ETH zürich

Climate Finance and Policy Group

CDR and ETS: Considerations on Direct Air Carbon Capture and Storage (DACCS)

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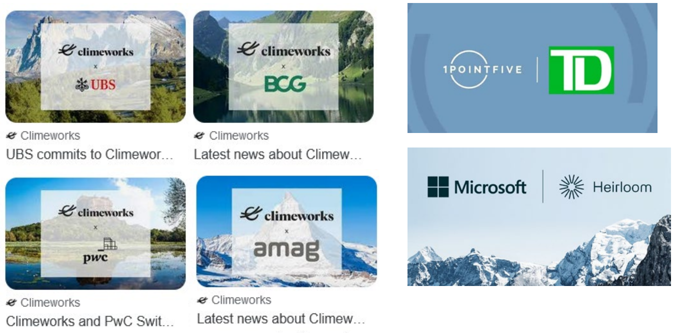
Ariadne @ Brussels, 6 Dec 2023

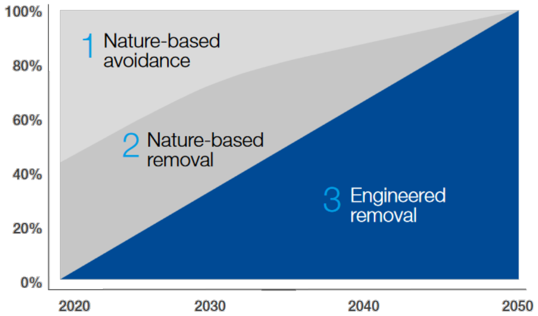
Agenda

1. Role of DACCS for net zero
2. DACCS and ETS integrity
3. Current and future cost of DACCS, vis-à-vis EU ETS
4. Funding of DACCS removals and the role of EU ETS
5. Conclusion

1. Role of DACCS for net zero

- Deep decarbonization the foundation for all climate change mitigation efforts
- Ad per IPCC AR6, 1.5–2°C pathways also require large amounts of CDR
- Land-based CDR expected to saturate by mid-century
- **DACCS** with potential for scalable and permanent CDR
- Deployment started driven by voluntary markets, though to date high costs hinder large-scale deployment



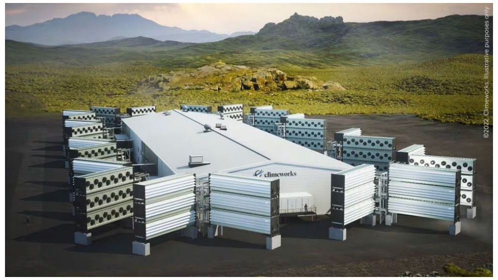


Source (chart bottom left): World Economic Forum (2023), The Voluntary Carbon Market: Climate Finance at an Inflection Point

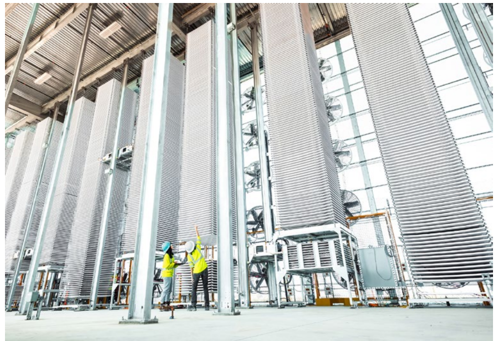
Key technologies

Liquid solvent

Solid sorbent



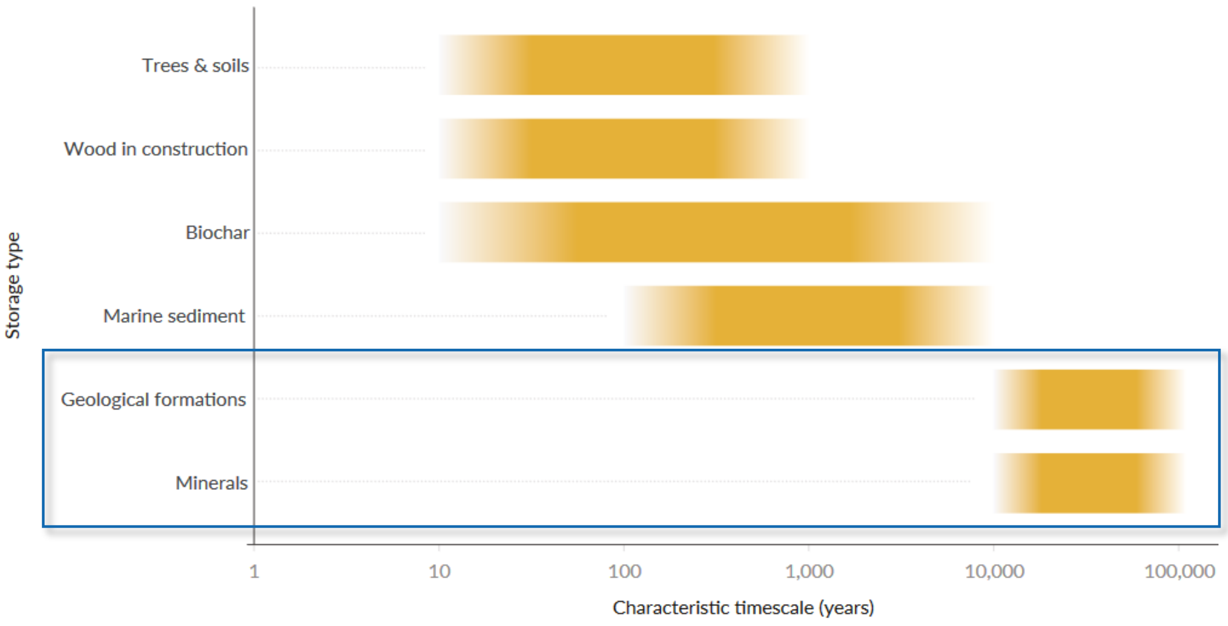
CaO ambient weathering



2. DACCS and ETS integrity

- Durability and MRV
- Scalability
- Cost?

Durability of different carbon storage pools



CDR method	Status (TRL)	Mitigation Potential ($GtCO_2$ yr^{-1})	Risk and impacts
DACCS	6	5–40	Increased energy and water use
Enhanced weathering	3–4	2–4 (<1–95)	Mining impacts; air quality impacts of rock dust when spreading on soil
Ocean alkalinity enhancement	1–2	1–100	Increased seawater pH and saturation states may impact marine biota. Possible release of nutritive or toxic elements and compounds. Mining impacts
Ocean fertilisation	1–2	1–3	Nutrient redistribution, restructuring of the ecosystem, enhanced oxygen consumption and acidification in deeper waters, potential for decadal-to-millennial-scale return to the atmosphere of nearly all the extra carbon removed, risks of unintended side effects
Blue carbon management in coastal ecosystems	2–3	<1	If degraded or lost, coastal blue carbon ecosystems are likely to release most of their carbon back to the atmosphere; potential for sediment contaminants, toxicity, bioaccumulation and biomagnification in organisms; issues related to altering degradability of coastal plants; use of subtidal areas for tidal wetland carbon removal; effect of shoreline modifications on sediment redeposition and natural marsh accretion; abusive use of coastal blue carbon as means to reclaim land for purposes that degrade capacity for carbon removal
BECCS	5–6	0.5–11	Competition for land and water resources, to grow biomass feedstock. Biodiversity and carbon stock loss if from unsustainable biomass harvest
Afforestation/ reforestation	8–9	0.5–10	Reversal of carbon removal through wildfire, disease, pests may occur. Reduced catchment water yield and lower groundwater level if species and biome are inappropriate
Biochar	6–7	0.3–6.6	Particulate and GHG emissions from production; biodiversity and carbon stock loss from unsustainable biomass harvest
Soil carbon sequestration in croplands and grasslands	8–9	0.6–9.3	Risk of increased nitrous oxide emissions due to higher levels of organic nitrogen in the soil; risk of reversal of carbon sequestration
Peatland and coastal wetland restoration	8–9	0.5–2.1	Reversal of carbon removal in drought or future disturbance. Risk of increased methane emissions
Agroforestry	8–9	0.3–9.4	Risk that some land area lost from food production; requires high skills
Improved forest management	8–9	0.1–2.1	If improved management is understood as merely intensification involving increased fertiliser use and introduced species, then it could reduce biodiversity and increase eutrophication

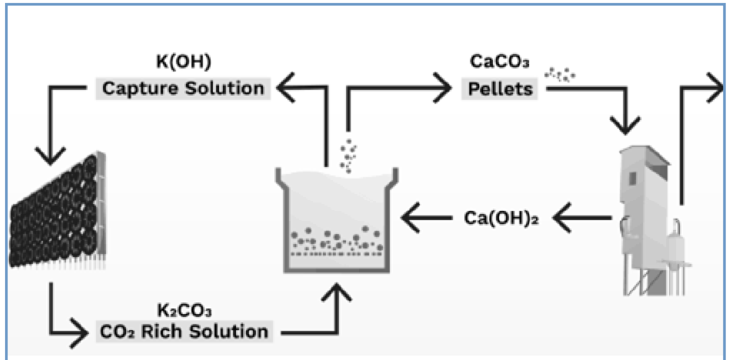
Source: IPCC WG3 AR6, chapter 12, table 12.6. Smith, S. M. et al. (2023). The State of Carbon Dioxide Removal, doi:10.17605/OSF.IO/W3B4Z.

3. Current and future cost of DACCS, vis-à-vis EU ETS

a. Decomposition of cost components

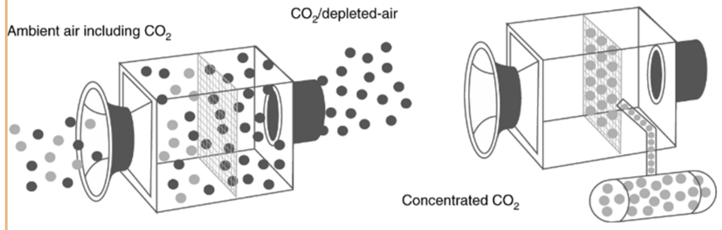
Novel components

Liquid solvent DACCS

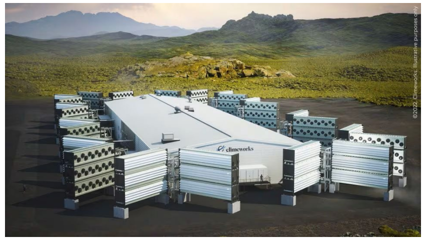


- Air contactor
- Pellet reactor
- Slaker
- Calciner
- System level

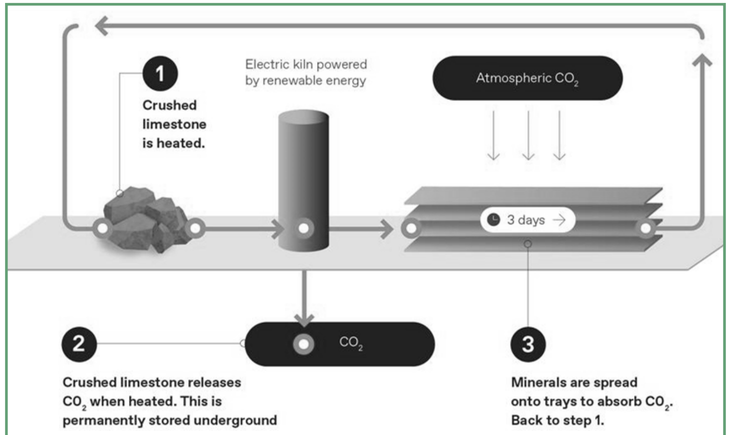
Solid sorbent DACCS



- Air contactor
- Sorbent material
- System level



CaO ambient weathering DACCS



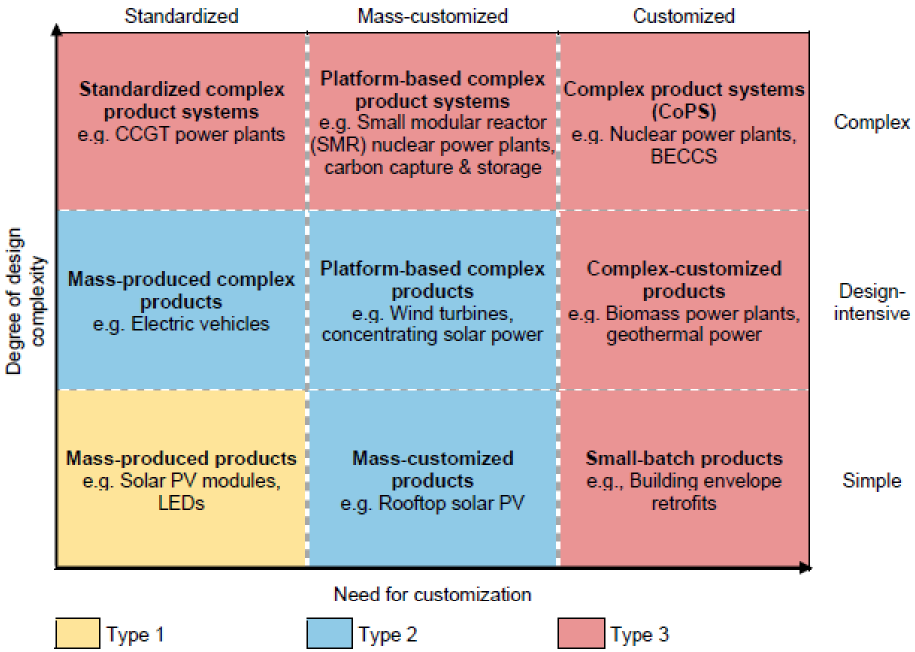
- Air contactor structure
- Electric kiln
- System level

Sources for process figures: Deutz et al. (2021); https://climatescience.org/advanced-direct-air-capture; Heirloom (2022)

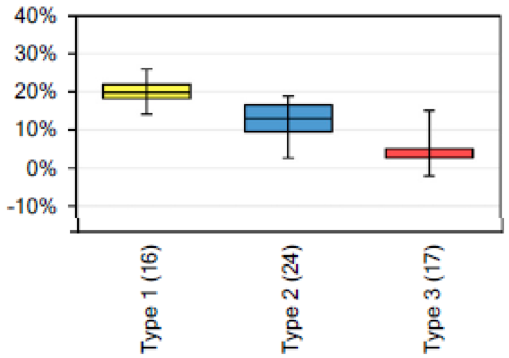
3. Current and future cost of DACCS, vis-à-vis EU ETS

b. Component-level assessment of cost reduction potential

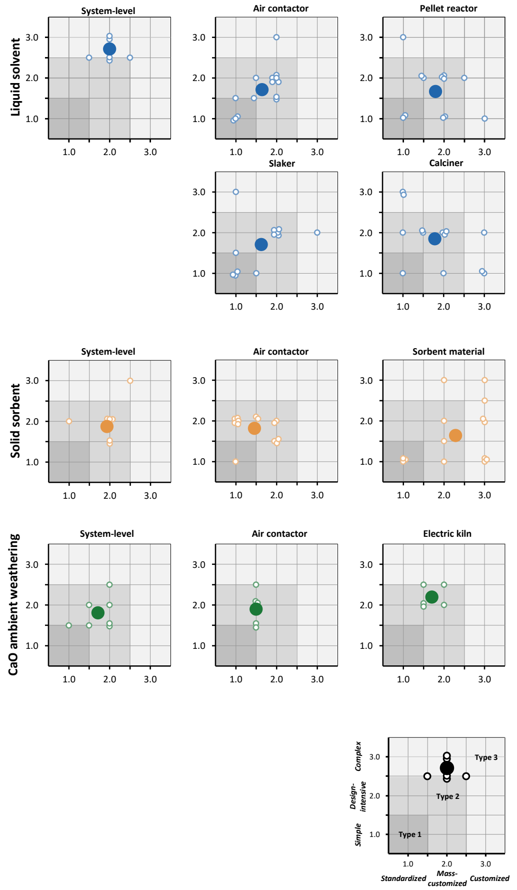
Typology of energy technologies



Learning rate estimates of different tech types



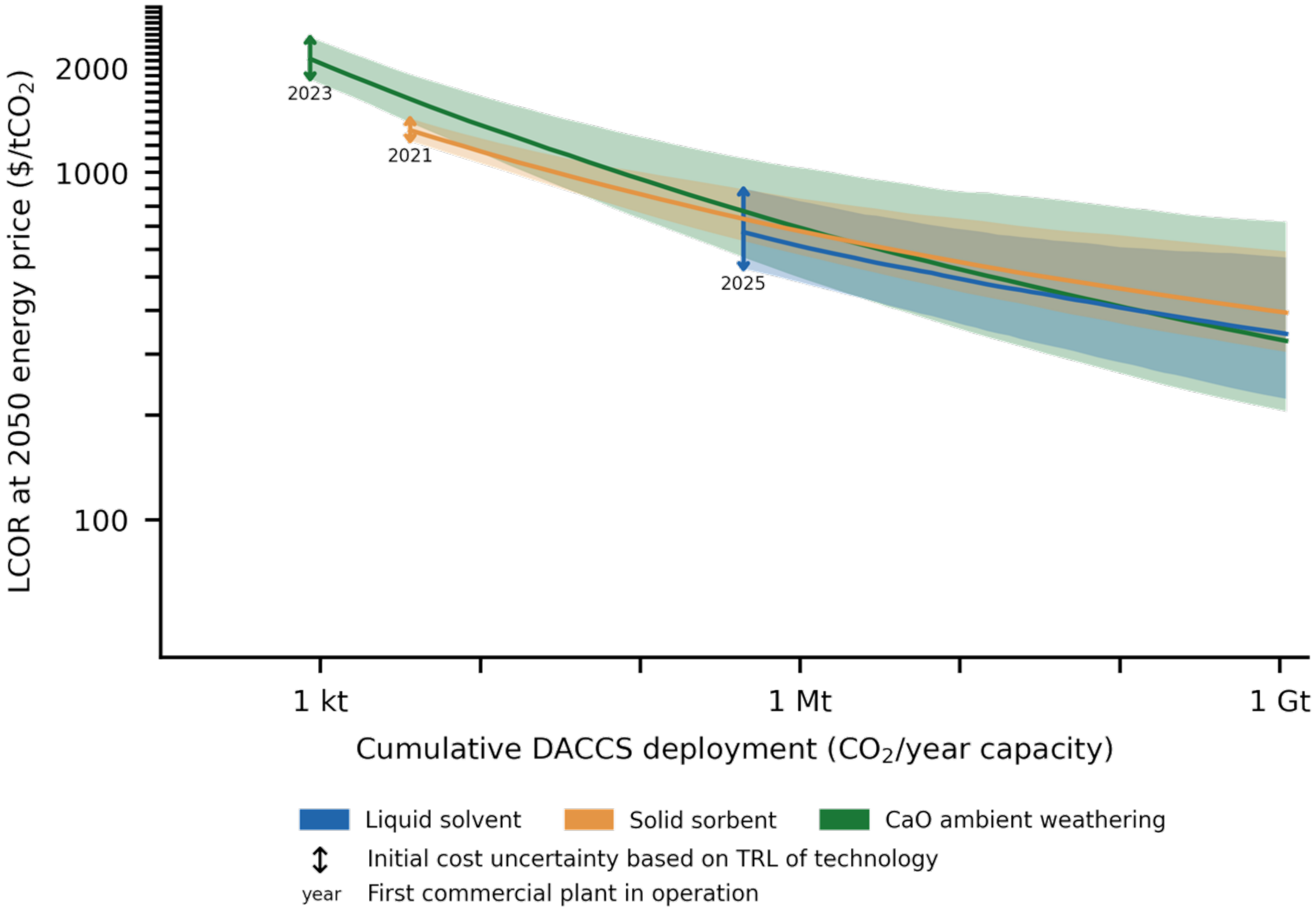
Classification of DACCS technologies



Source: Malhotra, A., Schmidt, T.S. "Accelerating Low-Carbon Innovation" *Joule* 4 (2020); Sievert K., Schmidt T.S., Steffen B. "Considering technology characteristics to project future costs of direct air capture" (unpublished manuscript)

3. Current and future cost of DACCS, vis-à-vis EU ETS

c. Projection of Levelized Cost of Carbon Removal



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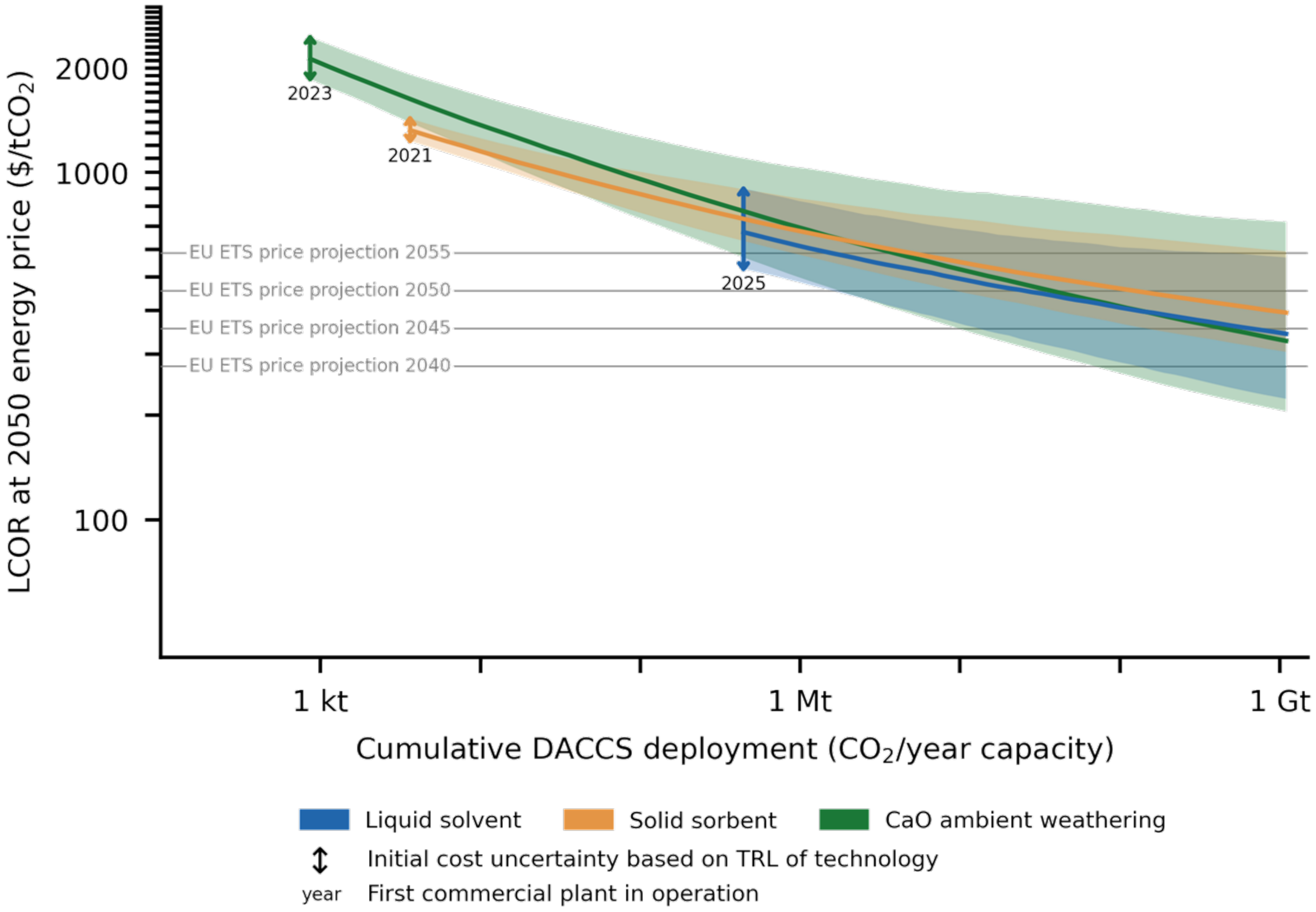

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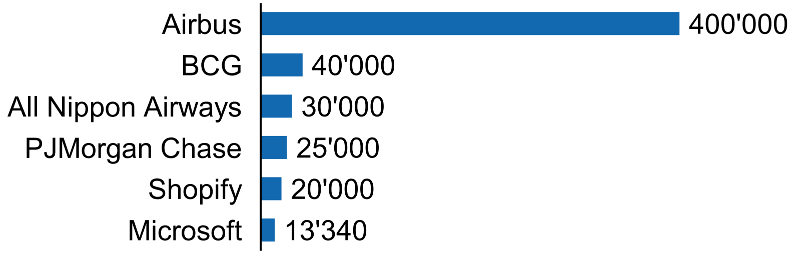
4. Funding of DACCS removals and the role of EU ETS

Today: Voluntary (prestige) markets

- Advanced market commitments
  - Started 2019 by Stripe, Shopify, Swiss Re, BCG
  - In 2020 billion-scale pledges by Microsoft and Bezos
- Over-the-counter, often non-disclosed USD/ton. Partly bundled with corporate investments and other services

Top buyers of DACCS offsets by Aug 2023 (tons)



Source (bottom left): Bloomberg New Energy Finance

Today: Public support

- Tax credits (examples)
  - United States **45Q**: 180 $/t (stored)
  - Canada: 60% of DACCS investment
  - Norway: 186 $/t
- R&D grants
  - United States **regional DAC hubs** (3.5 bn $ for 4 hubs)
  - EU Innovation Fund, Horizon Europe

Future: A role for EU ETS?

- <u>Mid-term</u>: emissions and removal trading system (***ERTS***) could
  - efficiently trade DACCS vs. very costly abatement
  - Procure CDR for overshoot
- <u>Short-term</u>: show pathway for DACCS removal offtake in compliance market
  - Certainty for investment in corporates and projects
  - Creating “lower bound” of revenues → bankability

5. Conclusion

- CDR important element to reach 1.5–2°C pathways, adding to indispensable deep decarbonization
- DACCS a durable and scalable solution, together with BECCS structurally different from other CDR
- At 1 Gt cumulative deployment, levelized cost of CO_2 removal in the magnitude of 250–450 \$/tCO_2 seem likely, thus not jeopardizing most decarbonization options
- Early deployment of DACCS driven by VCM and subsidies – a perspective for being part of an ERTS could provide a revenue baseline from compliance markets, improving investability and bankability