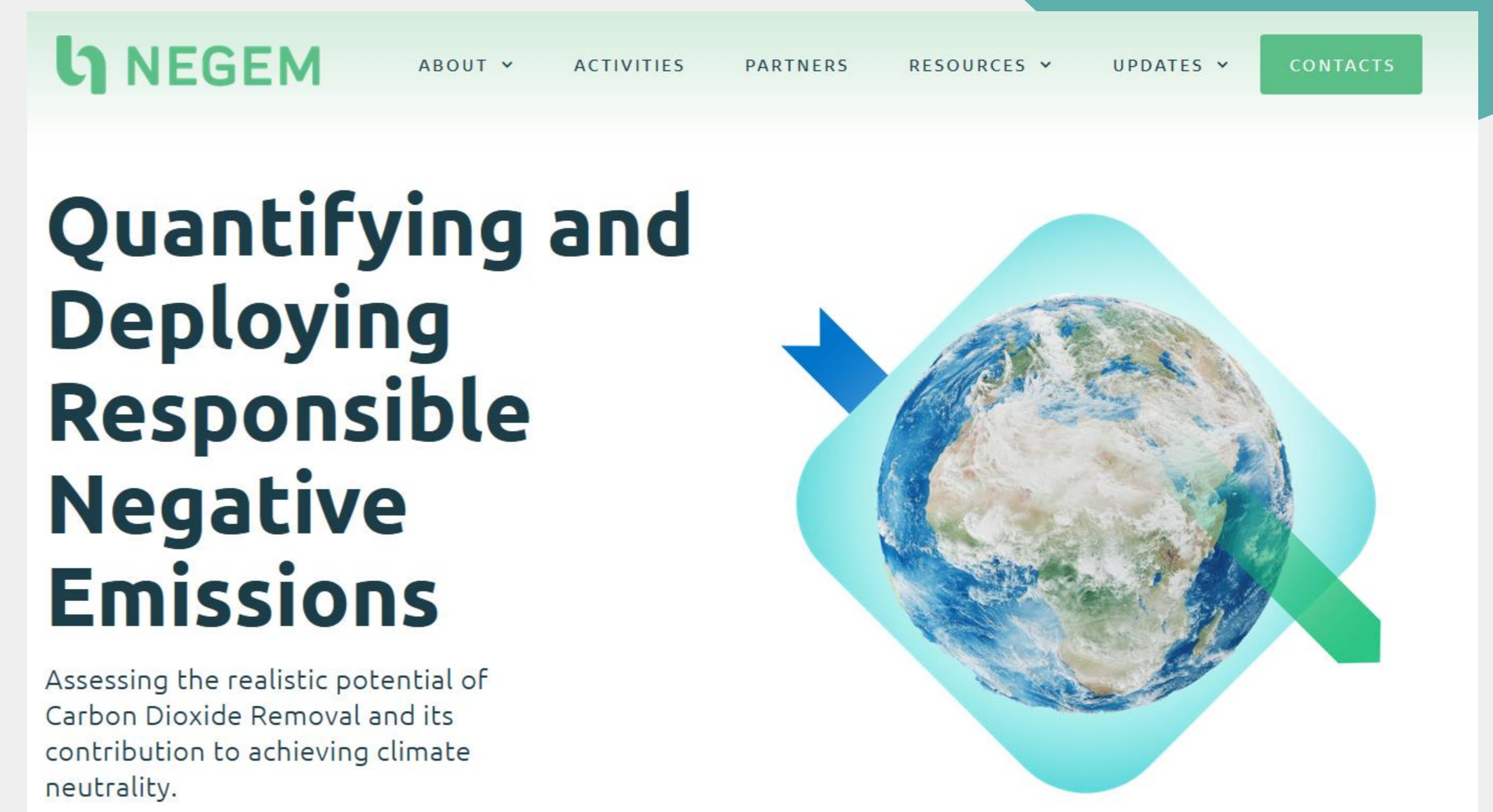


Assessing the realistic potential of Carbon Dioxide Removal (CDR) and its contribution to achieving climate neutrality

The European NEGEM Project

<https://www.negemproject.eu/>










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<https://www.negemproject.eu/>

Project partners

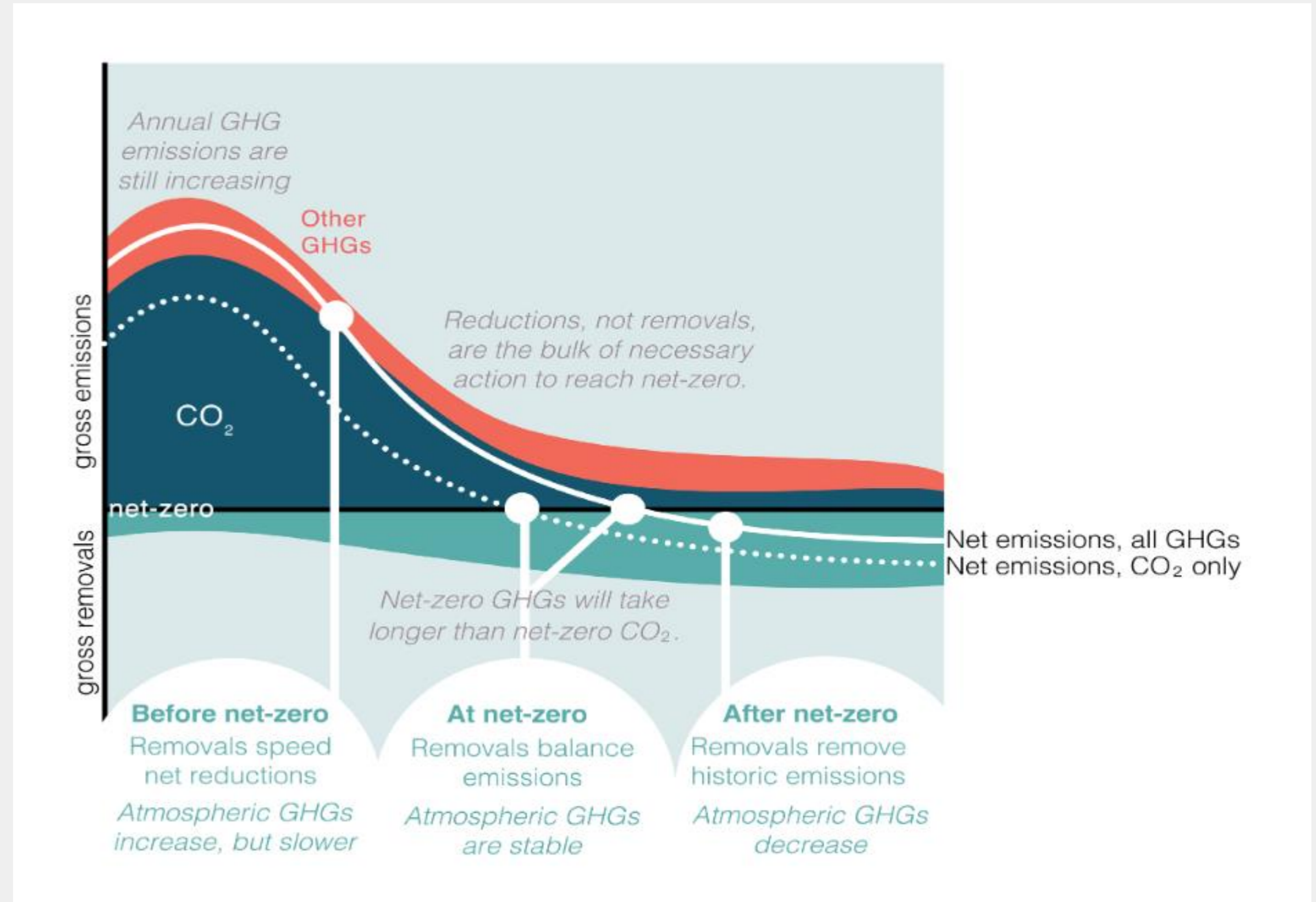
	VTT Technical Research Centre of Finland coordinator		Potsdam Institute for Climate Impact Research		Imperial College of Science Technology and Medicine
	University of Cambridge		Eidgenoessische Technische Hochschule Zuerich		Bellona Europa
	ETA Florence Renewable Energies		Norwegian Institute for Water Research		University of Groningen
	Institut National des Sciences Appliquées de Toulouse		Carbon Market Watch		University of Oxford
	Stockholm Exergi AB		ST1 OY		Drax Power Limited
	Sappi Netherlands Services				



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Carbon Dioxide Removal is unavoidable to meet Net-Zero targets

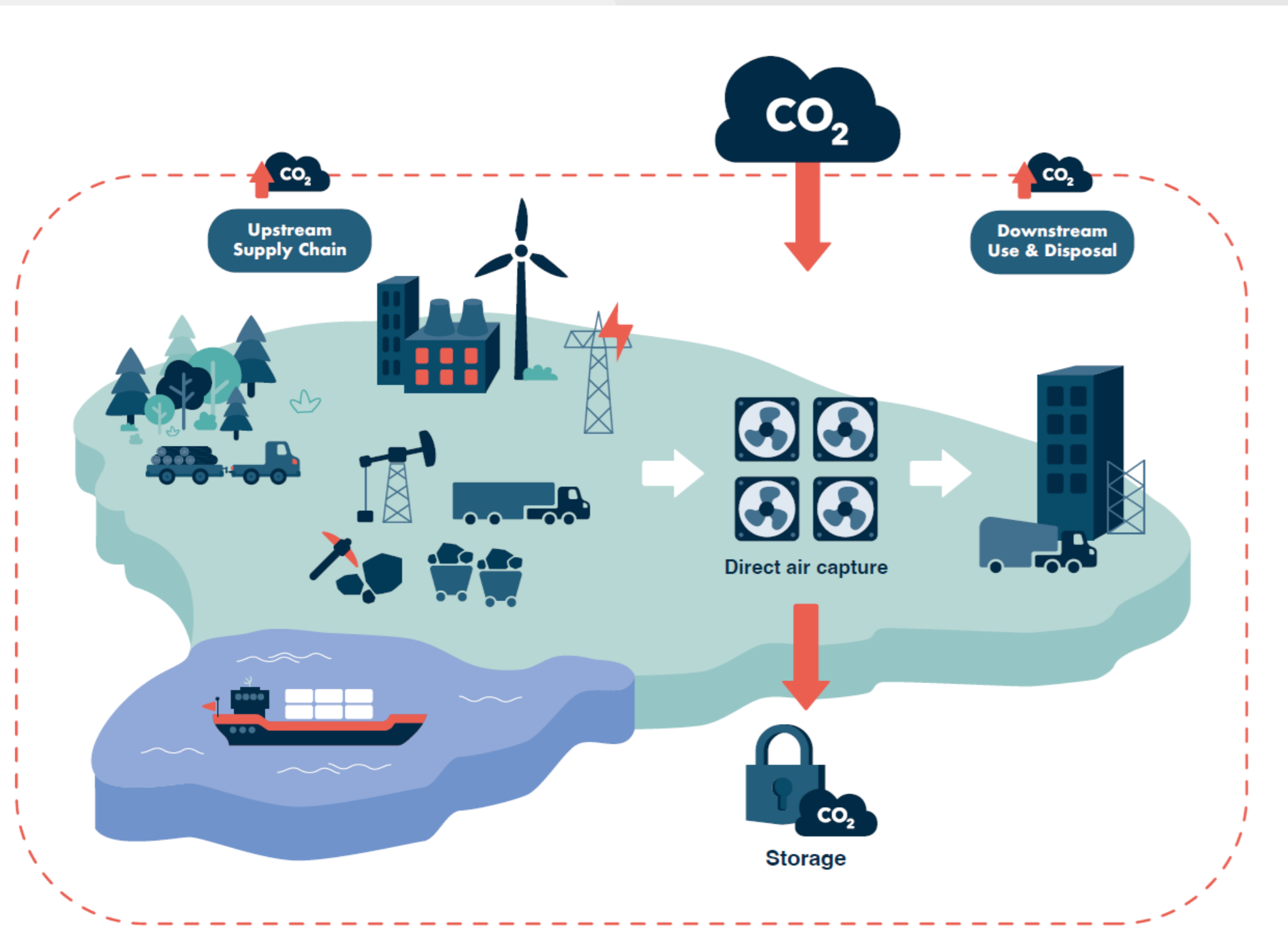
- To accelerate climate action
- To balance out residual GHG emissions
- To reduce global CO₂ concentrations



What is Carbon Dioxide Removal (CDR)

Key requirements

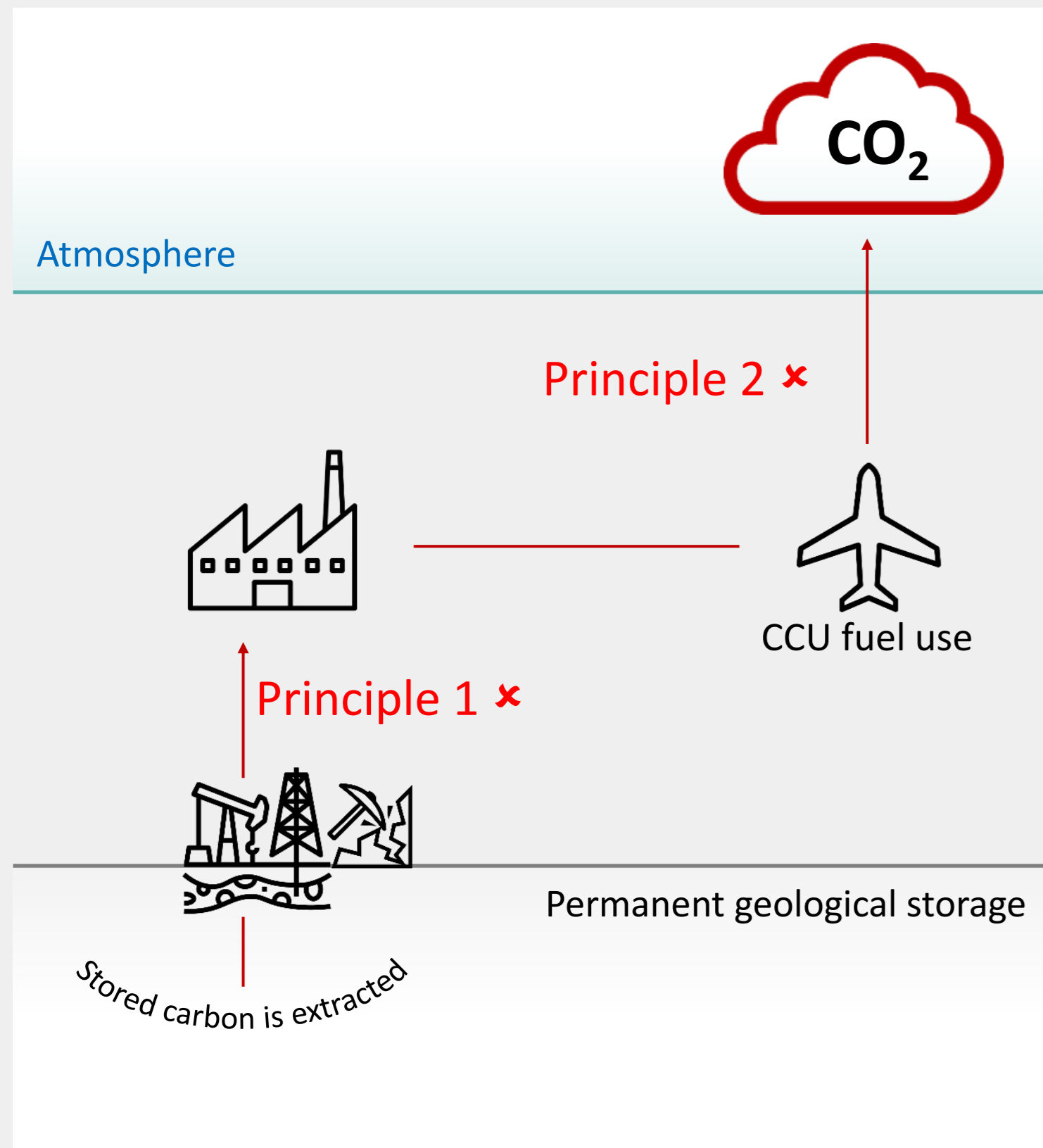
1. CO₂ physically removed from the **atmosphere**
2. Removed CO₂ is stored **permanently** (at least several centuries)
3. It is **additional** to natural processes.
4. All **associated emissions** estimated and accounted for
5. Total permanent removals **exceed** total associated emissions



What is (not) CDR

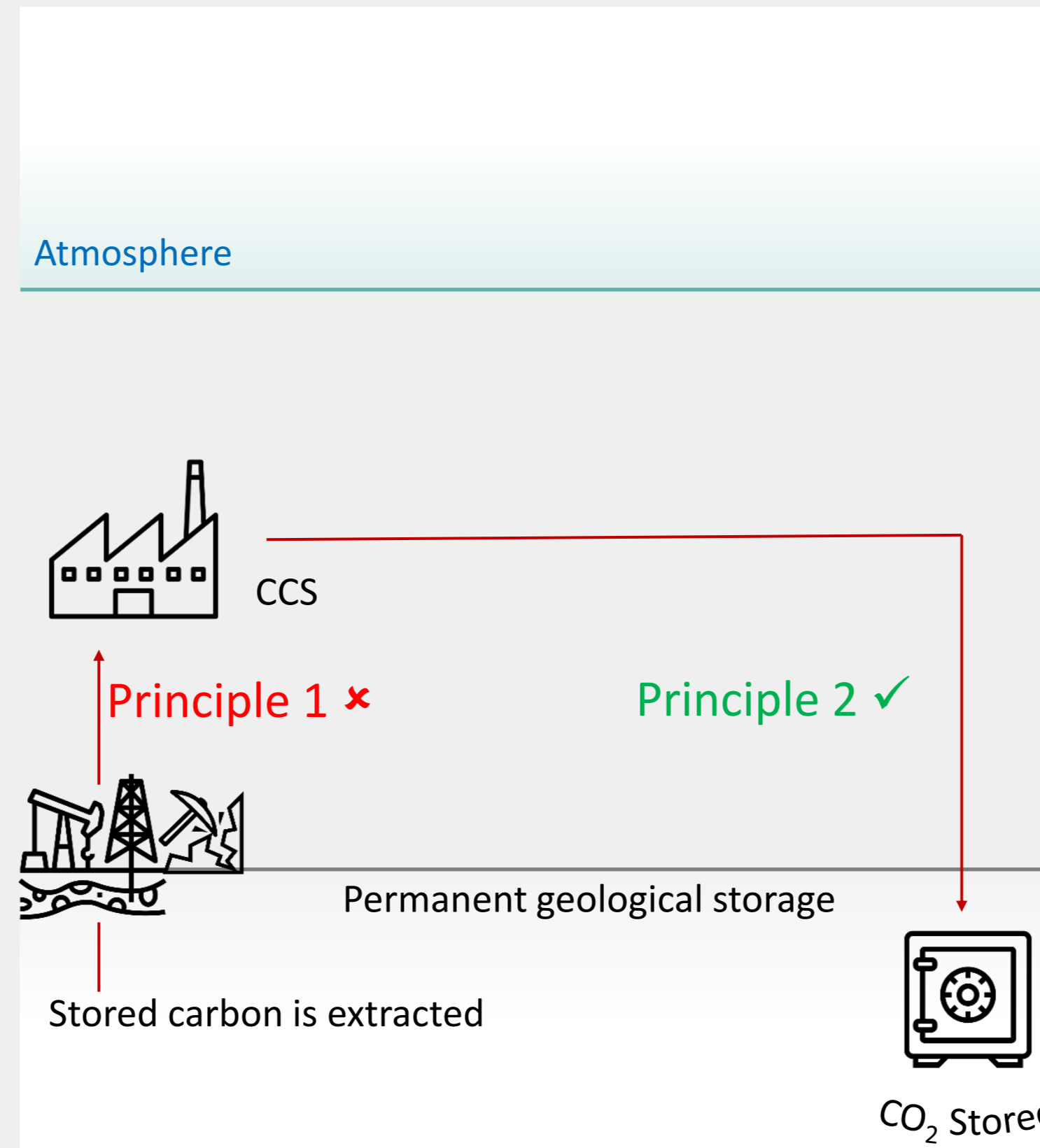
CCU

delaying hard-to-abate emissions



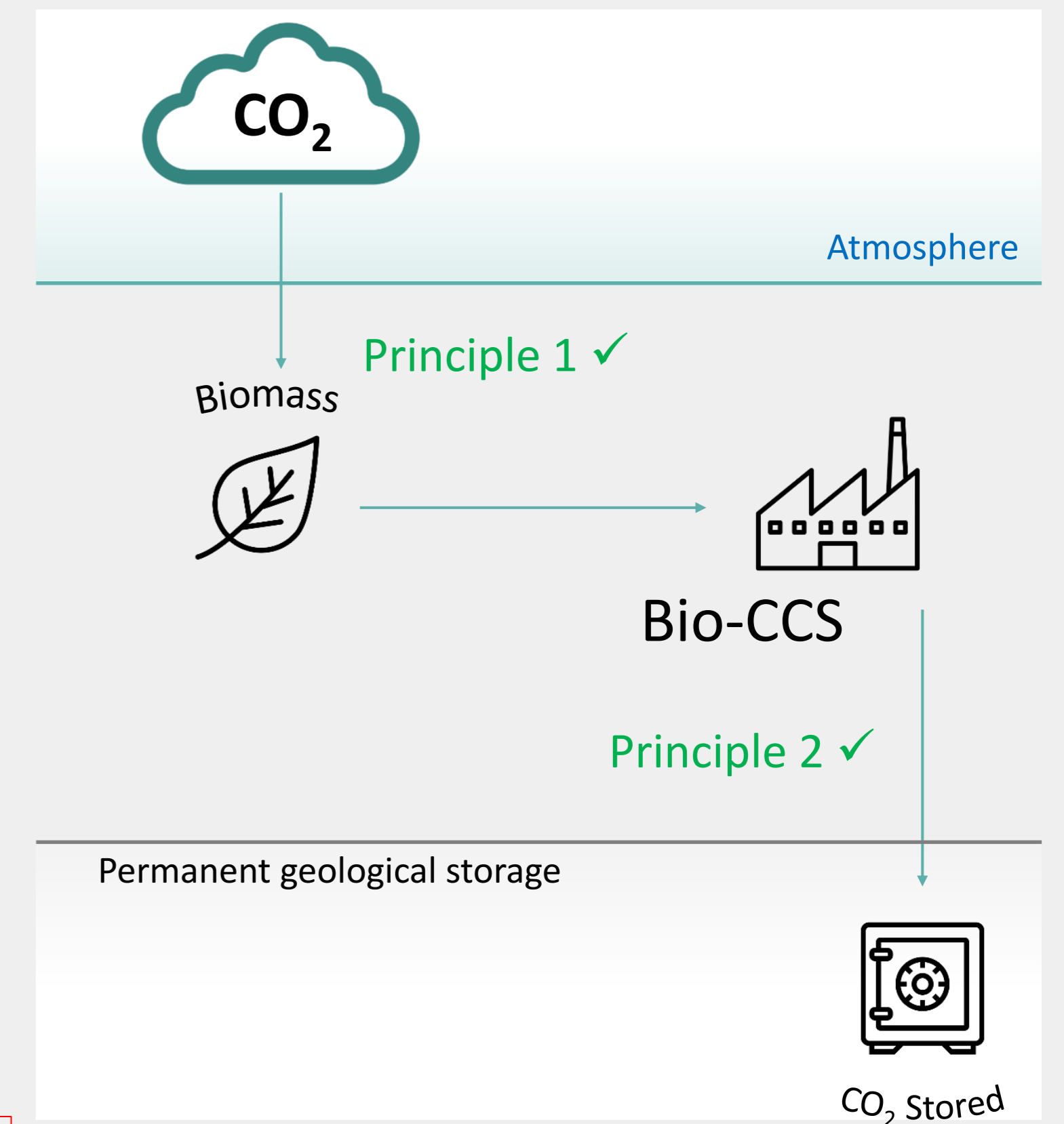
CCS

reducing hard-to-abate emissions



CDR

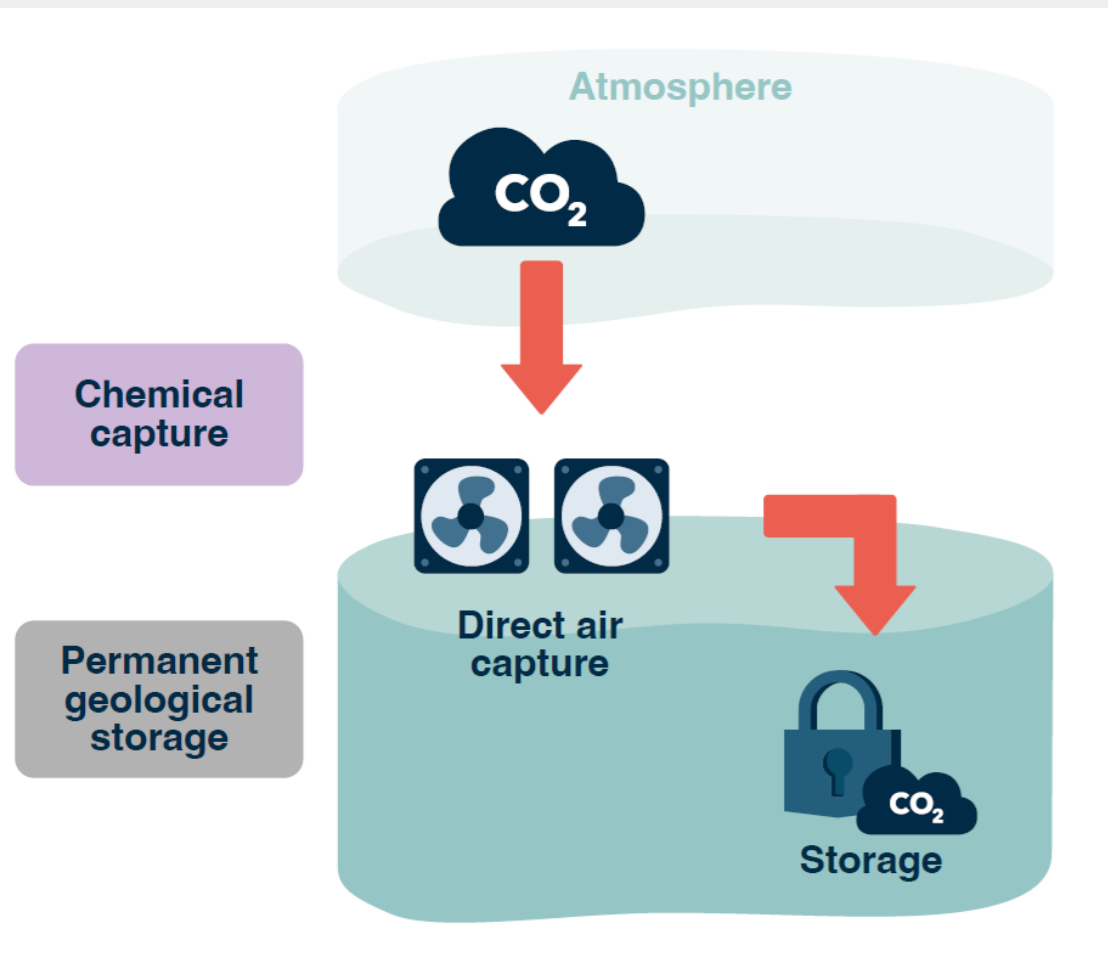
counterbalancing residual emissions



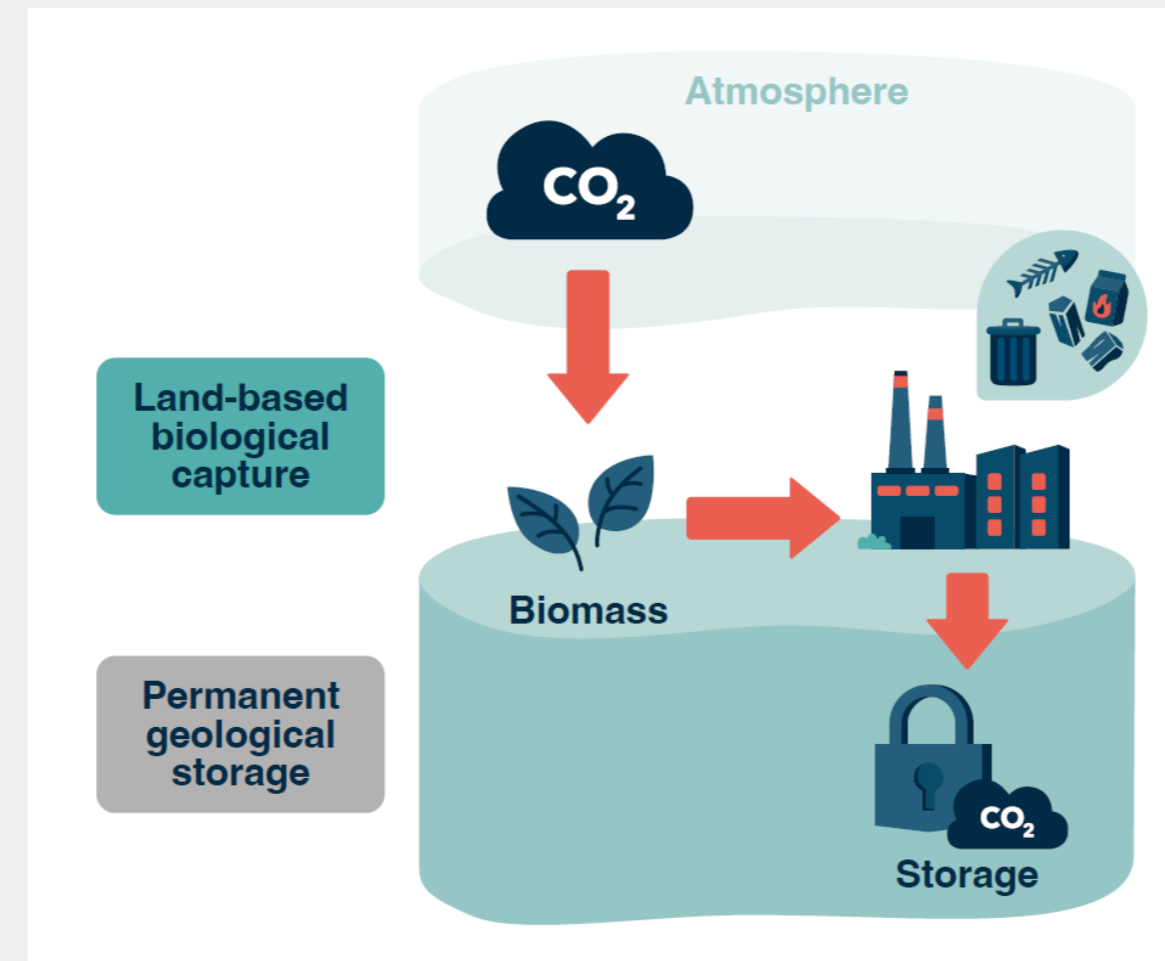
*Emissions **Avoidance is not**, and **never** can be Carbon Dioxide Removal*

CDR approaches

DACCS



BioCCS



Afforestation



Technologically

Cost, effectiveness, technological readiness, CO₂ reduction potential

Commercially

Potential value and option value (willingness to pay) negative emissions

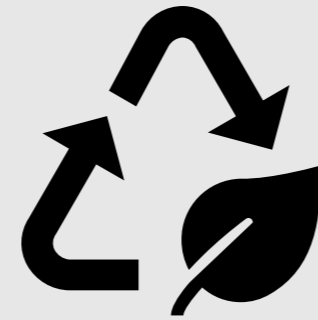
Environmentally

Impacts on planetary boundaries (land, biodiversity, human safety and ecosystems) and resource flows (food security, water, biomass, metals and minerals)

Socially

Public perception of cost, risks and benefits

Assessing the realistic potential and responsible deployment of CDR



Life cycle assessment (LCA)

How does the sustainability of different CDR approaches (biological, chemical, geochemical) compare?



Target-based approach (IAM)

How is CDR deployed to counterbalance residual emissions and reach mitigation goals at lowest cost?



Supply-constrained approach

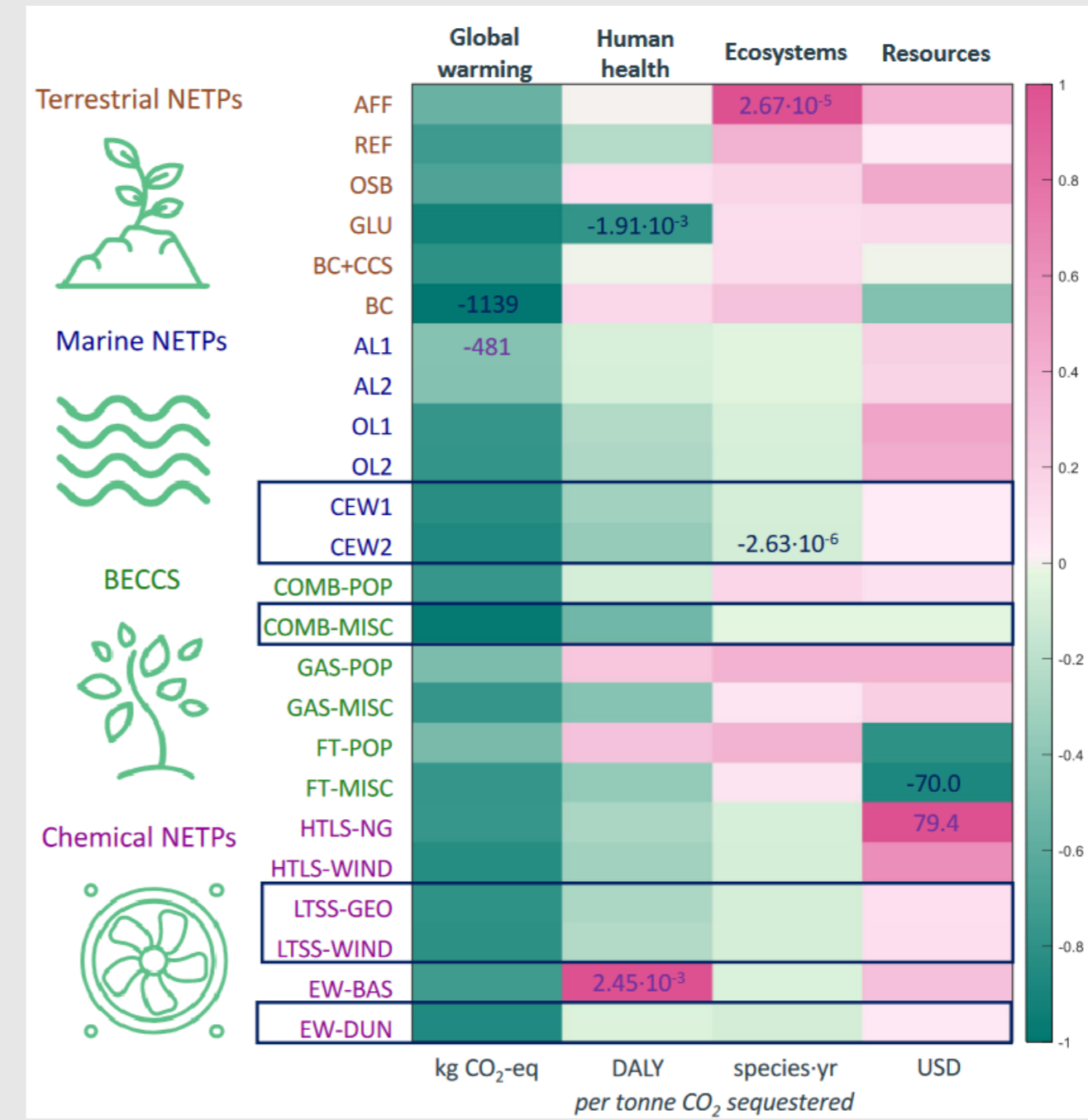
How much CDR can be achieved within resource limitations (e.g. land, water, biomass, energy) and without further straining planetary boundaries?



Cradle-to-grave life cycle assessment (LCA)

There is no NETP (CDR method) without a negative impact in at least one category.

A portfolio is needed to balance trade-offs and minimise local risks.



Net additional impact

Net prevented impact

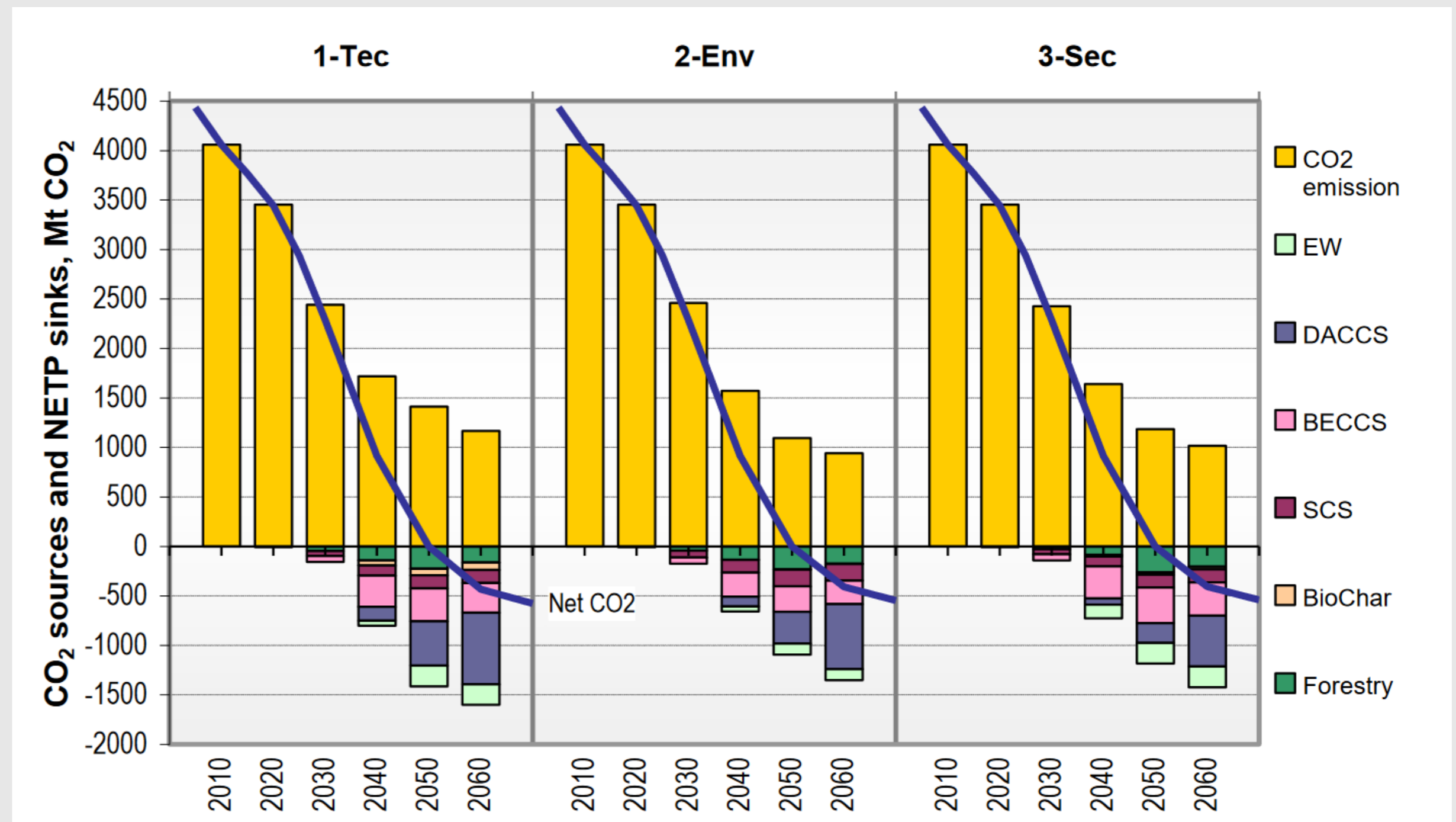


Target-based approach

Total EU CDR demand estimated at >1 Gt yr⁻¹ by 2050.

A portfolio is needed to balance energy supply and demand systemically.

EU-31 NEGEM scenarios



Source: Lehtilä et al. 2023, Quantitative assessments of NEGEM scenarios with TIMES-VTT (D8.2)

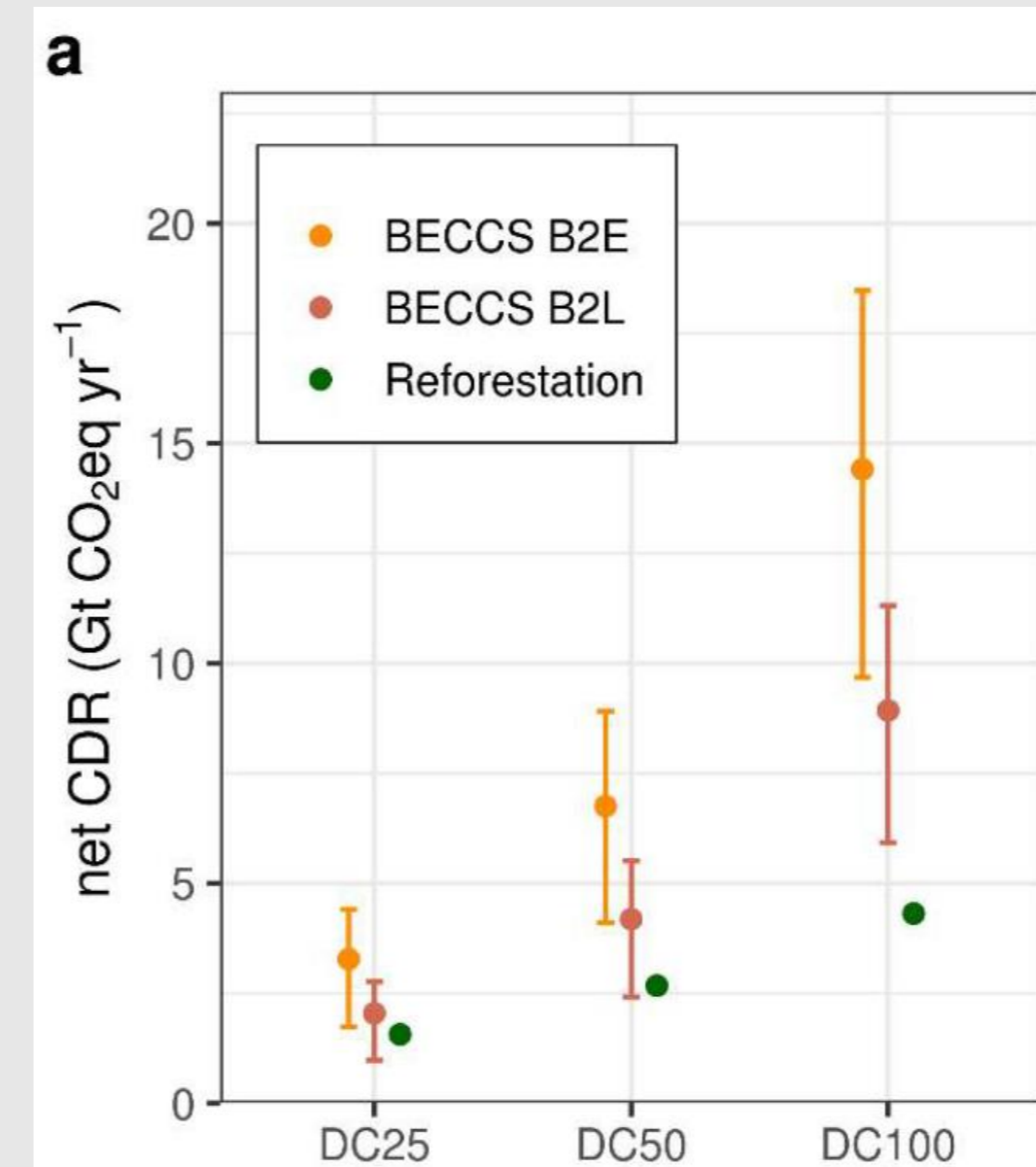




Supply-constrained approach

Biomass-dependent CDR potentials depend on large-scale dietary change.

Reforestation has lower CDR potential but higher potential co-benefits (e.g. enhancing biodiversity).




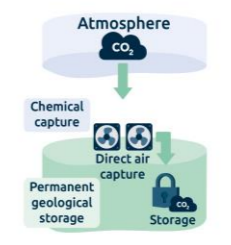
↑ Higher CDR potential

→ Shift to EAT-Lancet planetary health diet

Source: Werner et al. 2023, "Global assessment of NETP impacts utilising concepts of biosphere integrity" (D3.3)

There is no silver bullet: all CDR methods have trade-offs

Direct Air Capture with Carbon Storage 
A process that removes CO₂ directly from the atmosphere



Expected permanence	millennia
Reversal risk	low
Uncertainty in amount of initially captured carbon	low
Uncertainty in amount of carbon stored over time	low
Ease and accuracy of any	high
Key co-benefits	none

What is direct air capture with carbon storage and how does it store carbon?

Direct air capture with carbon storage (DACCS) refers to the chemical extraction of CO₂ from the atmosphere by chemical absorption, followed by the recovery and compression of CO₂ into a concentrated liquid and storage in geological reservoirs. It is an example of removals with key attributes: the capture and storage processes are relatively easy to quantify and measure. The process to separate CO₂ from the other components of ambient air is either done through absorption or adsorption. Once extracted, the carbon is then stored in geological reservoirs such as saline aquifers, or other mineral forms, in the earth's crust.

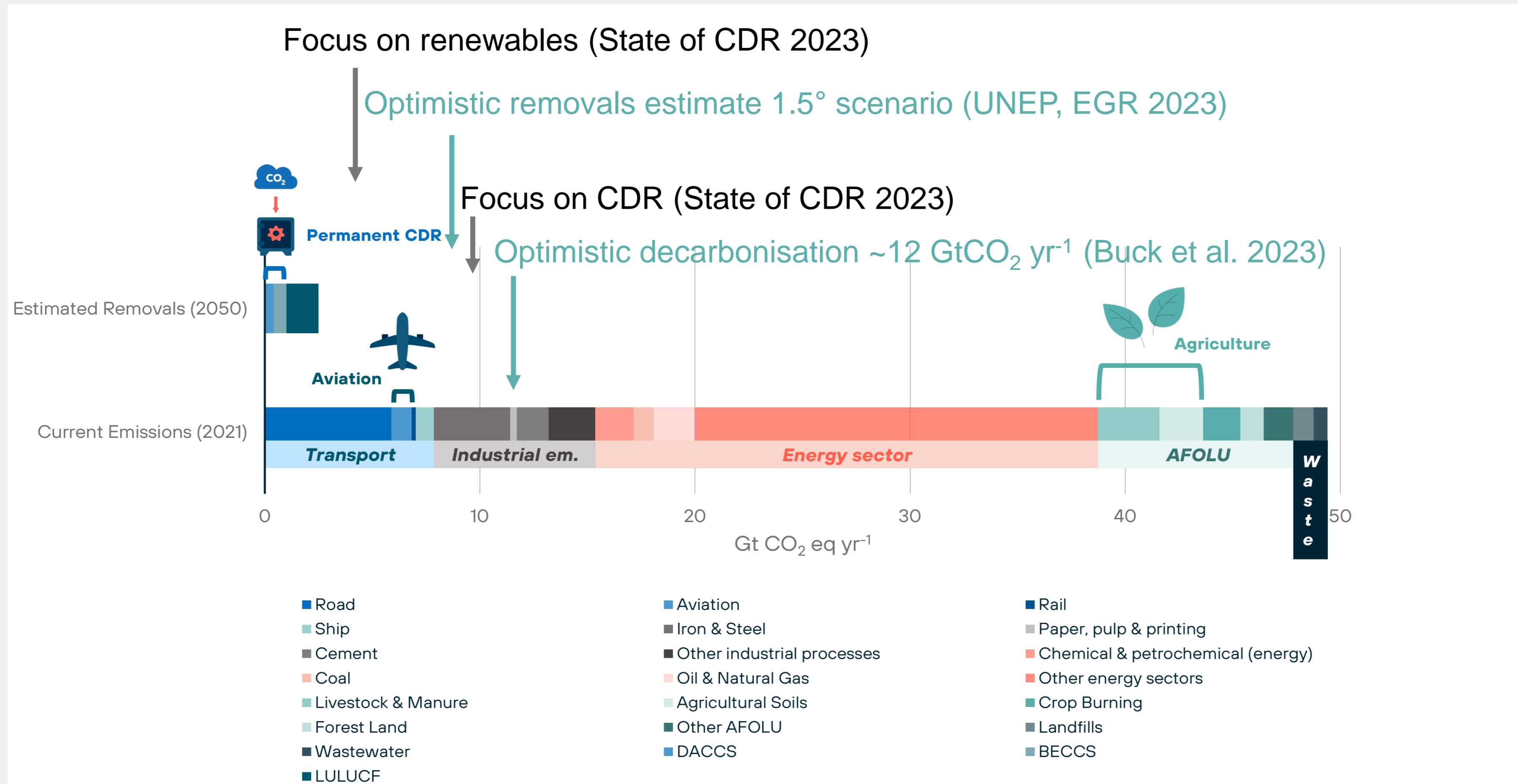
Solid solvent and liquid solvent DACCS are two common approaches used to capture CO₂ directly from the air in the liquid solvent. DACCS process, high-grade heat (DHPC) is supplied by natural gas or hydrogen, with electricity from the power grid. CO₂ released resulting from natural gas combustion are assumed to be captured within the plant limits. In the solid solvent DACCS process, heat and electricity are both obtained from the power grid, using an industrial fuel which converts electricity to low-grade heat (LPH). Future capture technologies use more economical, reversible carbonate-based chemical reactions (carbonation and calcination), which are cheaper. As of February 2024, there are over 20 DACCS plants in Europe. Current capacity at one of the largest plants in operation (DACCS) is on the scale of 4000 tons of CO₂ annually.

Relevant regulatory framework:
Geological storage is currently regulated under the EU CCS Directive (2009/31/EC). According to the EU, potential cross-border CO₂ transport may be regulated under the London Protocol, once ratified, or by other options that align with applicable international law.

ADVANTAGES	CHALLENGES
<ul style="list-style-type: none"> PERMANENT STORAGE Captured carbon is stored permanently with low risk of reversal. TRL DACCS is one of the more developed technologies (TRL 8), it is already being piloted. NEW Easy to quantify how much carbon is removed and stored. Benefits additional integration and DACCS, by default, considered additional. ENVIRONMENTAL BENEFITS Low impact on terrestrial biophiles, low emissions and may provide valuable freshwater source in arid regions. 	<ul style="list-style-type: none"> ENERGY INTENSIVE Dependent on pre-fuel (and renewable) energy jobs and source. Approximately 2000kWh of non-renewable is required for 1 tonne of CO₂ removed. PLANT LOCATION Limitations on plant location due to necessary proximity to renewable energy source. Storage capacity limited due to the current capacity of stable and permanent storage reservoirs. NEW CO-BENEFITS DACCS has been associated to co-benefits compared to land-based decarbonation. CCST Costs are high and infrastructure is expensive to build.

CDR handbook and factsheets

We need to manage expectations on the future role of CDR in climate policy.

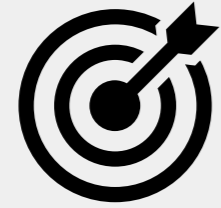


Emissions data from “Our World in Data”, modified from Paul et al. 2023, “Who should use NETPs?” (D6.5)

Recommendations for climate policy frameworks



Adopt a robust definition for CDR (4 principles).



Create separate targets and governance frameworks for emission reductions, permanent CDR and land-based sequestration. CDR must be **supplementary** to fast and deep emissions reduction.



Limit dependence on CDR, based on a supply-driven approach and to match residual emissions.



Accurately and comprehensively account for real removals and consider variable timescales of carbon removals.



Adopt a holistic perspective on Earth system stability, respecting Planetary Boundaries. Policies integrate climate stabilisation and biosphere stewardship to account for their equally fundamental role in supporting Earth system resilience.

Principles should be included in the **EU 2040 target** and **NDC** for international replication.

See more in “*CDR Handbook for Policymakers*”.

How should CDR be integrated into climate policy?

- **Supplement emissions reduction**, which remains critical
 - Lower net emissions in the near term
 - Counterbalance residual for climate neutrality
 - Reach net negative
- If used to replace or slow decarbonisation, it creates **mitigation deterrence**
 - Current reality in many policy frameworks
 - Inclusion of CDR in offsetting mechanisms
- CDR is **not equivalent** to emissions reductions
 - Cannot undo the damage of emissions
 - Potential risks and impacts associated



European Climate Law – CDR in EU climate targets

Current state of play

Net 55% reductions by 2030

- ~52% emission reductions
- LULUCF contribution capped at -225MtCO₂e
- LULUCF target is -310MtCO₂e
- De facto target of ~57% net reductions

Climate neutrality by 2050

- Balance between GHG emissions and CO₂ removal
- Aim for net-negative thereafter

Communication on 2040 target

- Net 90% emission reductions

Recommendations

Clarify definition of ‘climate neutrality’

- Recognise CO₂ neutrality comes before GHG neutrality
- Identify residual GHG emissions
- Minimise dependence on CDR
- Ensure CO₂ is counterbalanced only with permanent CDR
- Identify counterbalancing options for non-CO₂ emissions

Set out separate pathways for carbon removal

- Ambitious target for emission reductions
 - Approx 95% of effort
- Restoration of the land sink for its own merits
 - Sequestration as a co-benefit
- Realistic target for permanent CDR
 - Strong signal which doesn’t undermine reductions

Carbon Removal (Carbon Farming and Carbon Storage in Products) Certification Framework

Current state of play

Adopted

Separate categories of activities

- Carbon Farming
- Carbon Storage in Products
- **Permanent Carbon Removal**

Expert Group on Carbon Removals

- Technical Assessment Papers on DACCS/BioCCS
- Exploratory work on biochar

Geared specifically towards carbon crediting

- Unclear role in climate policy

Recommendations

Clarify the different roles of the different activities

- Only permanent CDR can be used for counterbalancing
- Temporary carbon sequestration as a co-benefit

Ensure methodologies accurately quantify net carbon flows

- All emissions resulting from an activity should be included
- Electricity for DACCS should be additional

Ensure methodologies can be used beyond carbon crediting

- Primary aim of methodologies should be to count net carbon flows
- Improve national GHG inventories and activity-based incentives/subsidies
- Carbon crediting approach should not be priority

EU Emission Trading System

Current state of play

Commission to explore options by July 2026

By 31 July 2026, the Commission shall report to the European Parliament and to the Council on the following, accompanied, where appropriate, by a legislative proposal and impact assessment:

(a) how negative emissions resulting from greenhouse gases that are removed from the atmosphere and safely and permanently stored could be accounted for and how these negative emissions could be covered by emissions trading, if appropriate, including a clear scope and strict criteria and safeguards to ensure that such removals are not offsetting necessary emissions reductions in accordance with Union climate targets as laid down in Regulation (EU) 2021/1119;

Recommendations

Don't rush it!

Consider physical and social credibility issues

- Respect resource constraints and limits to CDR deployment potential
- Ensure accurate climate outcomes
- Avoid fungibility between reductions and removals
- Ensure climate neutrality is met at Union-level, not only at level of individual operators

Pooling and use of portion of ETS revenues may be better

Explore full suite of financing options for CDR



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