Innovation for Cool Earth Forum
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Carbon Dioxide Removal by Using Direct Air Capture and Other Technologies

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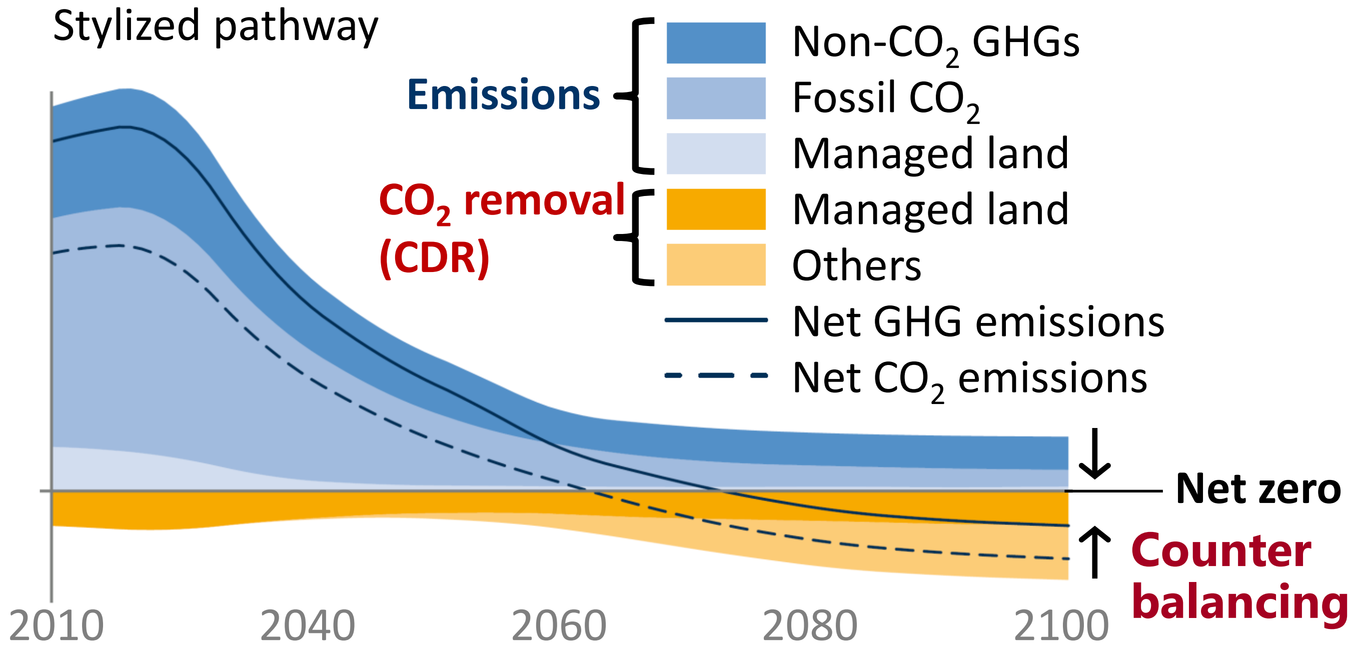
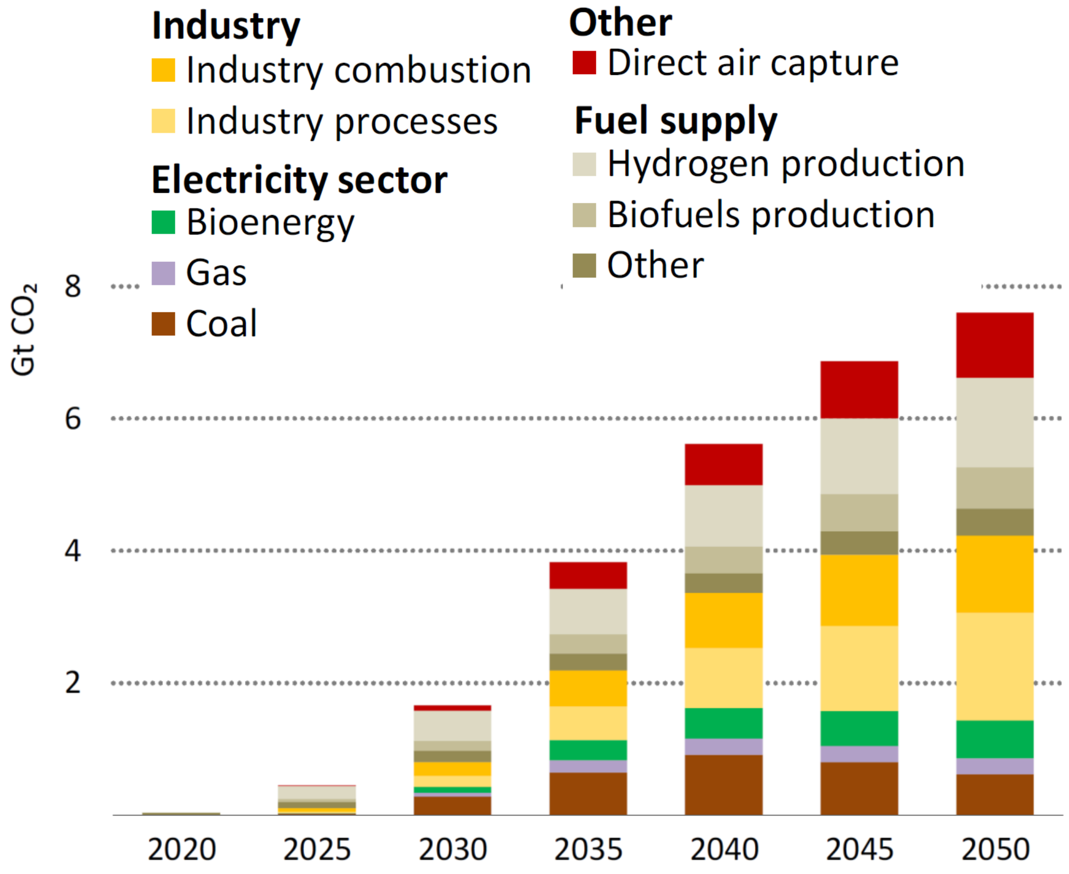
- Roles of carbon dioxide removal (CDR)
- CDR technologies and their readiness levels, costs and potentials
- Global trends regarding direct air capture (DAC)
- Challenges, problems and risks in CDR deployment

Roles of CDR in Global or National Mitigation Strategies



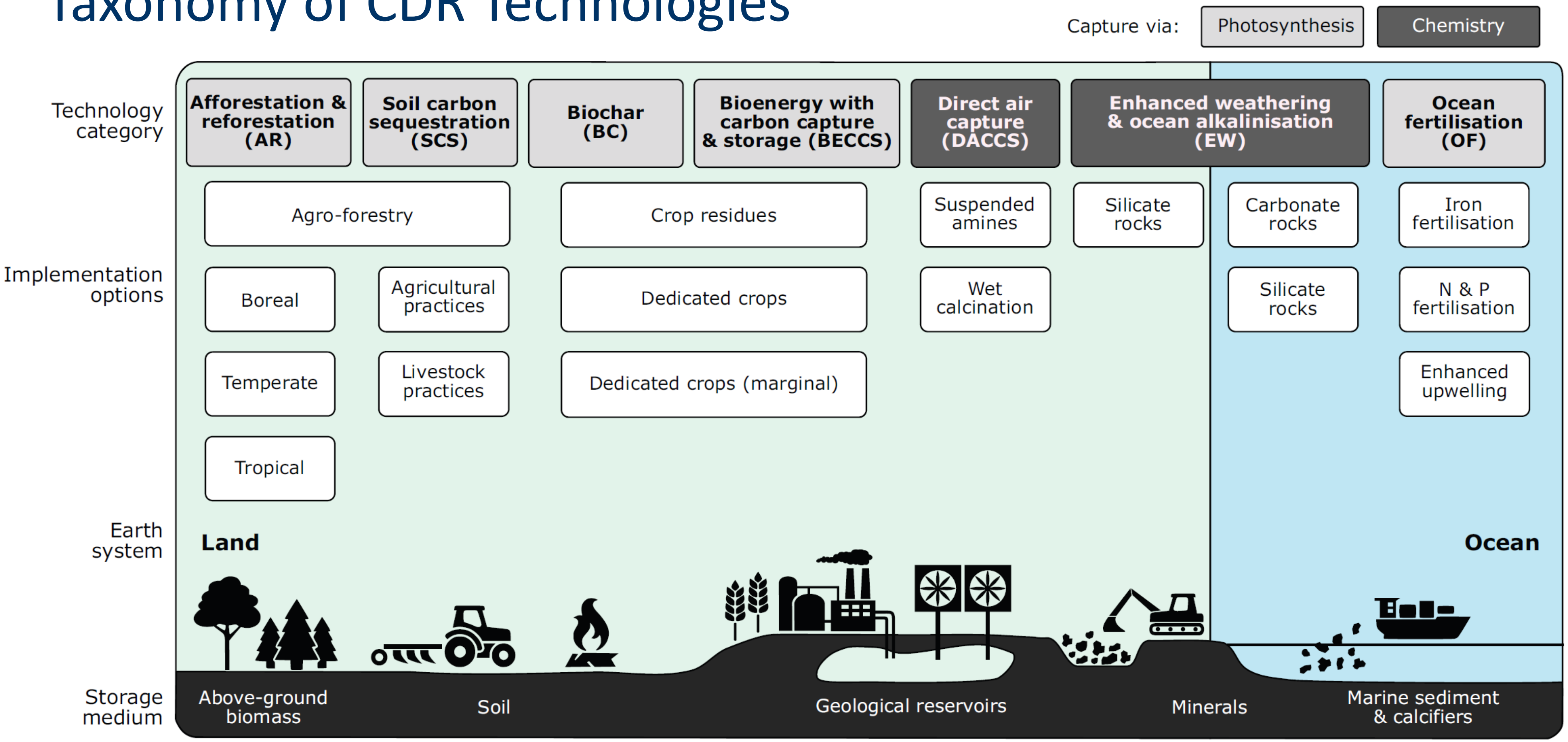
Intergovernmental panel on climate change (IPCC), Climate change 2022: Mitigation of climate change (2022)

Global CO_2 Capture by Source in IEA Net Zero Emissions Scenario



International energy agency (IEA), Net Zero by 2050 (2021)

Taxonomy of CDR Technologies



Minx et al, Environ Res Lett **13** 063001 (2018)

- Nature-based solutions: Afforestation/Reforestation, Blue carbon management
- Engineering-based solutions: DACCS, BECCS
- Hybrid solutions: Biochar, EW

Technology Readiness Level (TRL), Cost and Mitigation Potential of CDR Method

2020-2100 cumulative volumes

across the scenarios limiting warming to 2°C or below

- AFOLU (Agriculture, Forestry and Other Land Use): 20–418 Gton-CO_2
- BECCS: 168–763 Gt-CO_2
- DACCS: **0–339 Gt-CO_2**

Monitoring, reporting, and verification

- need developments of reliable-system
- clear and easy for DACCS

CDR method	TRL	Cost ($/ton-$CO_2$)	Mitigation potential（Gton-CO_2/y）
Afforestation/ Reforestation	8-9	0-240	0.5-10
Soil carbon sequestration	8-9	-45-100	0.6-9.3
Biochar	6-7	10-345	0.3-6.6
BECCS	5-6	15-400	0.5-11
DACCS	**6**	**100-300**	**5-40**
Enhanced weathering	3-4	50-200	2-4
Ocean Fertilization	1-2	50-500	1-3
Ocean alkalinity enhancement	1-2	40-260	1-100
Blue carbon Management	2-3	-	<1

IPCC, Climate change 2022: Mitigation of climate change (2022)

DAC's Start-up Leaders/Global Trends

Carbon Engineering (since 2009)

- ✓ absorbs CO_2 to form $CaCO_3$
- ✓ calcines $CaCO_3$ at ~900°C
- ✓ 5-8 GJ/ton-CO_2 heat and 1-2 GJ/ton-CO_2 electricity
- ✓ 0.2 km^2 for 1 Mton/y plant
- ✓ 1-7 ton water use per ton-CO_2 capture
- ✓ commercial operation in ~2025 at ~0.5 Mton/y

Climeworks (since 2009)

- ✓ regenerates adsorbents at ~100°C
- ✓ 3-6 GJ/ton-CO_2 heat and 1 GJ/ton-CO_2 electricity
- ✓ reaching Mton removal capacity by 2030

Orca: the world's largest capacity (4,000 ton-CO_2/y) plant in Iceland

https://carbonengineering.com
https://climeworks.com
https://www.meti.go.jp

CDR/DAC Purchasers

- ✓ Microsoft, Airbus, Amazon, NextGen, Shopify, JP Morgan, Google, ANA ·········

U. S

- ✓ launched Carbon Negative Shot in 2021
- ✓ developing 4 regional DAC hubs
- ✓ tax credit up to USD 180/ton-CO_2 for DACCS

Japan

- ✓ Moon shot R&D program

– promoting challenging DAC projects
– demonstration at Expo 2025 Osaka-Kansai

- ✓ Kawasaki Heavy Industries plans to demonstrate ~20,000 ton-CO_2/y in ~2025
- ✓ Minister of Economy, Trade and Industry

– established Committee for Creation of Negative Emissions Market in 2023
– developed DAC methodology for calculating removal amount in 2024

Challenges, Problems and Risks in CDR Deployment

- Cost and energy requirements – biggest obstacle: need for technological innovation
- Need to scale up faster than ever before: unprecedented scale-ups after 2025
- Concerns regarding biodiversity and other natural conservation: difficulty to gain public acceptance
- Moral hazard/Mitigation deterrence: CDR may delay CO_2 emission reductions, which may delay CDR deployment

Thank you!

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