Marine Carbon Dioxide Removal (mCDR) – approaches, risks, co-benefits, and governance

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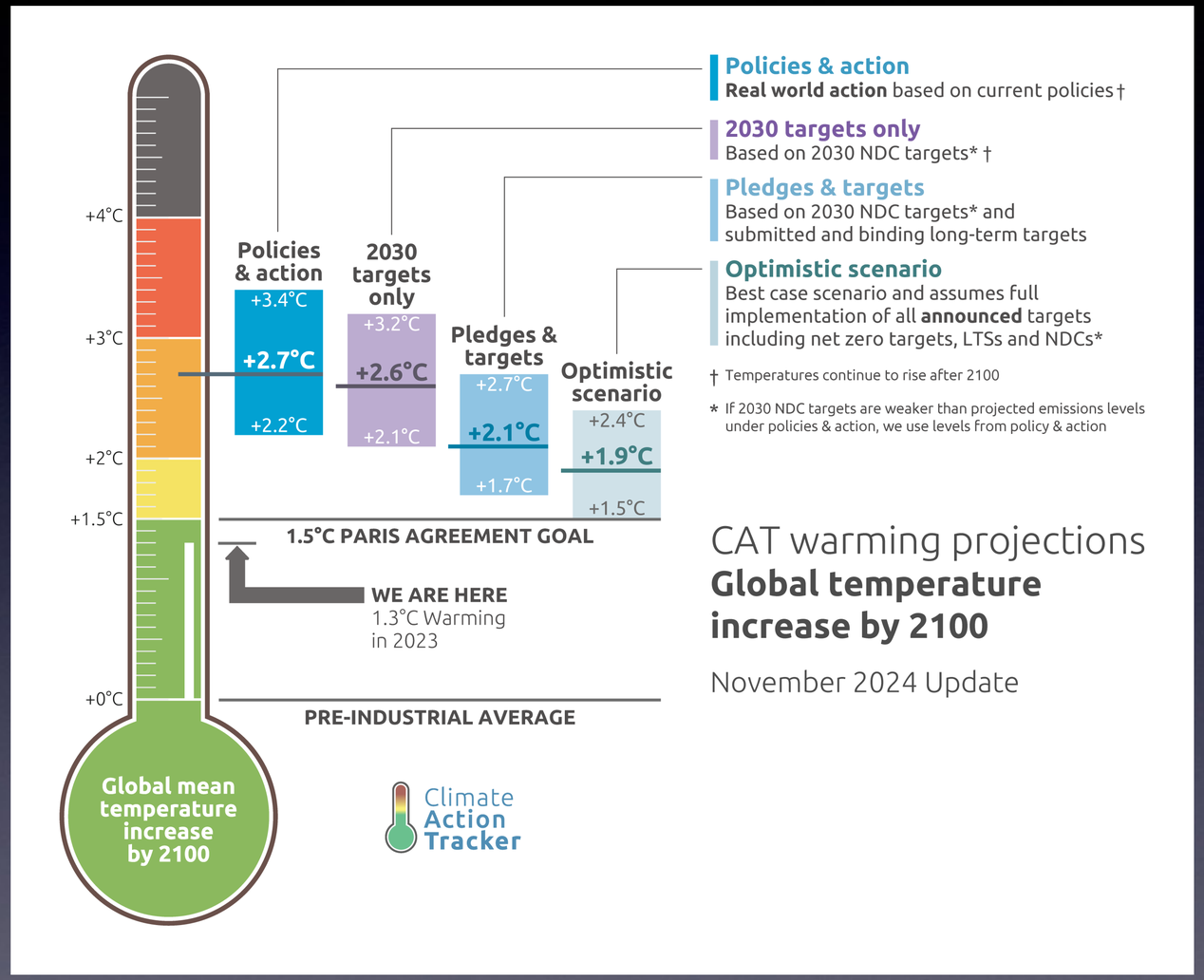
International climate policy

- **Paris Agreement**: “Holding the increase in the global average temperature to well below 2 °C above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5 °C above pre-industrial levels…”
- Emphasized the importance of achieving a **balance between sources and sinks of greenhouse gas**
- The concept of **Net Zero** has spurred political pledges towards actively eliminating carbon dioxide from the atmosphere (**CDR**).

International climate policy



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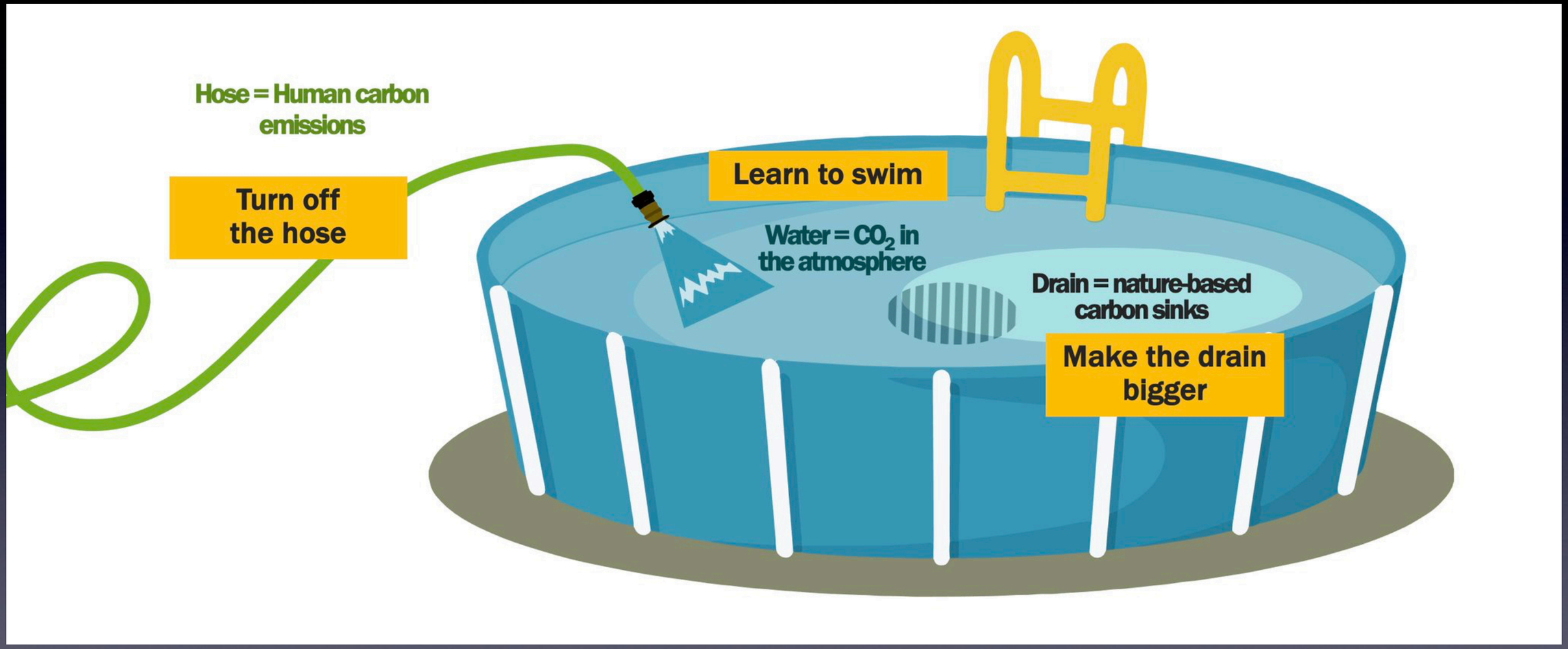
How do we tackle climate change



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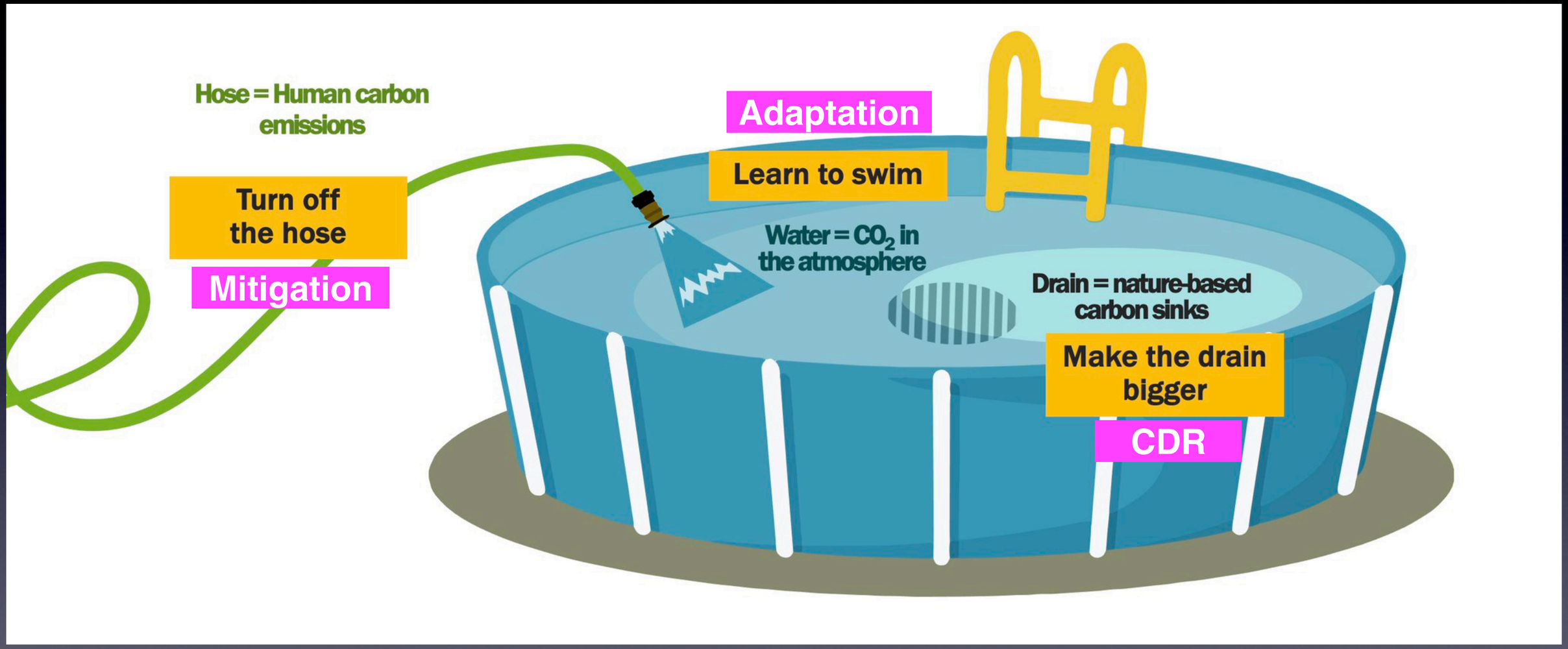
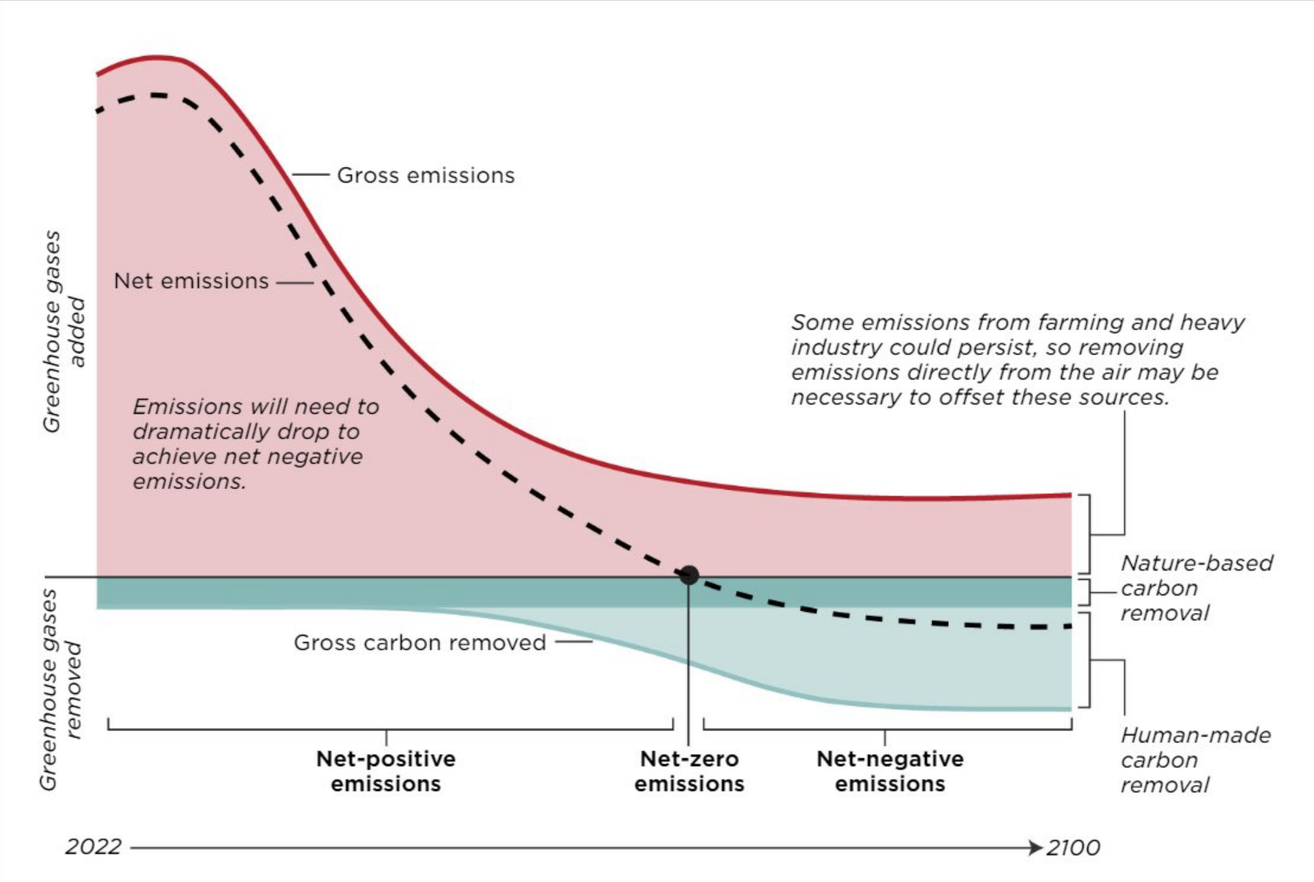


Need for negative emissions



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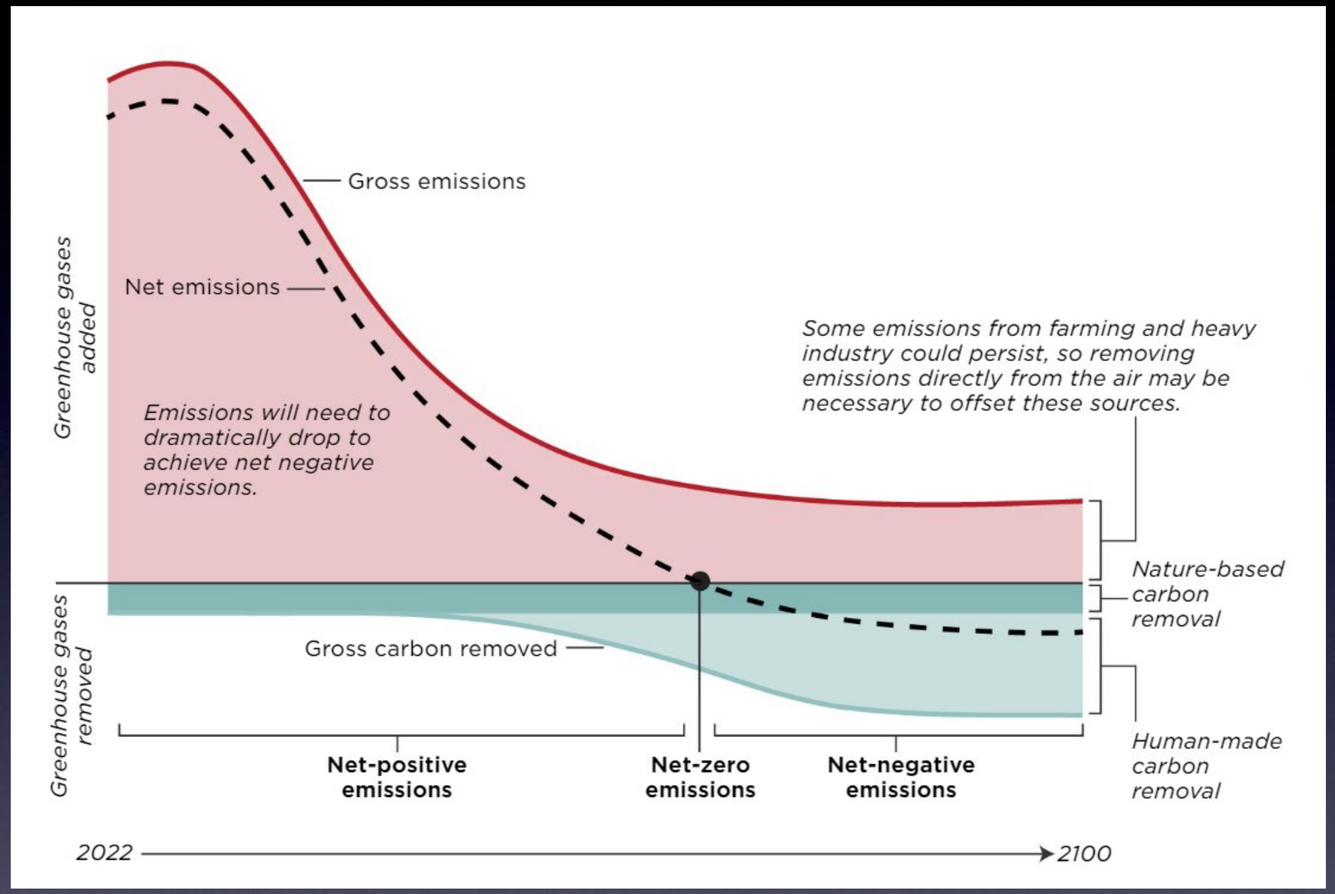
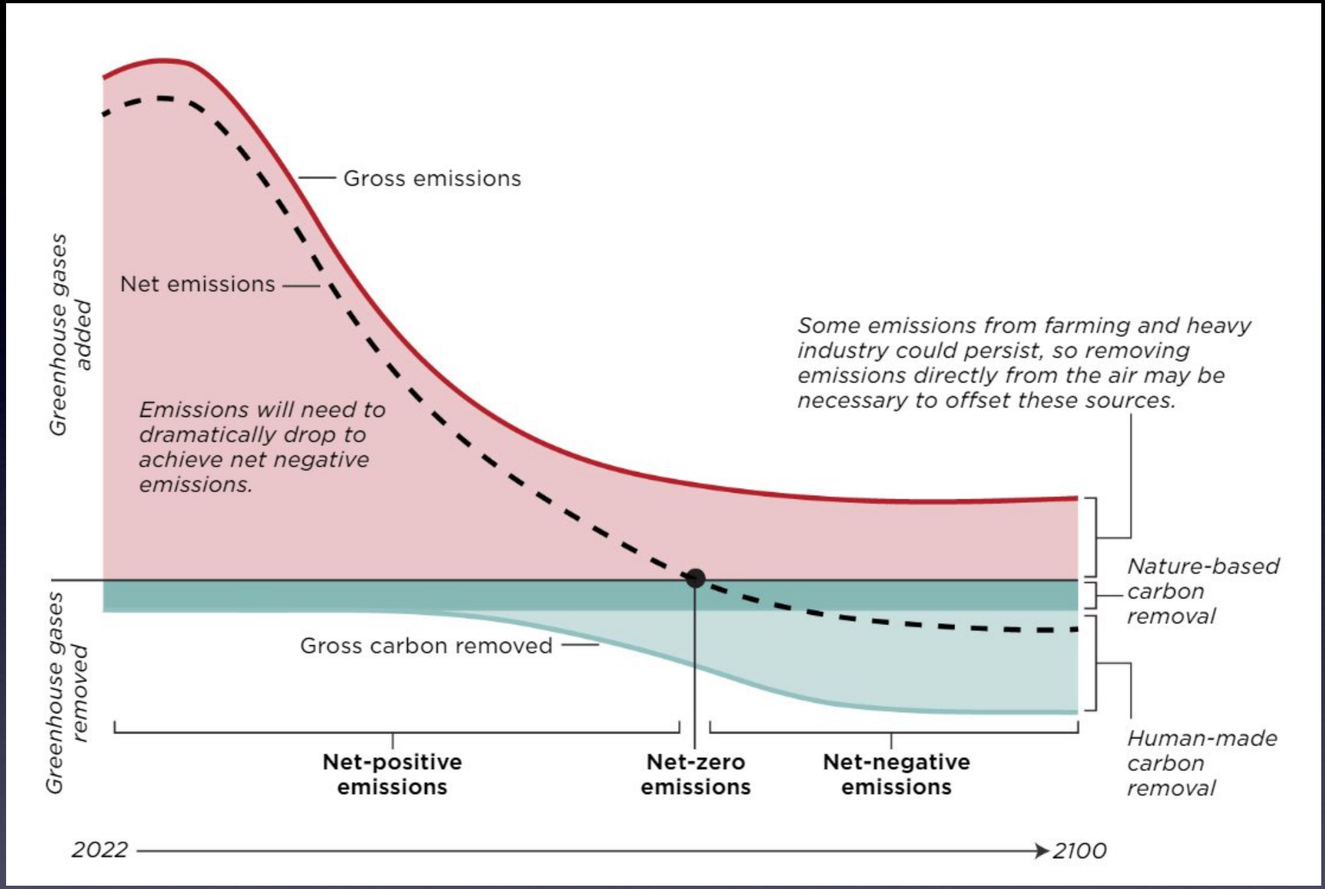


- **IPCC SR1.5**: Maintaining global warming at 1.5°C with limited or no overshoot requires the use of carbon dioxide removal (CDR) of 100–1000 Gt CO_2 over the 21st century
- **IPCC WG3**:
  - CDR is “an **essential element** of scenarios that limit warming to 1.5ºC or likely below 2ºC by 2100”
  - “CDR **cannot serve as a substitute** for deep emissions reductions but can fulfil multiple complementary roles”
- Ocean is a new **blue frontier** for carbon removal & storage
  - Multiple feasibility and sustainability constraints on land
  - Very large potential for C uptake
  - Huge surface area and volume
  - Chemical characteristics
- Monitoring, reporting and verification essential to keep the crediting system honest

CDR usage



Babiker et al. (2022, IPCC WG3):

CDR cannot serve as a substitute for deep emissions reductions but can fulfil multiple complementary roles:

- further reduce net CO2 or GHG emission levels in the near-term;
- counterbalance residual emissions from hard-to-transition sectors, such as CO2 from industrial activities and long-distance transport (e.g., aviation, shipping), or methane and nitrous oxide from agriculture, in order to help reach net zero CO2 or GHG emissions in the mid-term;
- achieve and sustain net-negative CO2 or GHG emissions in the long-term, by deploying CDR at levels exceeding annual residual gross CO2 or GHG emissions.

What is exactly CDR (vs CCS, CCU)

- **CDR (IPCC)**: *Human activities capturing CO2 from the atmosphere and storing it durably in geological, land or ocean reservoirs or in products. This includes human enhancement of natural removal processes but excludes natural uptake not caused directly by human activities.*
- 3 key principles (Smith et al., 2024):
  1. The CO_2 captured must **come from the atmosphere**, not from fossil sources.
  2. The subsequent storage must be **durable**, such that CO_2 is not soon reintroduced to the atmosphere.
  3. The removal must be a result of human intervention, **additional** to the Earth's natural processes

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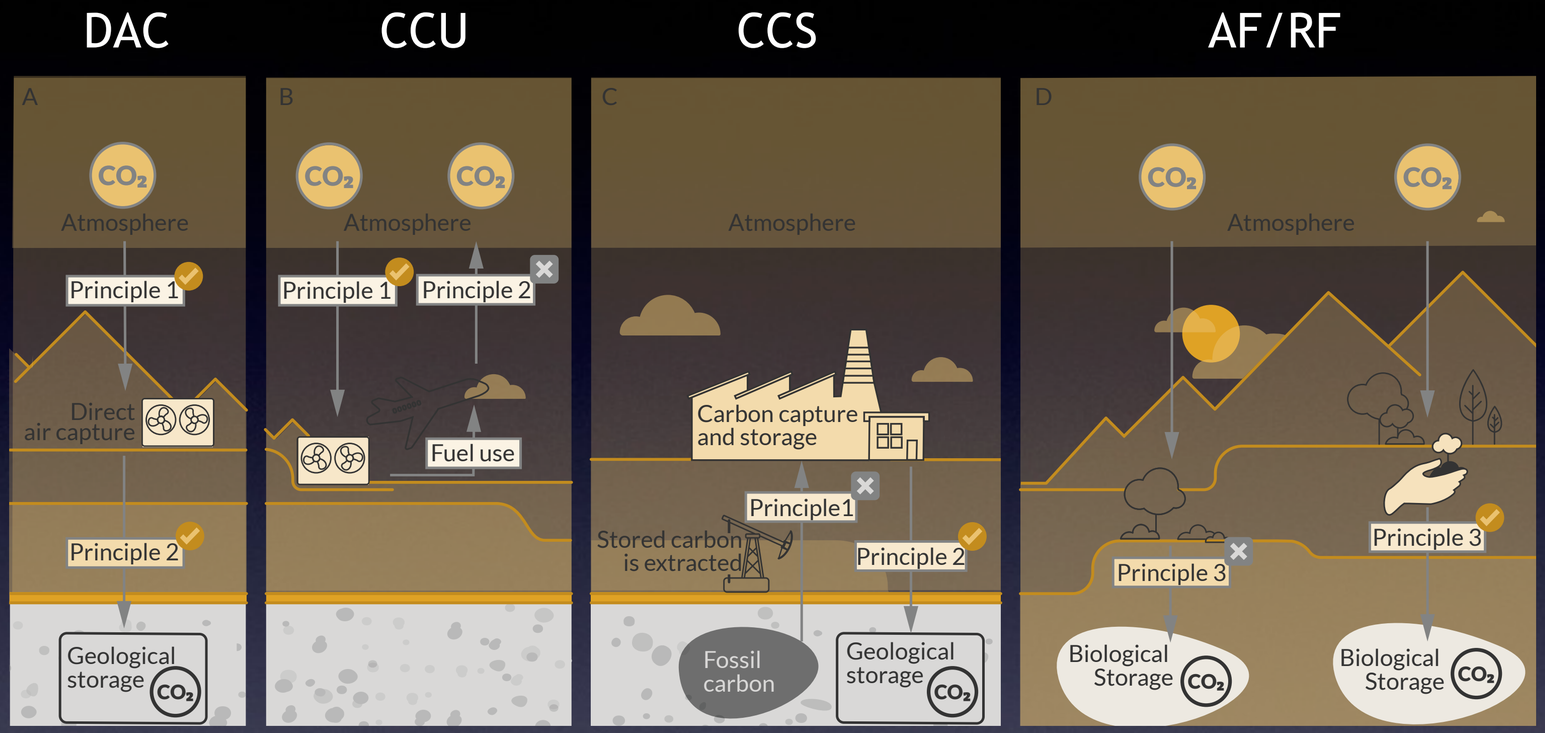

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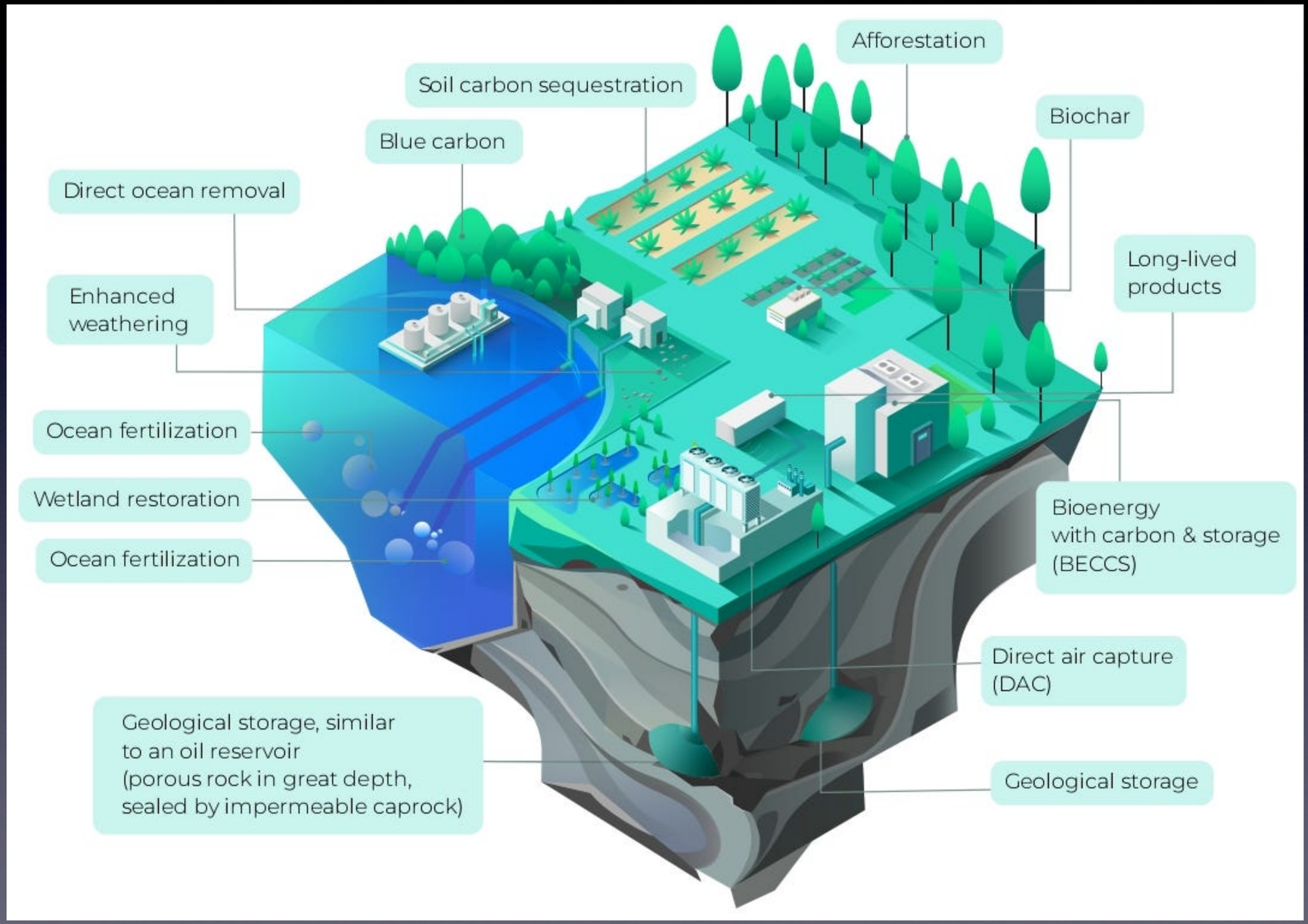
CDR overview



Unlimited creativity

Physics > Physics and Society

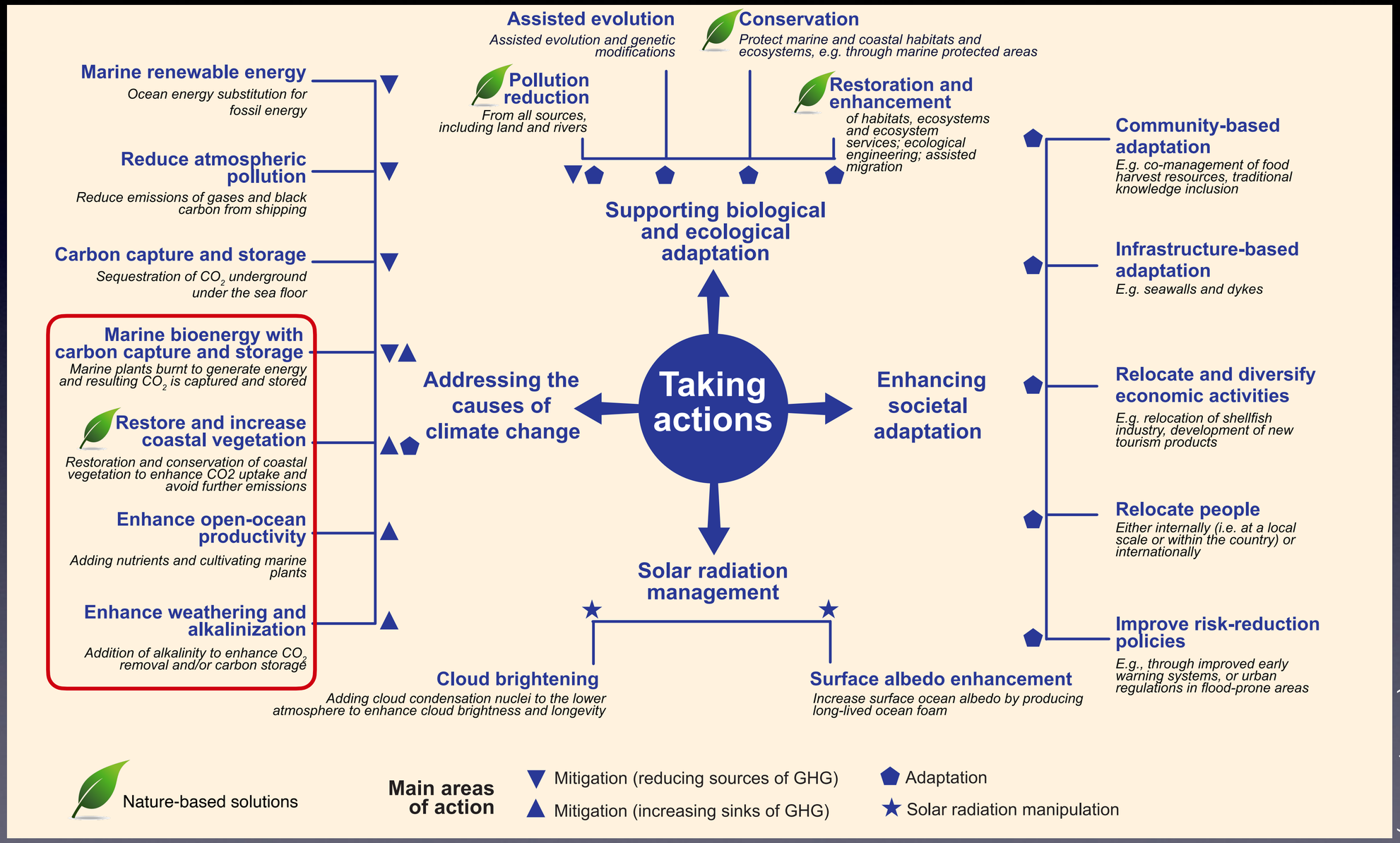
[Submitted on 11 Jan 2025]

Nuclear Explosions for Large Scale Carbon Sequestration

Andrew Haverly

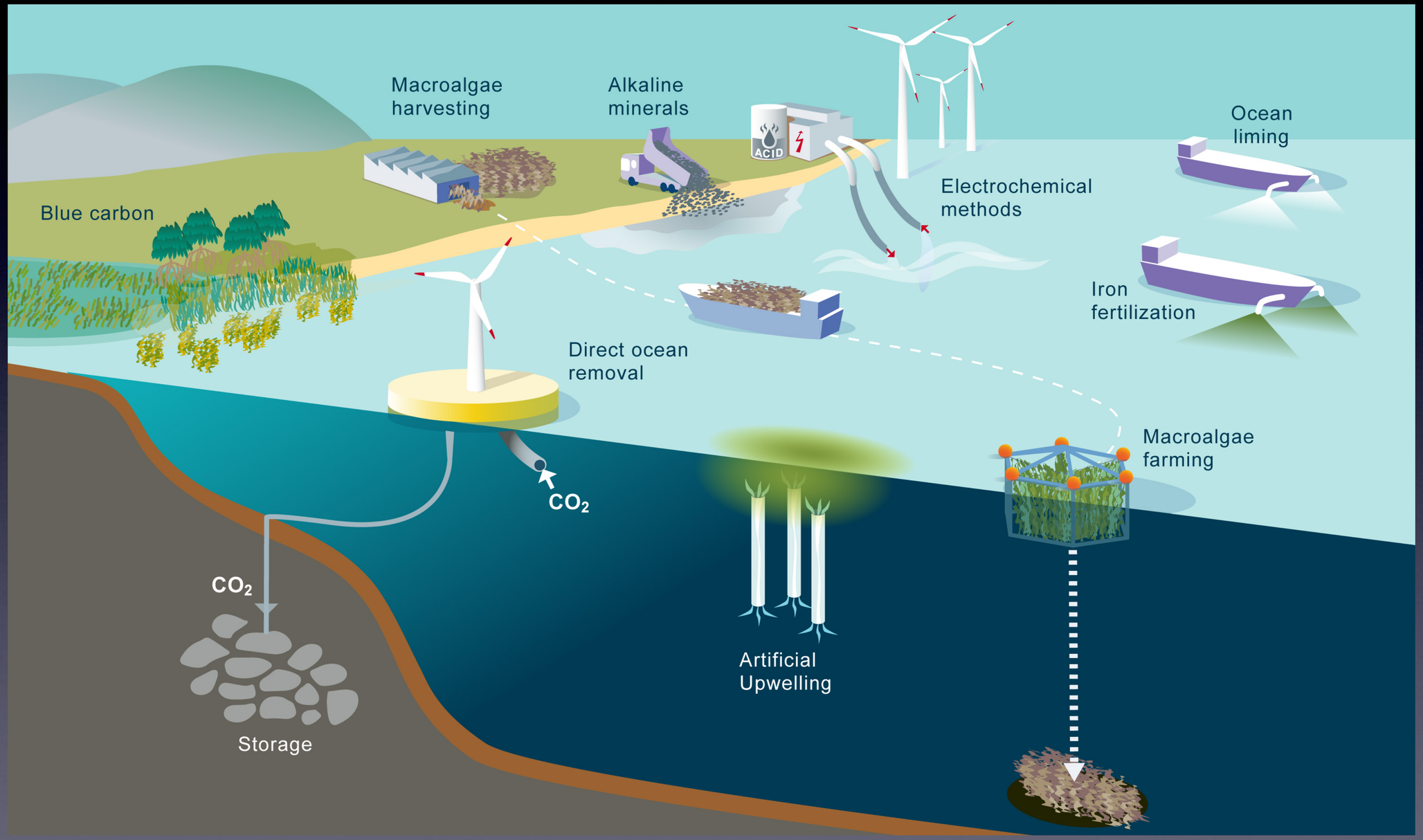
Confronting the escalating threat of climate change requires innovative and large-scale interventions. This paper presents a bold proposal to employ a buried nuclear explosion in a remote basaltic seabed for pulverizing basalt, thereby accelerating carbon sequestration through Enhanced Rock Weathering (ERW). By precisely locating the explosion beneath the seabed, we aim to confine debris, radiation, and energy while ensuring rapid rock weathering at a scale substantial enough to make a meaningful dent in atmospheric carbon levels. Our analysis outlines the parameters essential for efficient carbon capture and minimal collateral effects, emphasizing that a yield on the order of gigatons is critical for global climate impact. Although this approach may appear radical, we illustrate its feasibility by examining safety factors, preservation of local ecosystems, political considerations, and financial viability. This work argues for reimagining nuclear technology not merely as a destructive force but as a potential catalyst for decarbonization, thereby inviting further exploration of pioneering solutions in the fight against climate change.

Ocean-based measures



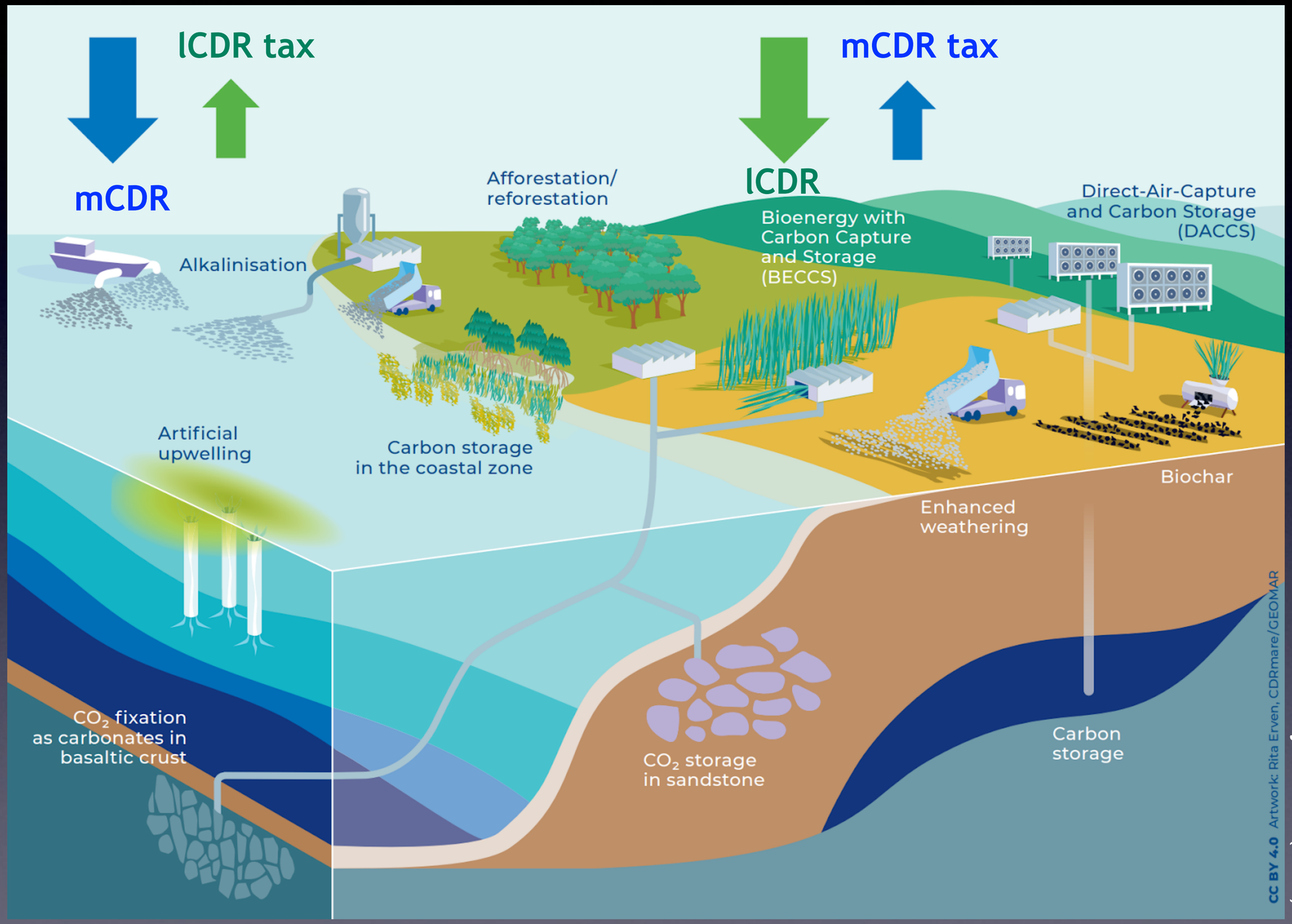
Gattuso et al. (2018, 2019)

What is marine Carbon Dioxide Removal?



Oschlies et al. (2025)

CDR tax implies consideration of One-Earth CDR

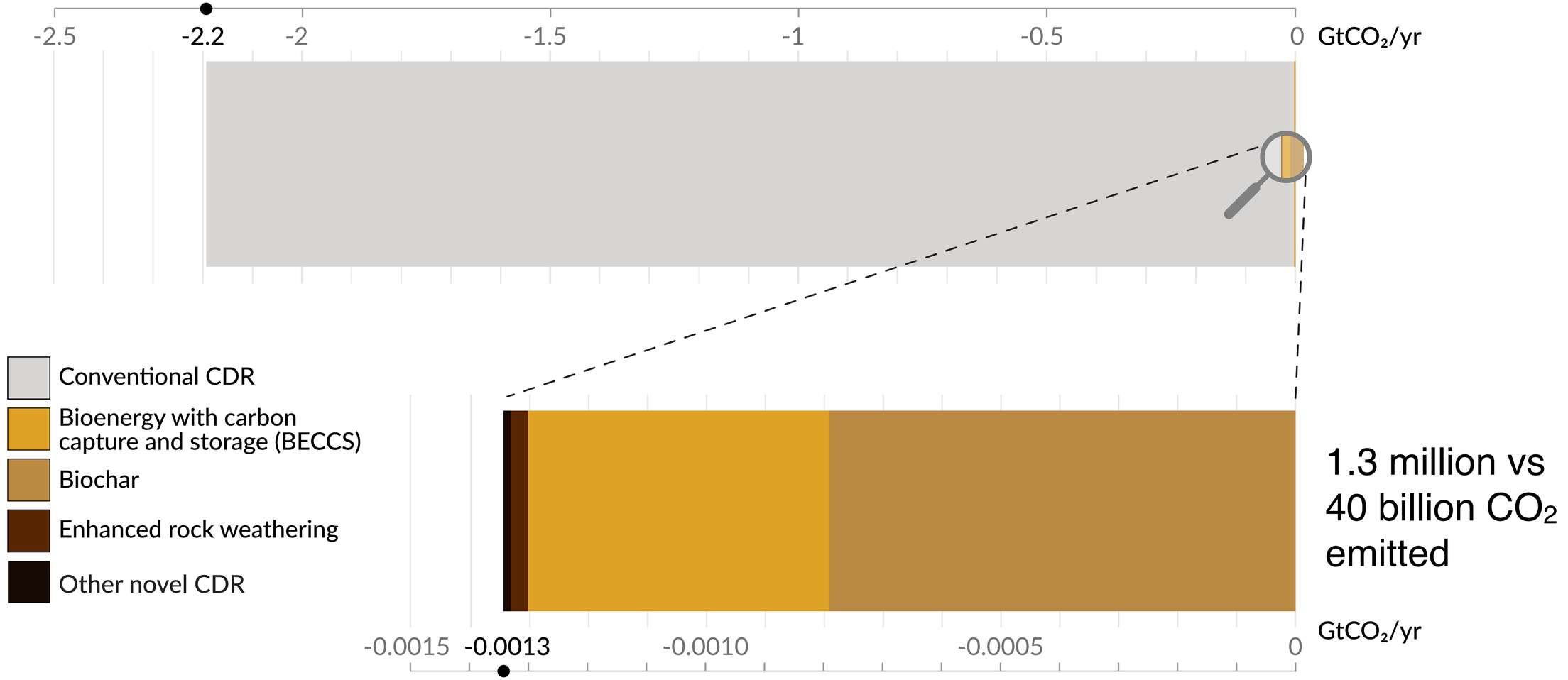


Boyd et al. (sbm)

State of CDR

Only a tiny fraction of all carbon dioxide removal results from novel methods

Total amount of carbon dioxide removal, split into conventional and novel methods ($GtCO_2/yr$)



Smith et al. (2024)

Integrity and effectiveness of mCDR

The **integrity** and **effectiveness** of mCDR in producing **honest carbon credits or offsets** are influenced by several factors:

- scientific understanding
- technological maturity
- scalability
- cost effectiveness
- permanence
- monitoring, reporting and verification
- framework of governance and policy

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Are we there yet? Many knowledge gaps

Need of major push for research

Science should be ahead of the industry

RUNNING TIDE

About Carbon Removal Deep Dives Purchase Carbon Removals

Jordan Breighner

3.14.24
Science
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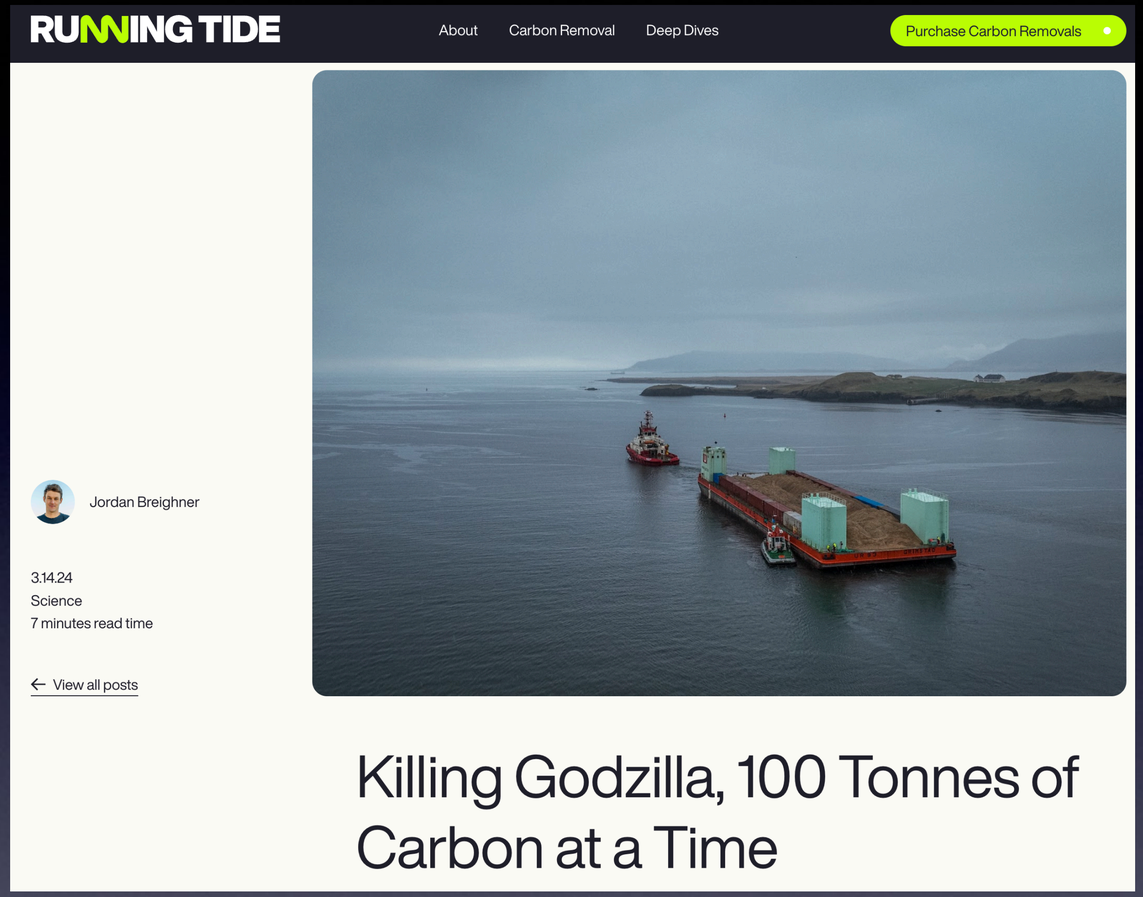
Killing Godzilla, 100 Tonnes of Carbon at a Time

Science should be ahead of the industry



- Ocean Vision field trials database (https://oceanvisions.org/mcdr-field-trials)
  - 19 led by academic institutions or research institutes
  - 30 led by startups
  - 3 others
- World Ocean Initiative:
  - 56% of the US$40m industry depends on ocean observation data
  - Future: >50% of industry's economic value will depend on observations
- Most ocean data are generated by public money, open-access, greatly benefitting the industry
- OAE guide to best practices:
  - results shared transparently, irrespective of outcome
  - public registry for field experiments
  - projects must be designed to answer scientific questions; be subject to peer review and transparency requirements; not be influenced by economic interests; and should be designed to avoid, minimize, or mitigate adverse environmental impacts.
  - One should remain mindful of the cost of inaction

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Thank you!