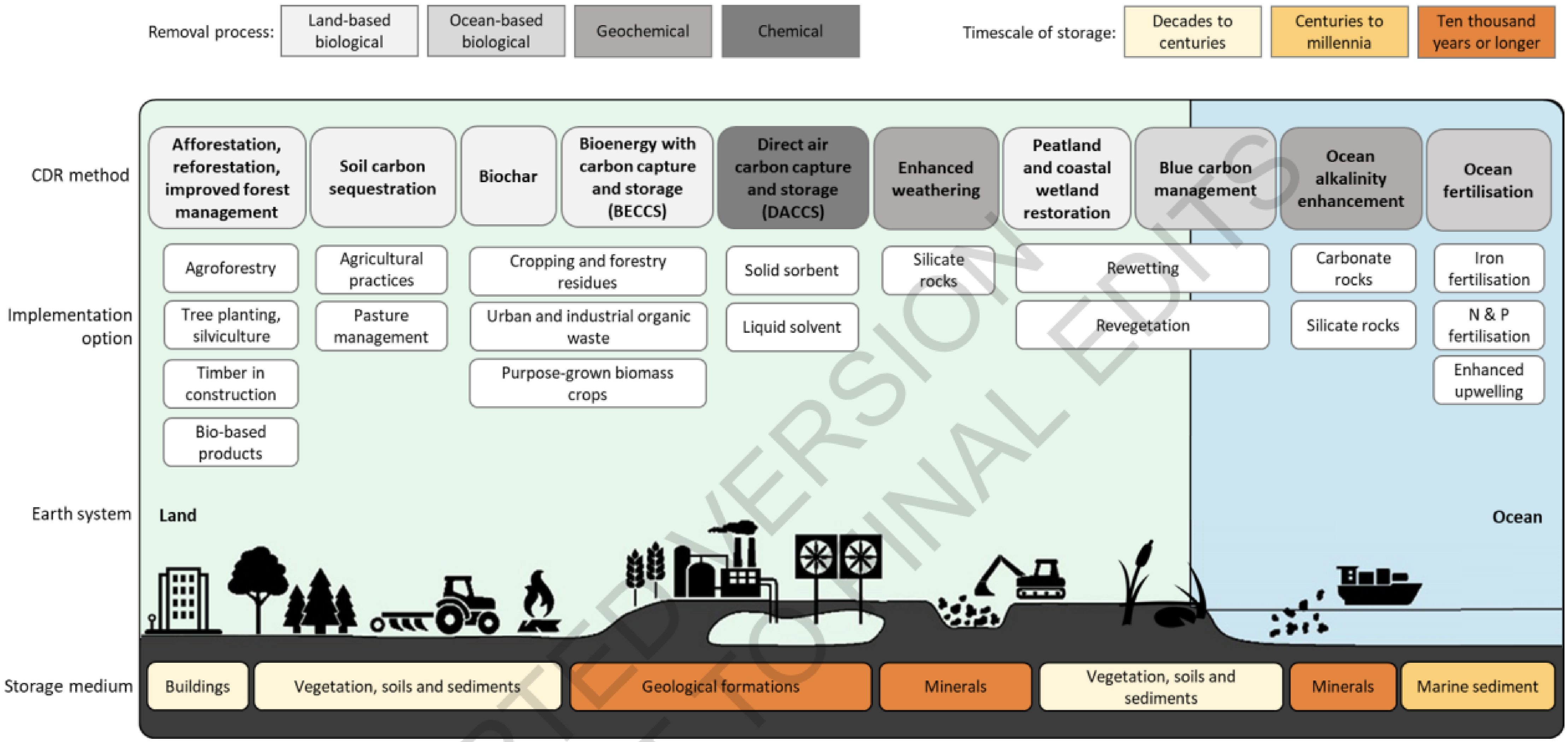
bp

Baker Hughes

JGC

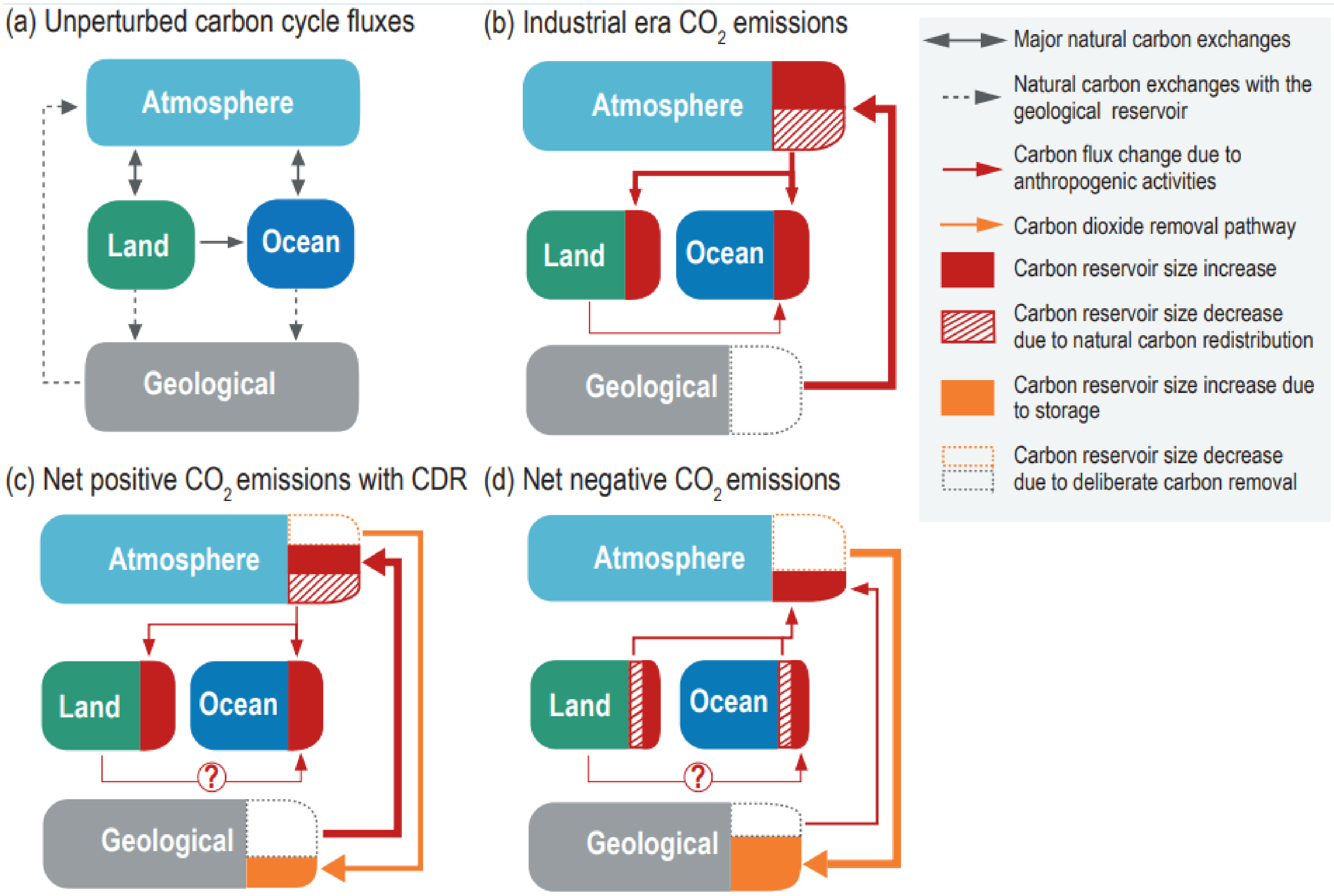
RWE

CDR methods & taxonomy



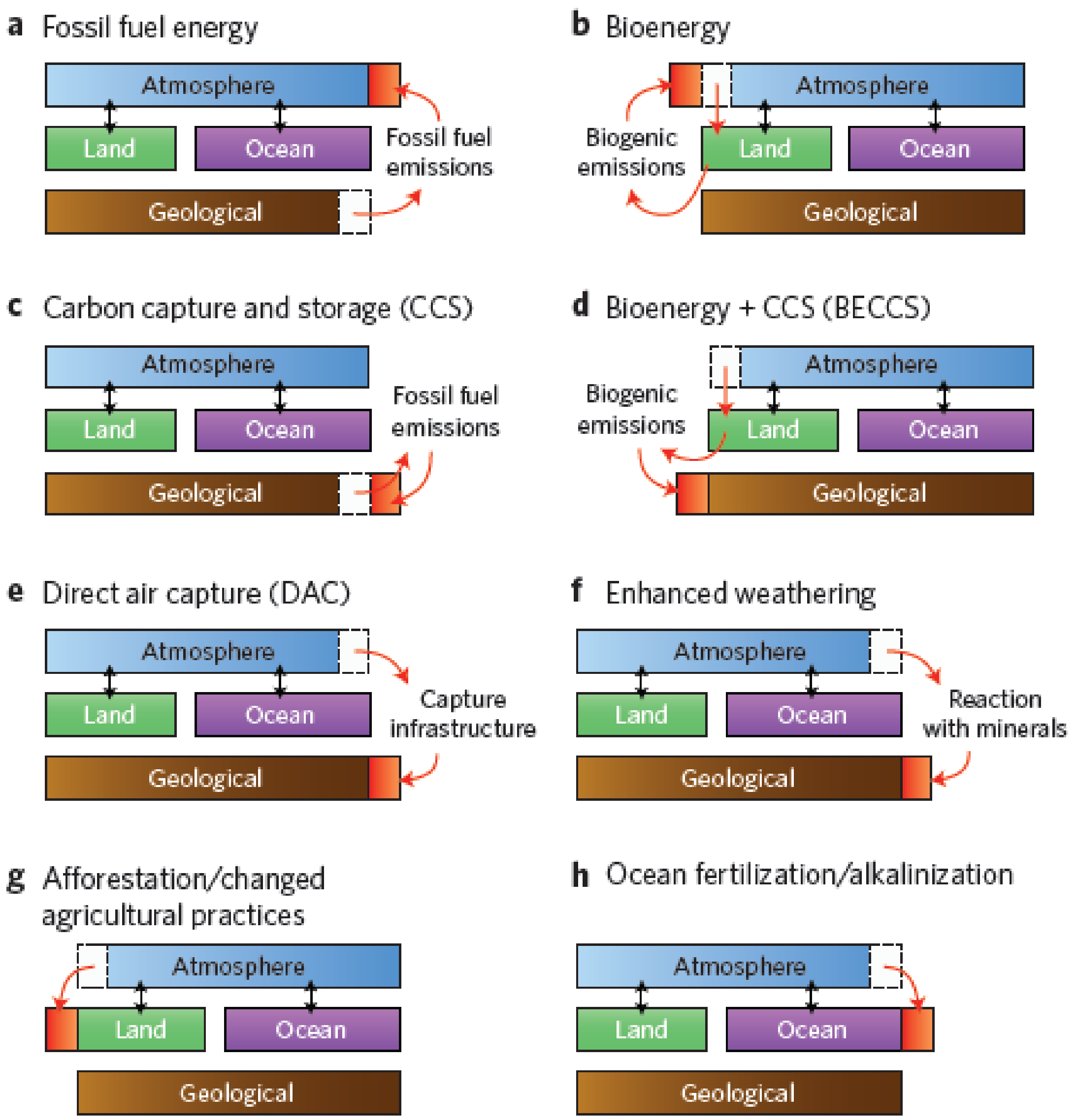
IPCC AR6 WGIII, Ch 12, Crosschapter Box 8, Figure 1

Carbon cycle and CDR



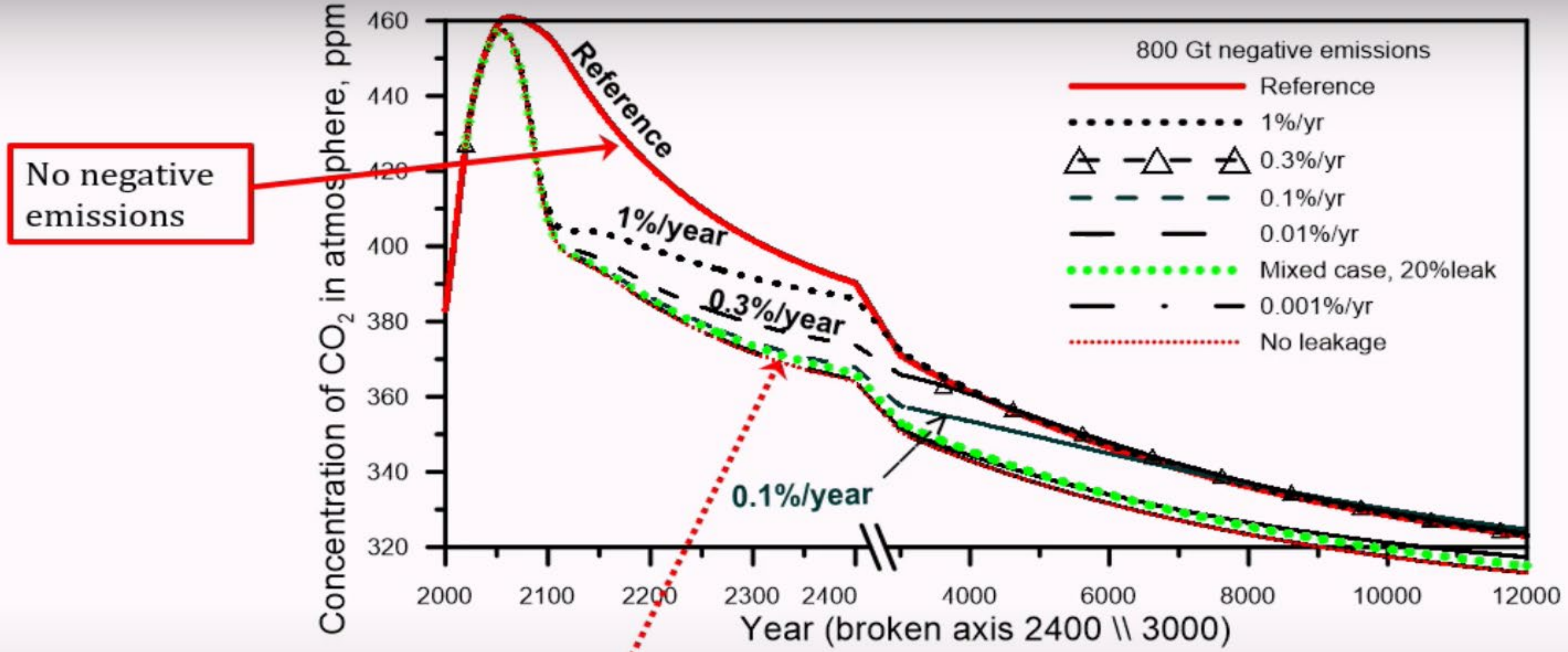
IPCC AR6 WGI, Ch 5, Box 5.3, Figure 1

Carbon cycle and CDR



Smith 2015

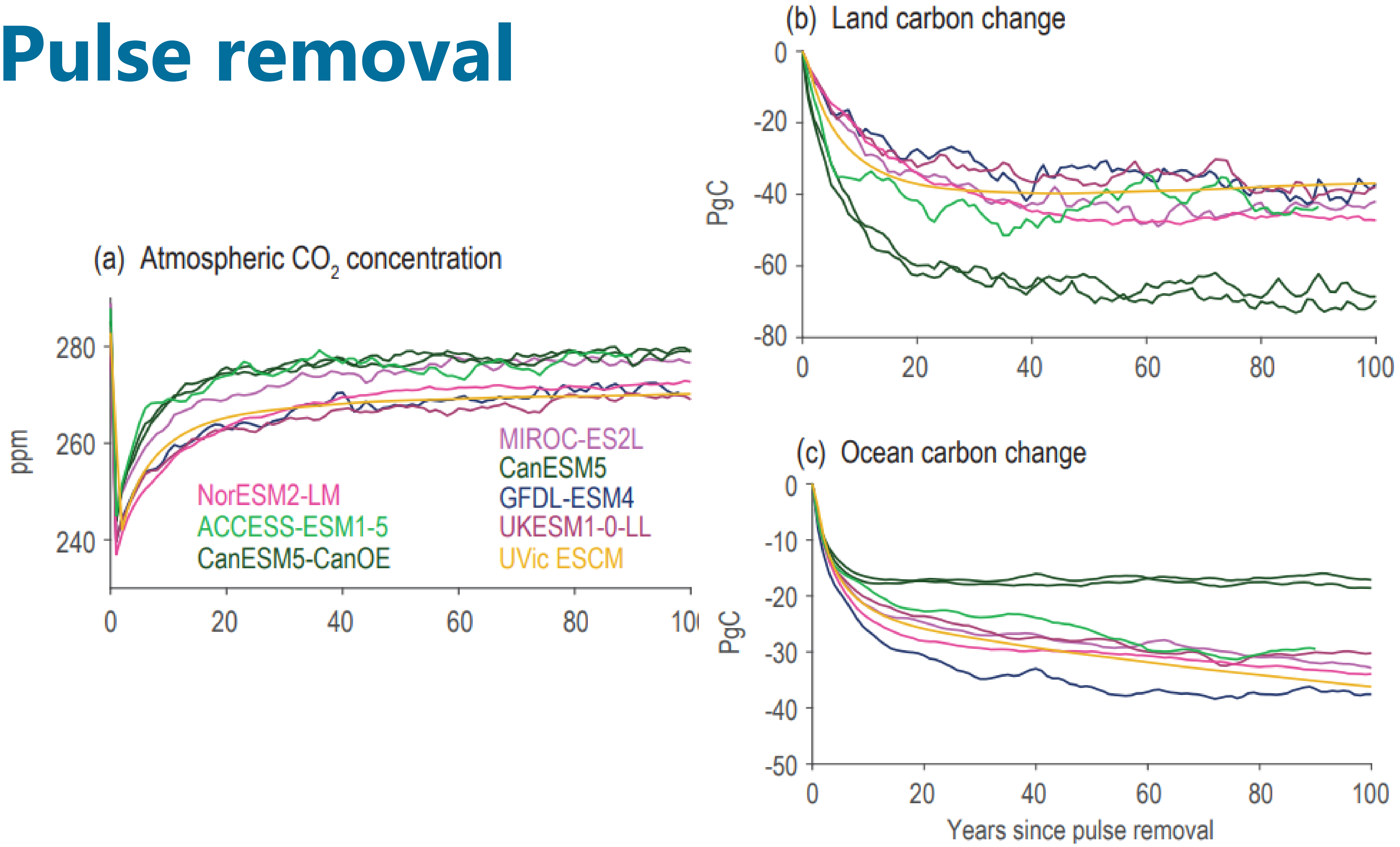
CDR with and without leakage



Atmospheric CO_2 for no negative emissions and negative emissions with and without leakage.

REF: Lyngfelt A, Johansson D, and Lindeberg E. Negative CO2 Emissions - An Analysis of the Retention Times Required with Respect to Possible Carbon Leakage. *International Journal of Greenhouse Gas Control* **87** (2019) 27–33.

Pulse removal



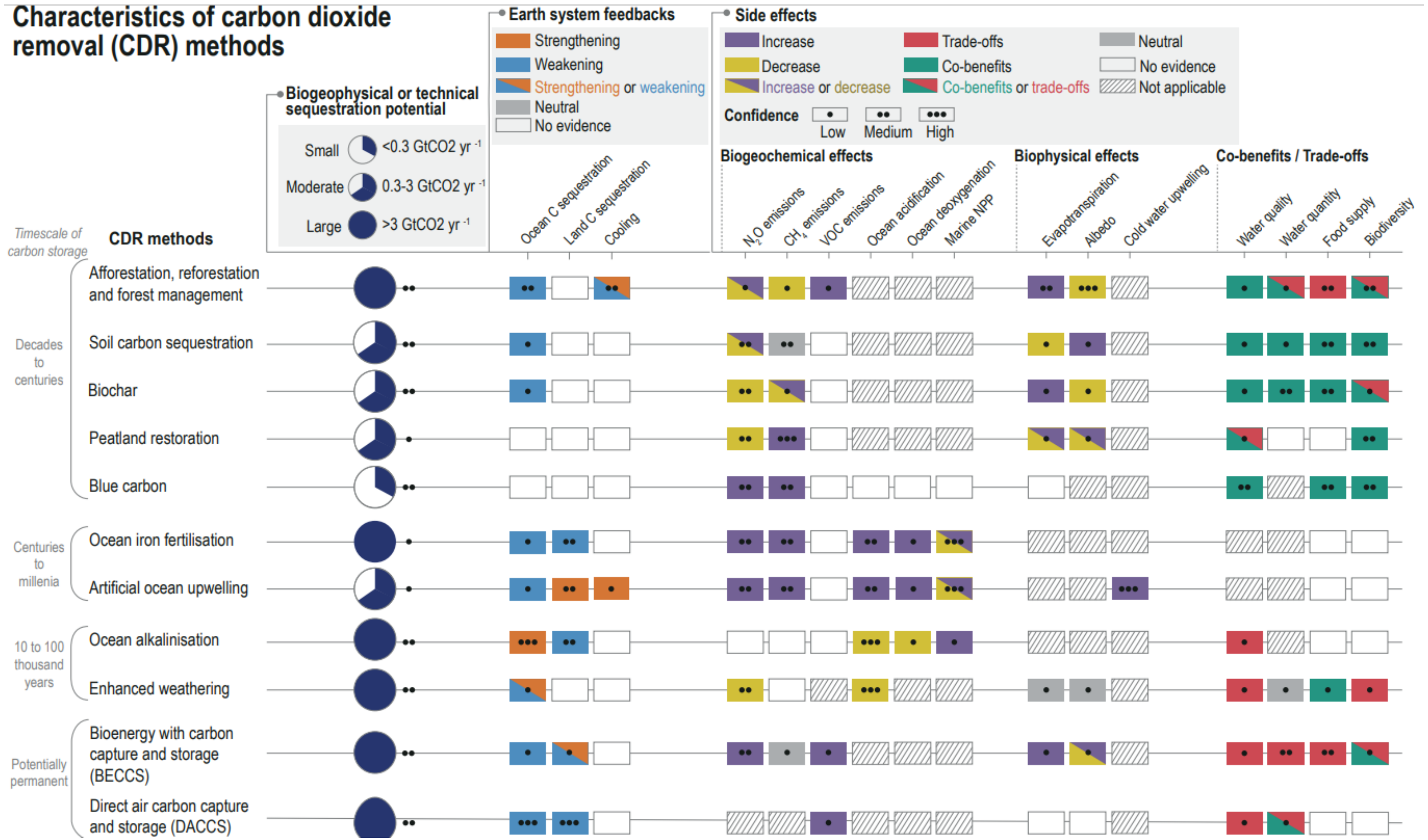
IPCC AR6 WGI, Ch 5, Figure 5.32

CDR methods

CDR methods	Status (TRL)	Cost (USD/tCO_2)	Potential ($GtCO_2$/a)
Direct air capture and storage (DACCS)	6	100-300	5-40
Enhanced weathering (EW)	3-4	50-200	2-4
Ocean alkalinity enhancement	1-2	40-260	1-100
Ocean fertilisation	1-2	50-500	1-3
Blue carbon management in coastal wetlands	2-3	100-10,000	1
Bioenergy with carbon capture and storage (BECCS)	5-6	15-400	0.5-11
Afforestation/Reforestation (A/R)	8-9	0-240	0.5-10
Biochar (BC)	6-7	10-345	0.3-6.6
Soil organic carbon sequestration (SOCS)	8-9	45-100	0.6-9.3
Peatland and coastal wetland restoration	8-9	Insufficient data	0.5-2.1
Agroforestry	8-9	Insufficient data	0.3-9.4
Improved forest management	8-9	Insufficient data	0.1-2.1

IPCC AR6 WGIII, Ch 12, Table 12.6

CDR feedbacks and side effects



IPCC AR6 WGI, Ch 5, Figure 5.36

Permanence

Imperial College London

Carbon storage methods: timescales & durability

Carbon storage method	Storage timescales (permanence)	Reversal risk of carbon removal
In vegetation or via soil carbon management	Decades to centuries	Storage reversed by human or natural disturbances; also prone to climate change impacts
Carbon in biochar (soil sequestration)	Decades to centuries	Less prone to reversal, but biochar decays and re-releases carbon over time
Geological reservoirs (via BECCS, DACCS)	**Up to ten thousand years or more**	**Less prone to reversal**

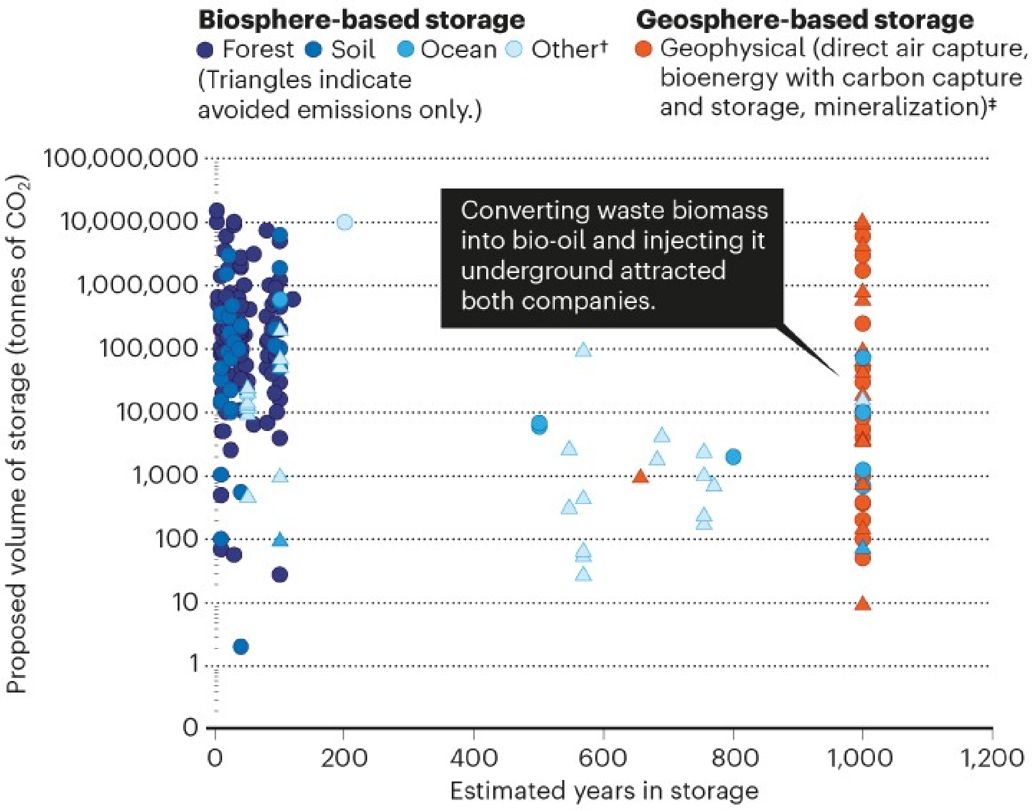
Bui et al, 2022, 2nd Negative Emissions Conference

CDR markets

https://www.nature.com/articles/d41586-021-02606-3

CARBON-MARKET SNAPSHOT

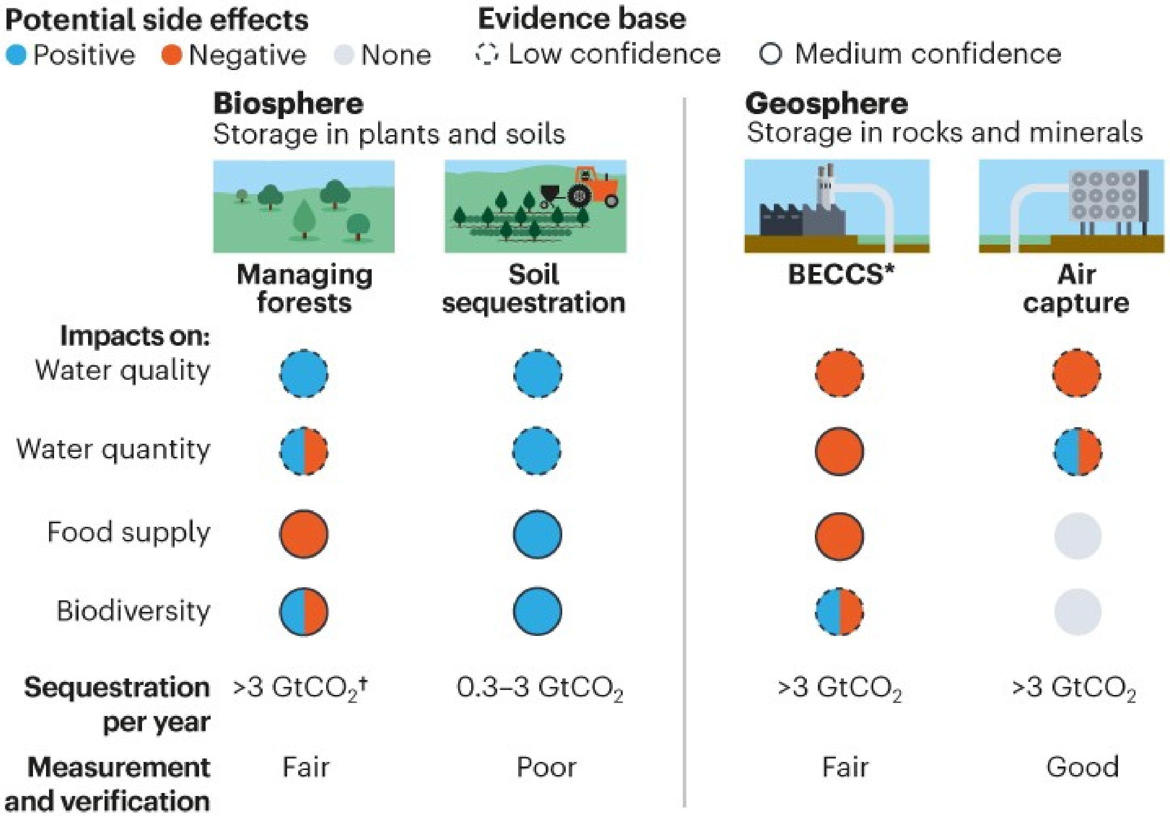
In 2020, Microsoft and financial-services firm Stripe received 189* and 47 proposals from companies, respectively, for locking away carbon dioxide. Of these, 95% used nature-based storage, which is less durable than geosphere-based. Few options were available for permanent removal. Only about 2 million tonnes' worth was judged reliable enough to purchase, of the around 170 million tonnes offered.



*Data on 161 proposals compiled by CarbonPlan (https://carbonplan.org); these exclude 28 further proposals to Microsoft that lacked sufficient information.
†Biomass, wood products and biochar. ‡Many geosphere-based solutions were classified as >1,000 years duration, but are shown here as 1,000 years for simplicity.

SOME CARBON-REMOVAL STRATEGIES

Nature-based methods for storing carbon dioxide are relatively cheap and currently available. But carbon stored in terrestrial ecosystems is at risk of release by fires and pests, for example. Geological storage could be permanent, but today's technologies are pricey and immature.



Impact ratings are from the Intergovernmental Panel on Climate Change (IPCC) Sixth Assessment Report, apart from 'Measurement and verification', which are based on the authors' judgement.
*BECCS, bioenergy with carbon capture and storage; †$GtCO_2$, gigatonnes of CO_2.

CDR – points for discussion

- Being clear whether we are talking about net zero or net negative and about carbon or greenhouse gas removals (CDR vs GGR)
  - Methane removals might be considered, too (e.g. co-capture of CO_2 and CH_4 through DACCS processes)
- CDR/GGR must not be pursued as a substitute for quick and robust action on emissions reductions
- Storage permanence/durability of the removed carbon
  - ➢ CDR/GGR must result in a permanent net reduction of atmospheric carbon
  - ➢ Case-by-case scrutiny of CDR/GGR supply chains, long-term indirect emissions and potential re-emissions
  - ➢ Low quality offsets encouraged by per-tonne pricing that doesn't take into account all the externalities of a CDR method → danger of 'greenwashing'

CDR – points for discussion

- Temporal aspects of CDR/GGR
- Removal efficiency (well managed and used to maximise carbon storage)
- Immature markets for offsets and removals
  - Polluter pays principle and carbon takeback obligations
- Robust monitoring, reporting and verification (MRV) for GGRs/CDRs
  - Some methods/elements have already relatively established MRS (e.g. CCS, forest management) while others do not
  - Independent auditors
  - Roll-out at scale
  - Cost implications
  - Potential bottlenecks
- Multi-use/cascading biomass systems (both coastal and land based)

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Thank you, any questions?

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