What is a removal?

Removing CO$_2$ from the atmosphere?

Close, but incomplete…

Removing CO$_2$ from circulation in the *active carbon cycle*, and stewarding its storage in a monitored carbon stock.

Removal is more completely described as the end-to-end process of “carbon removal and storage”
What is a removal?

Adapted from Hepburn et al 2019
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What is a removal?

Avoided deforestation
Improved forest management

Emission avoidance / reduction

CDR
CCU
CCS

MIXED <10% REMOVALS!

Adapted from Hepburn et al 2019
What is a removal?

**Carbon removal with storage**

Before carbon project:
- No activity, zero emissions

After carbon project:
- CO₂ removed from atmosphere
- Resulting CO₂ is stored or utilized with some degree of permanence
- Offset purchaser continues to emit

**Emission reduction with storage**

Before carbon project:
- No change in CO₂ emissions

After carbon project:
- CO₂ emission is reduced to zero
- Resulting CO₂ is stored or utilized with some degree of permanence

**Emission reduction through avoided emission (no apparent CO₂ storage)**

Before carbon project:
- CO₂ is not produced, no storage required

Emission is avoided with some degree of certainty

Unpublished
What is a removal?

How is the offset generated?

- Emission reduction
- Carbon removal

Is carbon stored?

- No
- Yes

How is carbon stored?

Ⅰ. Avoided emissions, or emission reduction without storage
   - Forward-looking, counterfactual baseline:
     - Renewable energy
     - Cleaner cookstoves
   - Clear retrospective emissions data:
     - N₂O abatement
     - Methane abatement

Ⅱ. Emissions reduction with short-lived storage
   - Avoided damage to ecosystems
   - Changes to ag practices that retain already-stored carbon

Ⅲ. Emissions reduction with long-lived storage
   - CCS on industrial facilities
   - CCS on fossil-fuel power plant

Ⅳ. Carbon removal with short-lived storage
   - Afforestation & reforestation
   - Soil carbon enhancement
   - Ecosystem restoration

Ⅴ. Carbon removal with long-lived storage
   - DACCS
   - BECCS
   - Mineralisation
   - Enhanced weathering

Less permanent, higher risk of reversal
More permanent, lower risk of reversal
What is a removal?

The market will soon demand a clear distinction between removals and avoidance/reduction!

- Eliminate ambiguity
- Be forthright
- Ask: “who should define what is and is not carbon removal?”

Introducing the Carbon Takeback Obligation
Carbon Takeback / Storage Obligation

- The bulk of the benefits (profits) from emissions accrue upstream at the wellhead (fossil fuel extraction), but *few climate policies harness this value.*

- The most expensive mitigation we’ll need to stop climate change is permanent carbon storage, but *conventional climate policies fail to incentivise it before it’s too late.*

The Carbon Takeback / Storage Obligation links these two insights, requiring the permanent storage of CO$_2$ as a condition of extracting more carbon from the Earth.
The only sustainable way to stop fossil fuels from causing global warming: high-durability CO$_2$ disposal

Not for long...
CO$_2$ energy and industrial process emissions in cost-effective 1.5$^\circ$C and <2$^\circ$C scenarios

Blue lines: 1.5$^\circ$C (SSPx-19) and <2$^\circ$C (SSPx-26) scenarios
Red lines: Trajectory delivered by a Carbon Takeback Obligation
Jenkins et al, 2021
Tracking progress to Net Zero CO$_2$ emissions:
Emissions = Production – Storage → 0

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Tracking progress to Net Zero CO$_2$ emissions: Stored Fraction = Storage/Production → 100%

Blue lines: 1.5°C (SSPx-19) and <2°C (SSPx-26) scenarios
Red lines: Trajectory delivered by a Carbon Takeback Obligation
Jenkins et al, 2021
So it is clear what is needed: why are we taking so long to develop CO$_2$ storage?

We can halve emissions with very little use of CO$_2$ storage, but we can’t get to net zero…
Red lines: a stylized “Carbon Takeback Obligation” scenario

Fossil fuel suppliers store a rising fraction of the CO$_2$ contained in their products, increasing quadratically to 100% in 2050.

\[ F = S/P \]

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From physics to policy

Carbon Takeback basics:

• Extractors & importers (or suppliers) must permanently store an escalating fraction of the fossil carbon contained in their products

• Carbon Storage Units (CSUs) can be traded among obliged entities

• Stored fraction escalation dictated by policy:
  – Quadratic increase to 100% by 2050
  – OR driven by warming itself…. 100% by the time 1.5C reached

See Zakkour et al 2020 and preceding papers for more on CSUs
The surprising economics of Carbon Takeback

- Initially low stored fraction…
- …very low initial cost of compliance, while still delivering permanent carbon storage!

The surprising economics of Carbon Takeback

- Initially low stored fraction…
- …very low initial cost of compliance, while still delivering permanent carbon storage!
- Blended cost of compliance gradually approaches the cost of DACCS

Mitchell-Larson and Allen 2021, Prosets: making continued use of fossil fuels compatible with a credible transition to net zero.
Why adopt Carbon Takeback?

- **PREDICTABLE.** Pathway to net zero, market discovers its own least-cost means of permanent \( \text{CO}_2 \) storage.
- **SIMPLE.** Light regulatory burden.
- **NO TAX.** No direct taxpayer subsidy, price support mechanisms, or taxes.
- **AFFORDABLE.** Initially high costs of geological storage ($50 - $100/t\text{CO}_2$ depending on source) spread over the full volume of fossil fuels sold. Desired outcome (permanent storage in line with climate requirement) assured with a small addition to carbon price.
- **SAFE.** \( \text{CO}_2 \) is stored safely and permanently, primarily underground and offshore, reducing pressure on ecosystems and aboveground land uses.
- **ALIGNED WITH PUBLIC SENTIMENT.** Bake in the cleanup costs into a still profitable industry!
Thank you

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https://carbontakeback.org
https://netzeroclimate.org
Global warming has passed 1.1°C, and rising at over 0.2°C per decade

Figure SPM.1 from the 2018 IPCC Special Report on 1.5°C
Global warming has passed 1.1°C, and rising at over 0.2°C per decade

Figure SPM.1 from the 2018 IPCC Special Report on 1.5°C
To meet Paris goals, we need to stop global warming before the world stops using fossil fuels.
To meet Paris goals, we need to stop global warming before the world stops using fossil fuels almost certainly.

Allwood, J. et al, 2019: https://doi.org/10.17863/CAM.46075
Tracking progress to Net Zero $\text{CO}_2$ emissions: $\text{Emissions} = \text{Production} - \text{Storage} \rightarrow 0$

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The surprising economics of Carbon Takeback

• Suppose CO\textsubscript{2} disposal costs
  – $50/tCO\textsubscript{2} \textit{stored} initially (CO\textsubscript{2} captured at source),
  – $250/tCO\textsubscript{2} at net zero (point sources + direct air capture).

• Cost per tCO\textsubscript{2} of fossil carbon sold = \( S(50+200S) \) where \( S \) is stored fraction.

• This is equivalent to a carbon price of:
  – $ 0.52 \$/tCO\textsubscript{2} at \( S=1\% \) (early 2020s)
  – $12.00 \$/tCO\textsubscript{2} at \( S=15\% \) (early 2030s)
  – $250 \$/tCO\textsubscript{2} at \( S=100\% \) (2050s)