



Mercator Research Institute on
Global Commons and Climate Change



UNIVERSITY OF LEEDS

Priestley International
Centre for Climate

Options for Carbon Dioxide Removal

Jan C. Minx

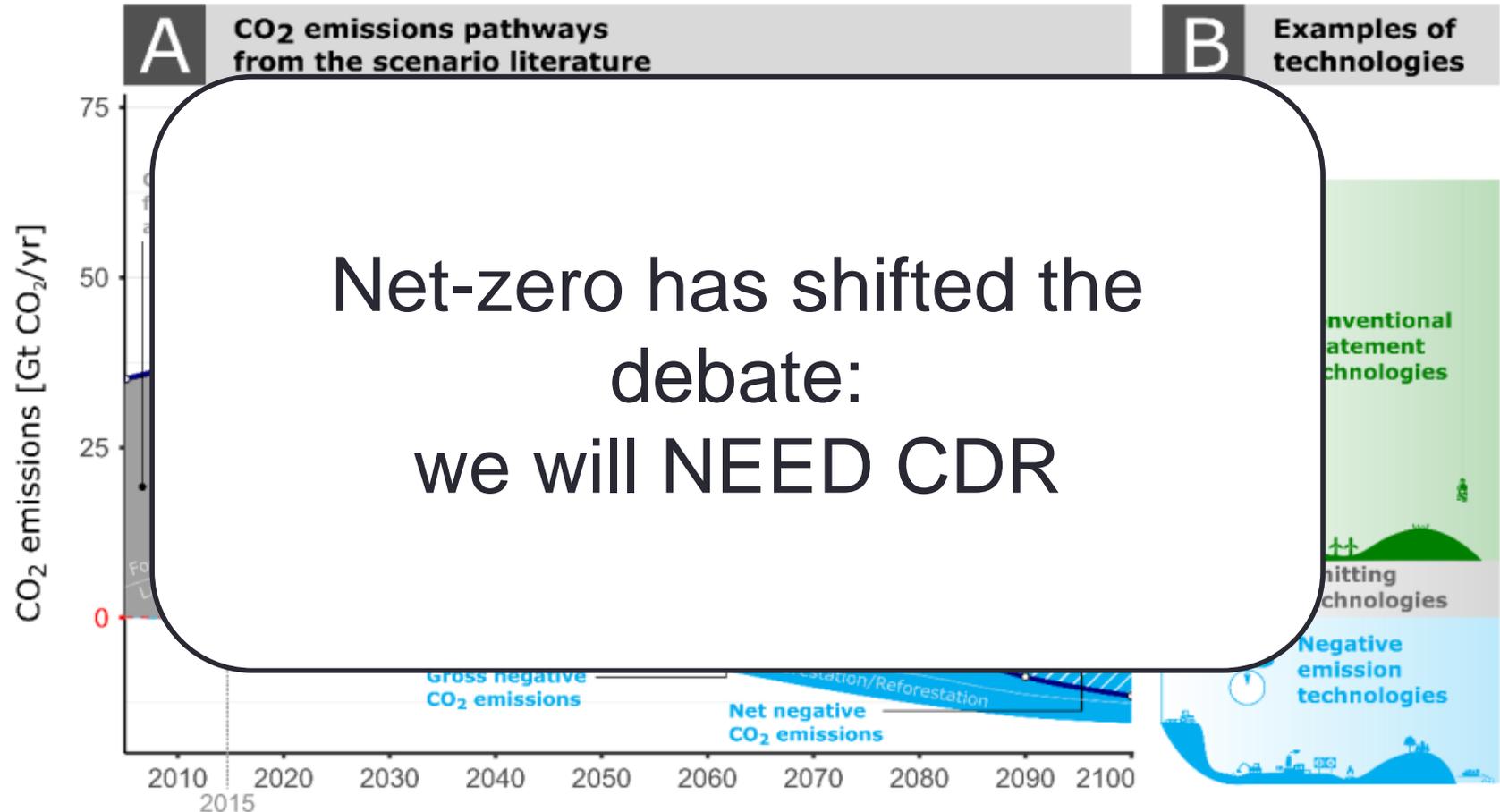
Final Symposium – BMBF-PEP1.5

PIK Potsdam

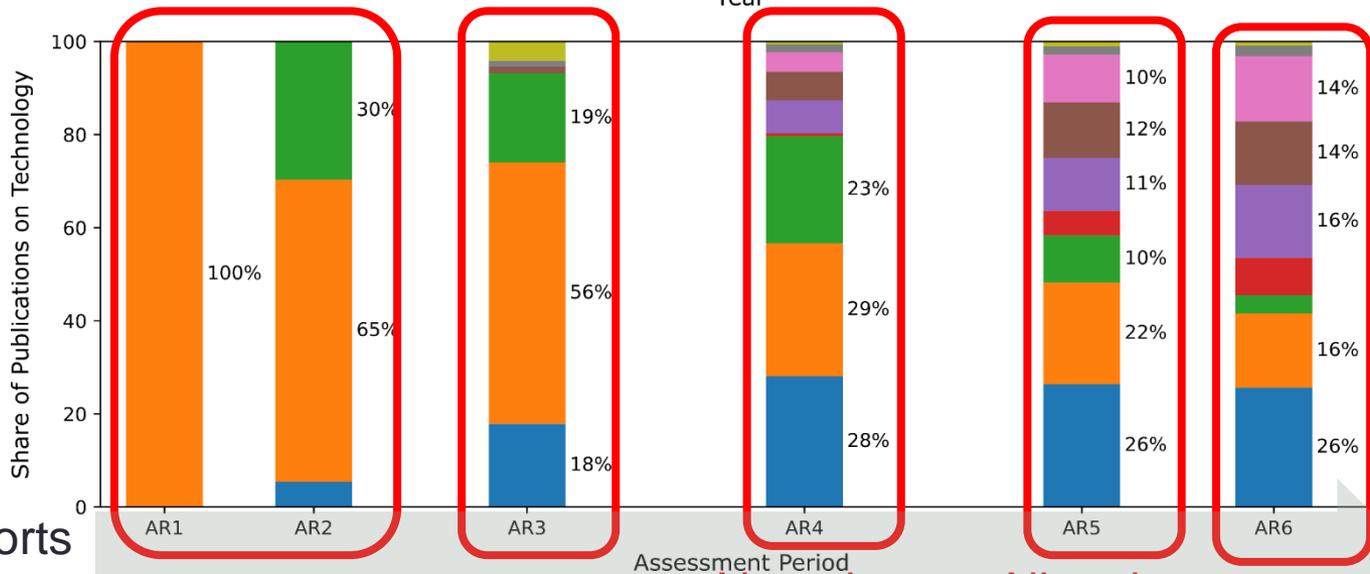
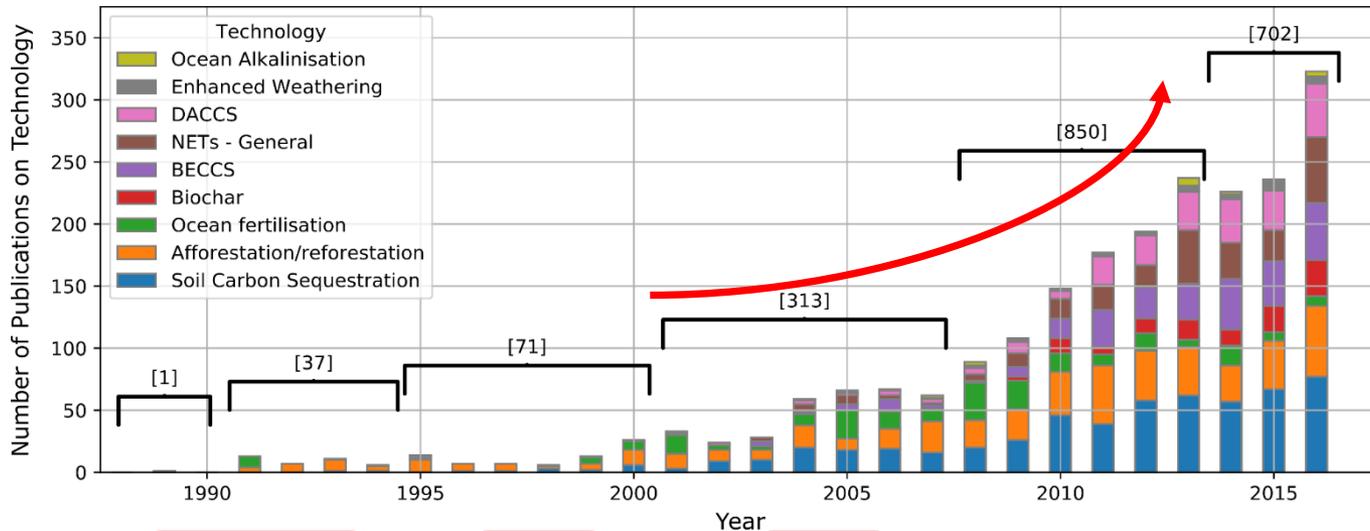
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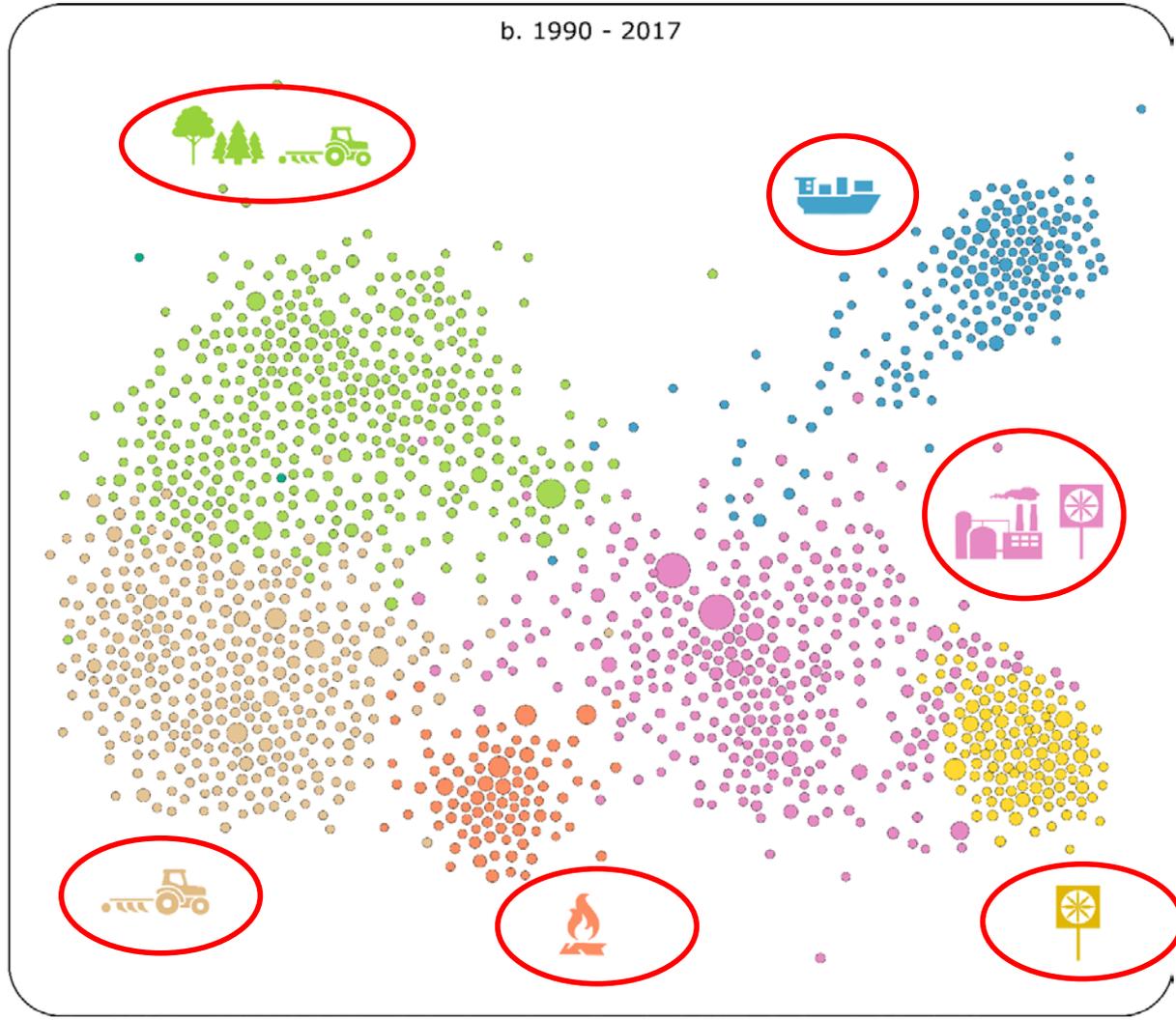
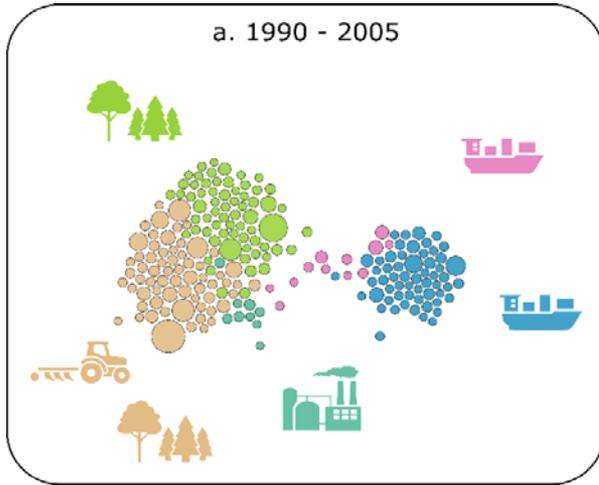
Net-zero emissions & carbon dioxide removal



From discussions of individual CDR options towards portfolios



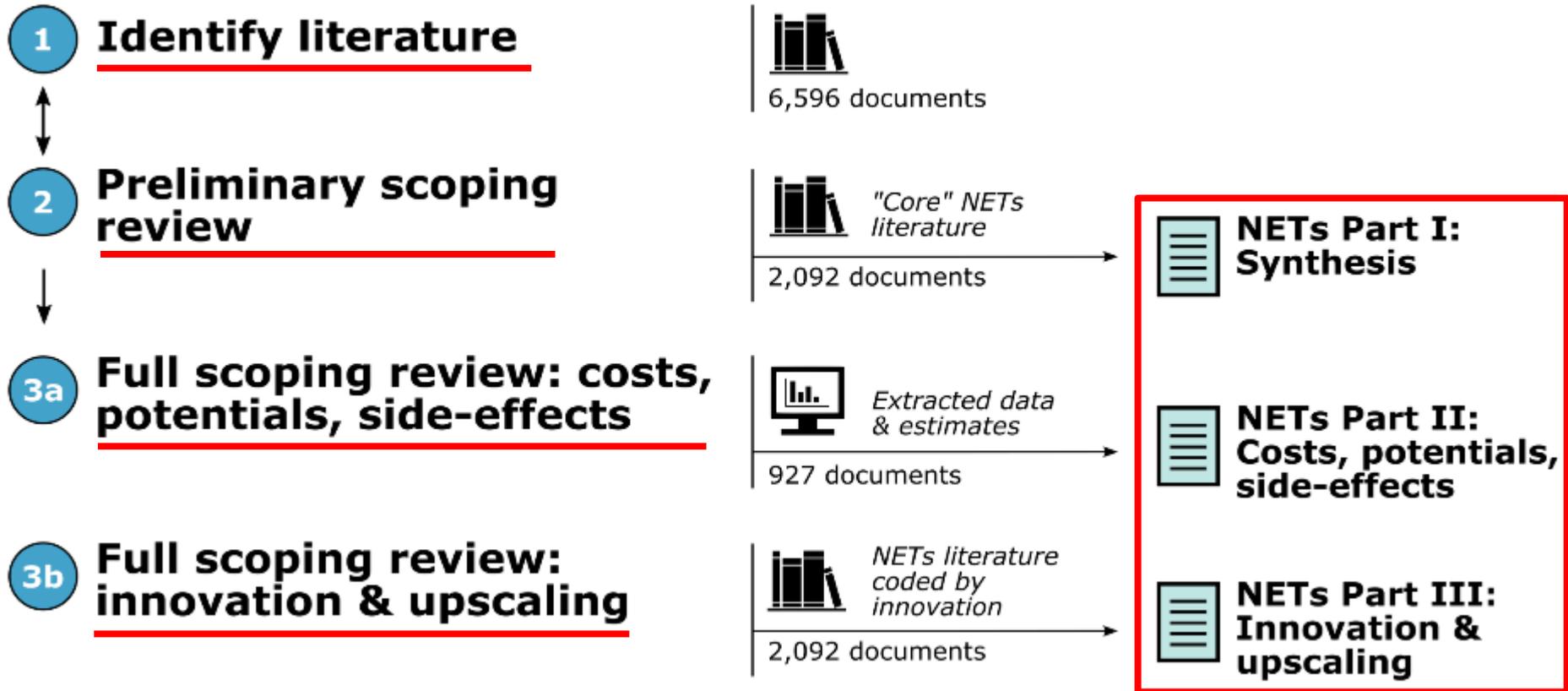
Matured clusters of scientific research around the various CDR options



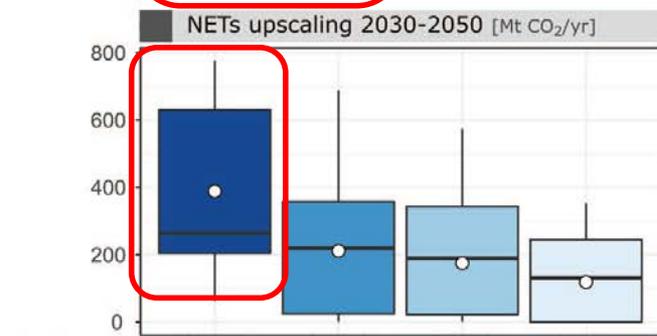
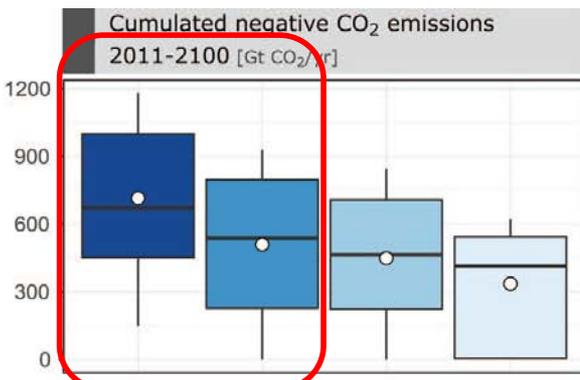
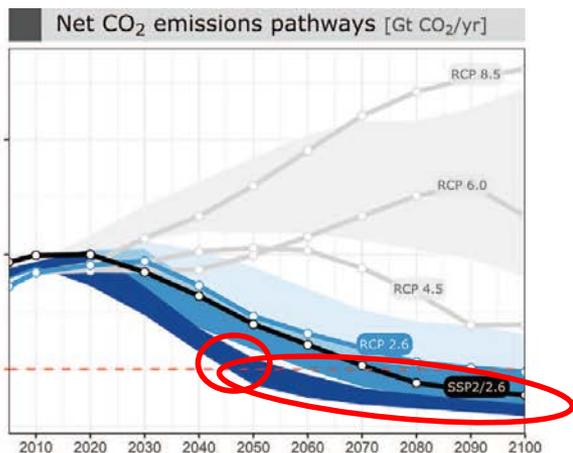
-  Afforestation/reforestation
-  Bioenergy carbon capture & storage
-  Biochar
-  Direct air capture
-  Ocean fertilisation/enhanced weathering
-  Soil carbon sequestration



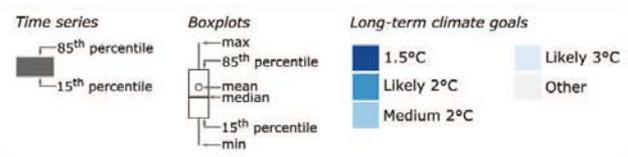
Assessing the CDR space – linking bottom-up and top-down



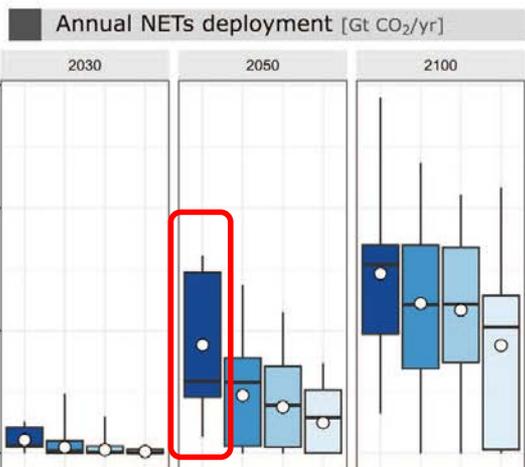
While 1.5°C fundamentally depend on CO₂ removal, this is not the case for 2°C scenarios



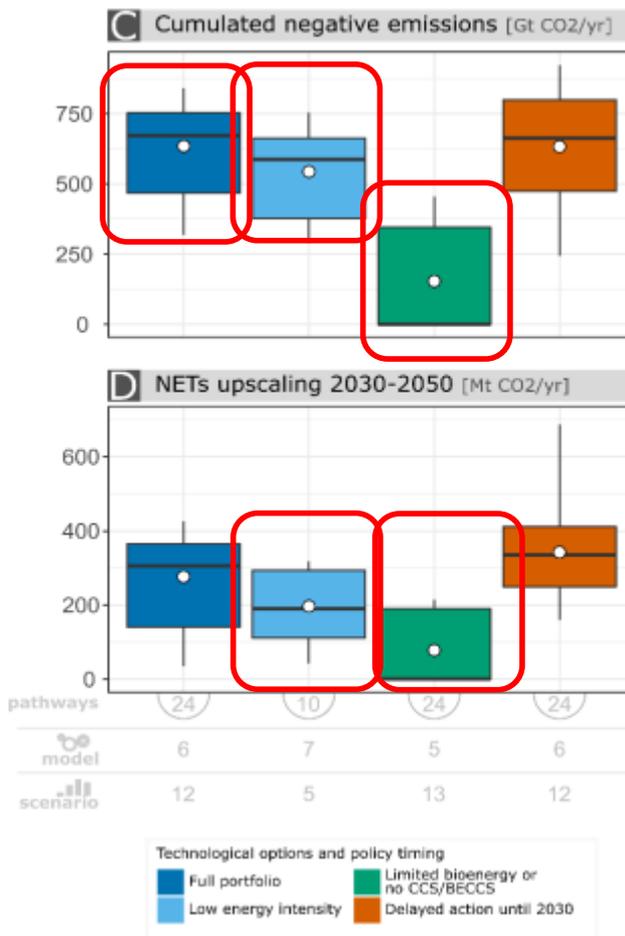
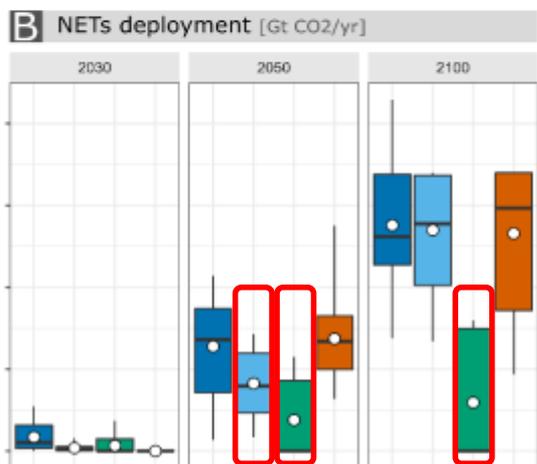
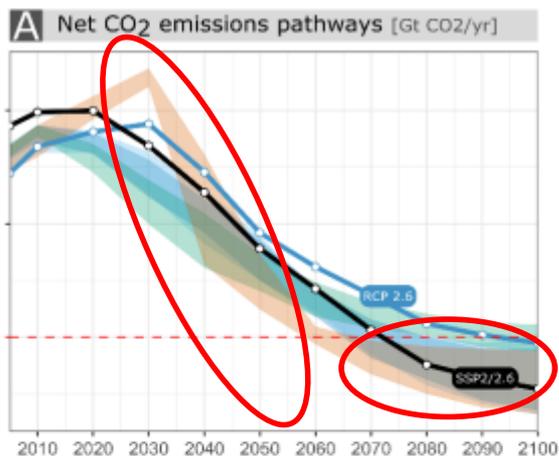
# pathways	38	101	200	119
# models	8	15	18	15
# scenarios	29	69	148	44



- Carbon budget for 1.5°C is small and finite
- Fully decarbonized world economy by 2050 (sharp emissions reductions)
- Sustained period of deep net negative emissions thereafter
- Up to 15Gt of NETs deployment in 2050
- Near-term upscaling substantially faster in 1.5°C scenarios
- All 1.5°C scenario require NETs – not the case for 2°C



NDC trajectory leads to similar dependence on CO₂ removal in 2030 like for 1.5°C limit today

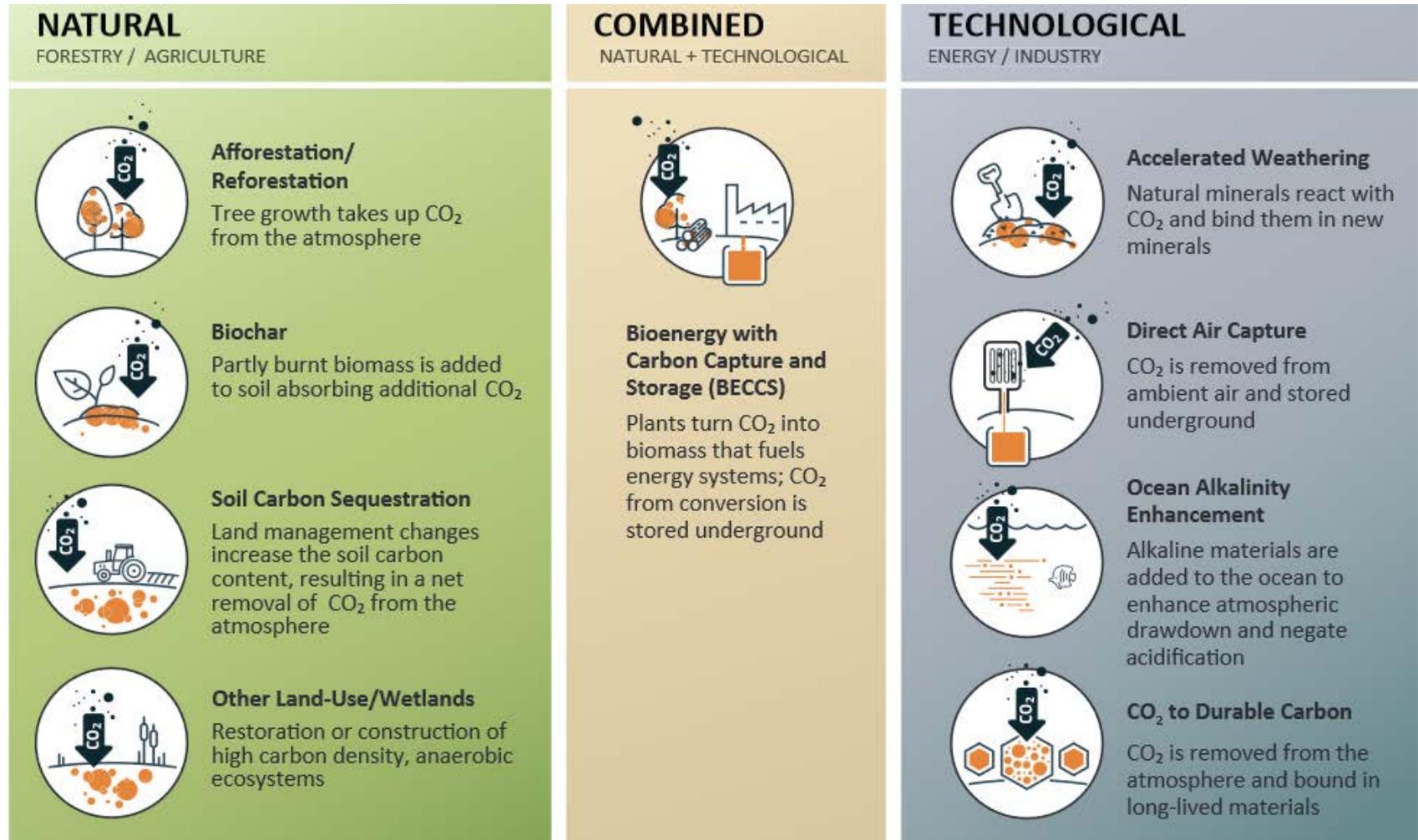


Role of NETs varies in 2°C scenarios, but can still be limited:

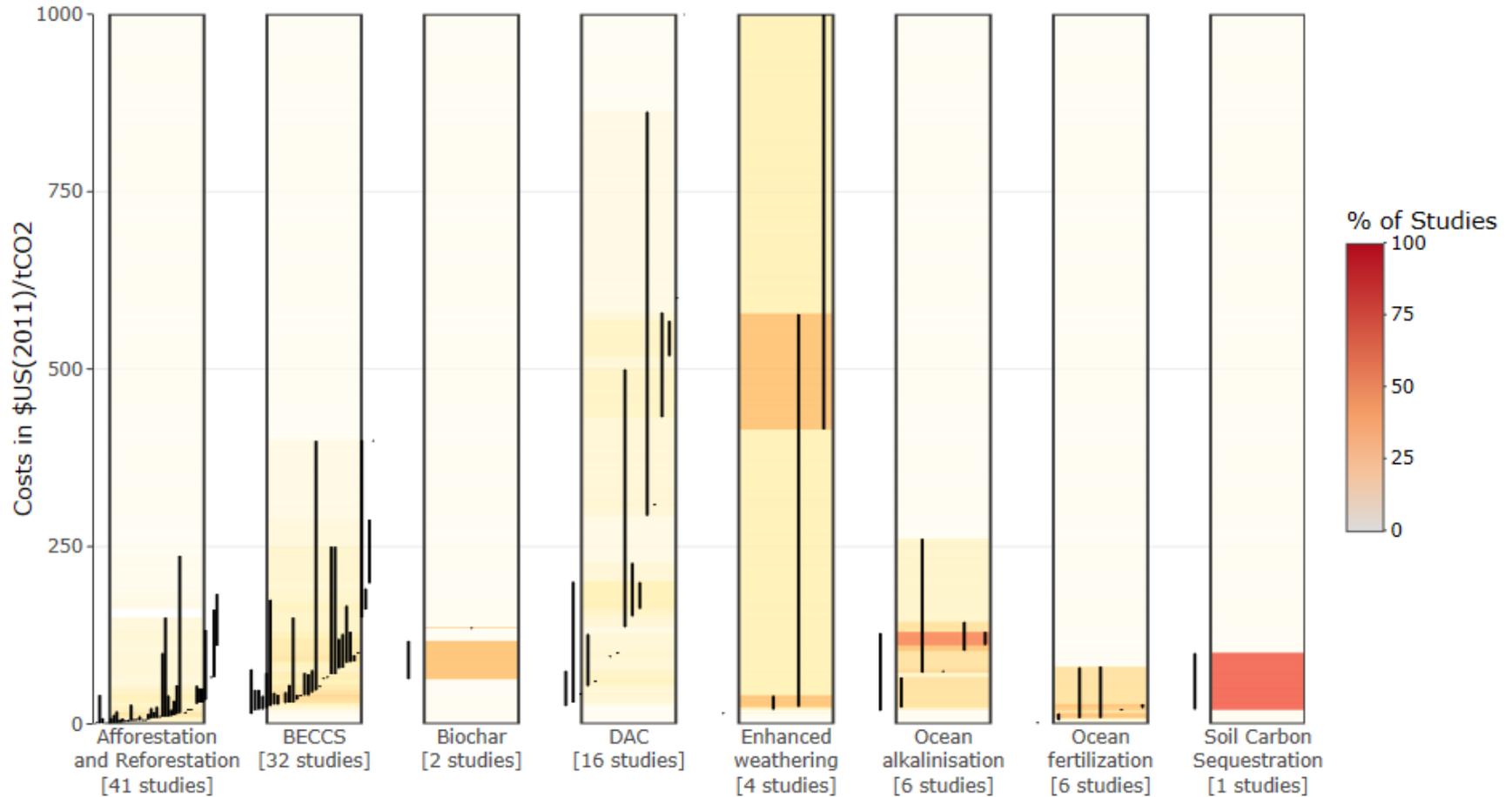
- Full tech, immediate action scenarios feature large-scale NETs deployment
- There are scenarios without or limited NETs deployment
- Low energy demand pathway provide additional flexibility for NETs deployment



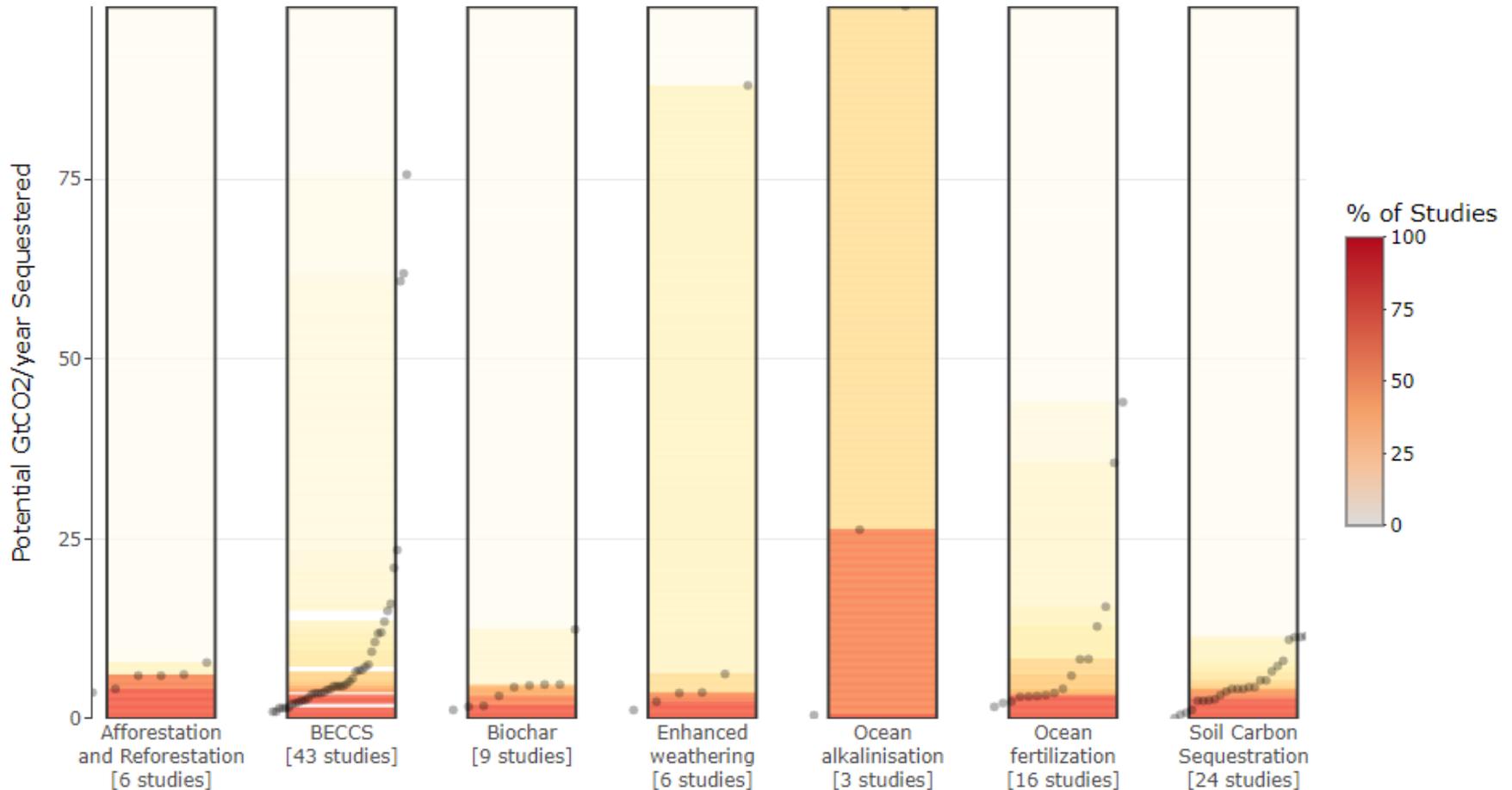
While the recent discussions have mainly focussed on BECCS, the spectrum of options is large



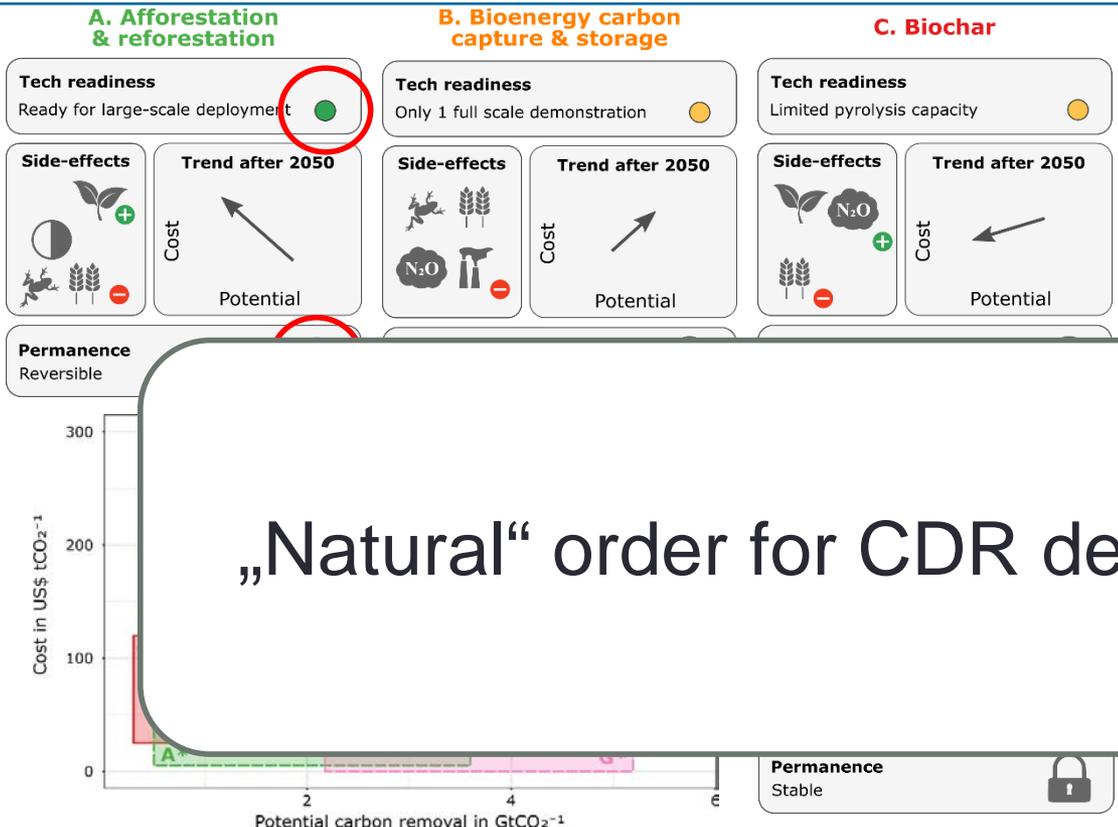
Costs (US\$/ton CO2 in 2050)



Non-additive potentials (Gt CO₂/year in 2050)



Most CDR options show relevant potentials, but all have limits



A. Afforestation & reforestation

Tech readiness
Ready for large-scale deployment

Side-effects

Trend after 2050
Cost ↑ Potential ↑

B. Bioenergy carbon capture & storage

Tech readiness
Only 1 full scale demonstration

Side-effects

Trend after 2050
Cost ↑ Potential ↑

C. Biochar

Tech readiness
Limited pyrolysis capacity

Side-effects

Trend after 2050
Cost ↓ Potential ↓

- Relevant potentials for all CDR options, except ocean fertilization
- Potentials are all constrained by bio-

Permanence

Reversible

„Natural“ order for CDR deployment?

conomic
t additive
n unlikely
entials
y
nably
multiple CDR

options, each deployed at modest scales can hedge risks and seem more realistic

E. Direct air capture

Tech readiness
Deployed in niche markets

Side-effects

Trend after 2050
Cost ↓ Potential ↓

Permanence
Stable

F. Ocean fertilisation

Tech readiness
10s of small demonstrations

Side-effects

Trend after 2050
Cost ↓ Potential ↓

Permanence
Stable but uncertain

G. Soil carbon sequestration

Tech readiness
Ready for large-scale deployment

Side-effects

Trend after 2050
Cost ↓ Potential ↓

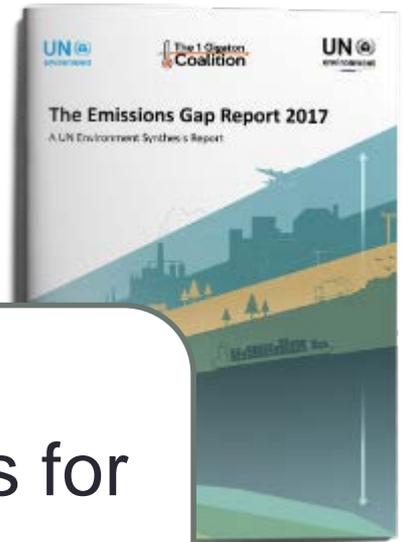
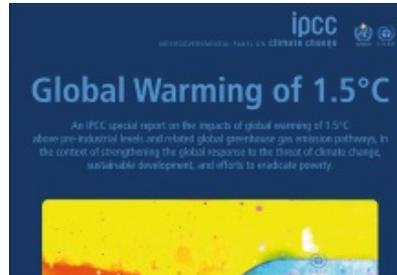
Permanence
Reversible

- Important differences in development status and secure CO₂ storage

Evidence synthesis is a lot of work - but it is worth it!

- Prominently picked up by recent climate change assessments
- A series of scientific assessments
- Large public requests for evidence synthesis
- Governmental bodies: Commons, Royal Society, German NGOs, etc.
- Wide media-coverage
- Triggered German Roundtable on Negative Emissions

Need to organise synthesis process for AR6!



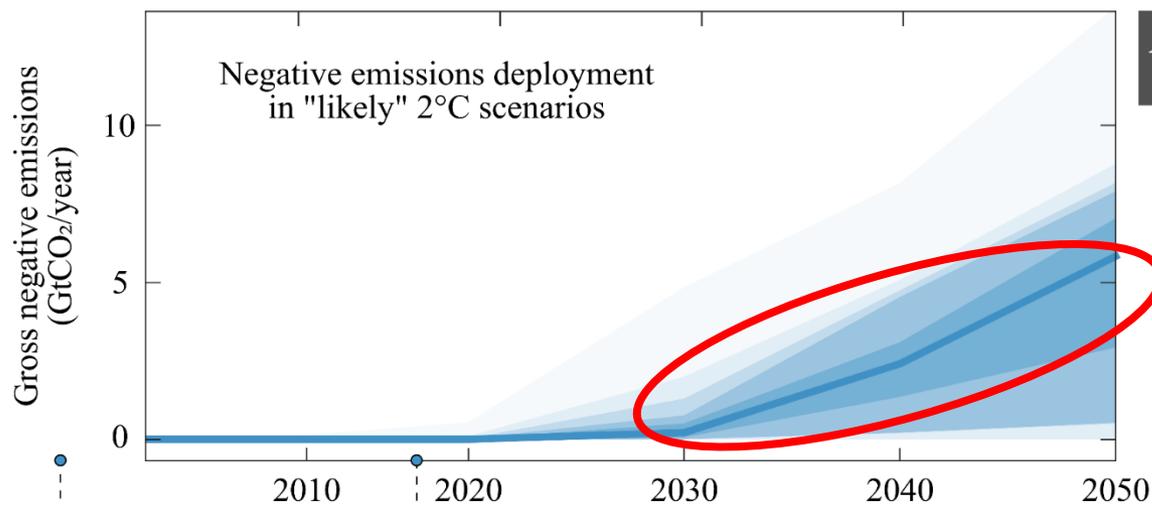
Weigh the ethics of plans to mop up carbon dioxide

Financing climate hopes on negative emissions technologies is dangerous as it deflects attention from the social aspects, warn Dominic Lertzl and colleagues.

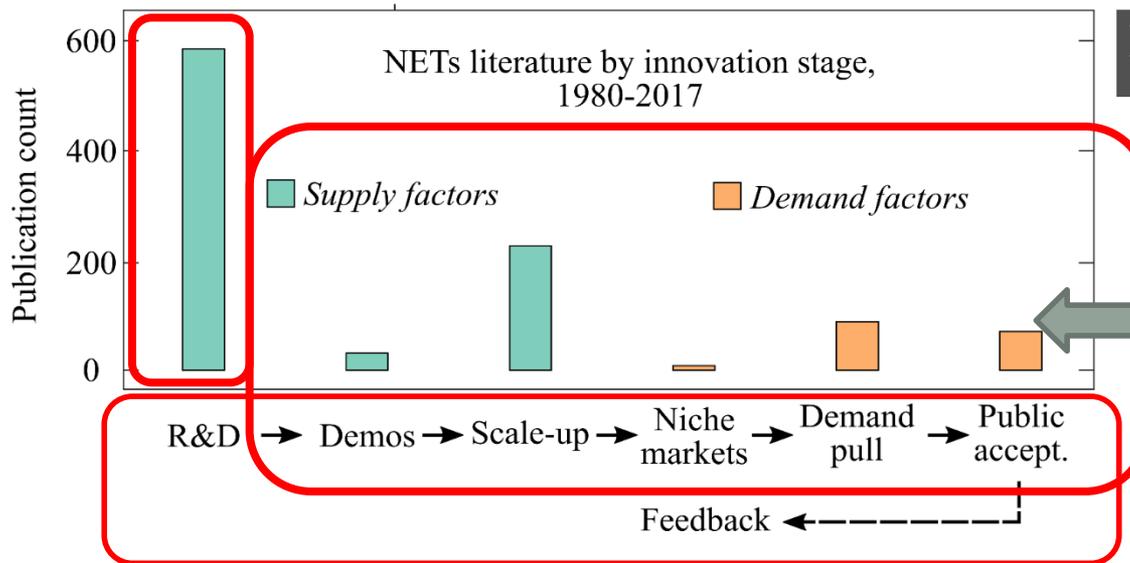
As the Intergovernmental Panel on Climate Change (IPCC) will release its special report on keeping global temperature below 1.5°C, climate scientists are warning that the world must take action to avoid a 2°C rise. However, they warn that the world must take action to avoid a 2°C rise. However, they warn that the world must take action to avoid a 2°C rise.



Technological transitions often take time! Urgency in developing CDR portfolios



A The scale-up challenge



B The current focus of research

We need more work here



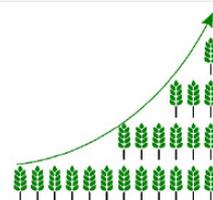
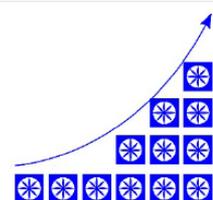
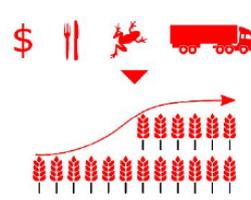
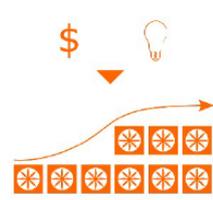
The need for acceleration in innovation and diffusion of CDR technologies



Minx and Nemet (2018), The inconvenient truth about carbon capture, *Washington Post*;
Figure by William Lamb (MCC)

Requirement to spell out development paths

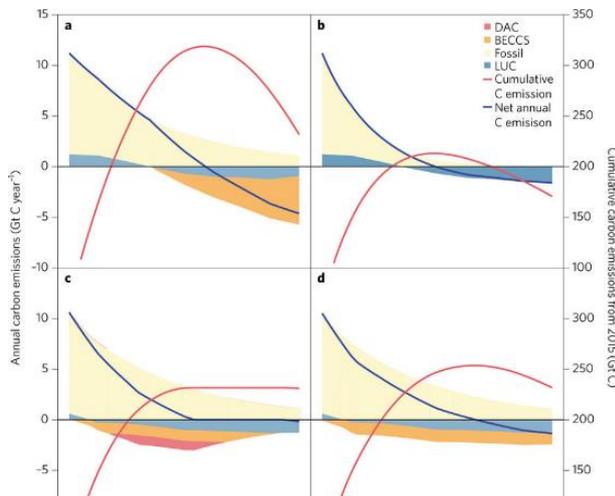
Innovation archetype	Technology role model	CDR analogue
High-tech, iterative disruptive	PV	DAC
Low-tech, small, distributed	Green revolution	Soil carbon sequestration
Large, system integration intensive	Chemical plants	BECCS

BECCS	DACCS
 <p>Yields</p> <p>Efficient BECCS plants are powered by very high yield biomass with limited land footprint and algae options. Competition with food and/or biodiversity is avoided, via synthetic food routes, high-yield C4 plants, and/or humanity giving up on biodiversity.</p>	 <p>Innovation</p> <p>Considerable innovation in DACCS leads to reduce investment cost, and higher potential in low-cost locations/logistics. The energy demand of DACCS can be matched by a low-cost energy system based on PV and storage technologies for electricity and/or heat.</p>
 <p>Land</p> <p>The technological development of BECCS remains slow because of the high costs of land and logistics. Land competition with food, biodiversity and human settlements emerges as a key barrier, resulting in high land prices.</p>	 <p>Energy</p> <p>DACCS innovation ramps up only slowly, and so does demand for this technology. Logistical issues, high and costly energy demand and technological costs prevent DACCS from falling below \$200 even after many innovation phases.</p>



Nemet (2019), How solar energy became cheap, Routledge; Creutzig et al. (2019), The mutual dependence of negative emissions technologies and energy systems, *Energy Environ Sci*

Major avenues for research



- Closing the innovation gap – accelerating development and diffusion
 - Models of innovation for CDR
 - Public perceptions
 - Policy design & instruments
- Learning about the CDR policies & governance
 - Evidence synthesis
 - Ex-post policy assessments
 - Policy design & instruments
 - Governance
- CDR portfolios & pathways and their risks
 - Scenario analysis from differ
 - Political economy & socio-technical transitions
 - Evidence synthesis: co-benefits & risks

Take away messages

- **CDR has arrived in policy - growing understanding that CDR is essential for meeting climate goals – net zero fundamental**
- **There are more technologies available than BECCS with relevant potentials.**
 - Potentials are all constrained by bio-physical or economic limits.
 - Any single CDR option unlikely to provide the potentials observed in many scenarios sustainably: Portfolios of multiple NETs, each deployed at modest scales seem more realistic.
- **There is a large gap between CDR upscaling in scenarios and in reality.**
 - Limiting dependence on CDR through a rapid scale-up of short-term action
- **Concerted, community driven research agenda needed around policy, governance and innovation and linkage to scenarios work**



Thanks!



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MCC was founded jointly by Stiftung Mercator and
the Potsdam Institute for Climate Impact Research



Things to work towards in AR6

- Clear home for CDR synthesis & common approach across chapters (sound top-down/ bottom-up link)
- Clear conceptual framing around net-zero that takes into account related discourses such as committed carbon



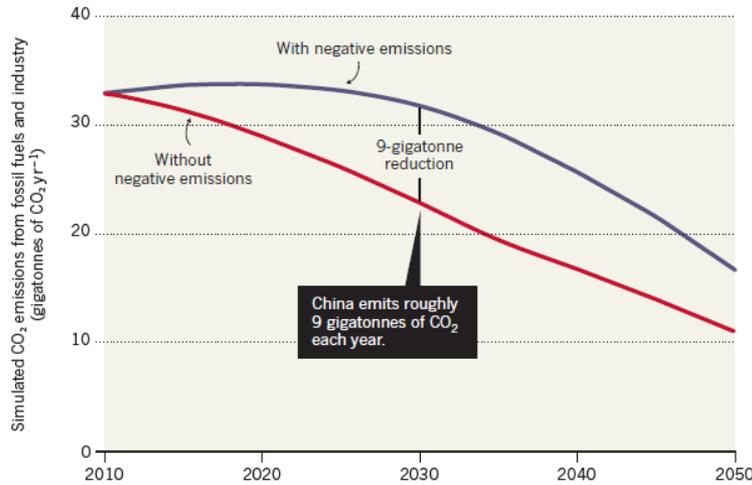
Insufficient ethical discussion around CO₂ removal

THREE-FOLD FOLLY

Technologies that capture carbon dioxide on a planetary scale might help to avert dangerous levels of climate warming, but they are risky.

COULD DELAY CUTS

Policymakers and industry could delay the reduction of emissions in the belief that these can be clawed back later with negative emissions.



REQUIRES STEEP SCALE-UP

Designing climate policy around technologies that might never sufficiently scale up is a gamble.

□ = 100 biomass power plants with carbon capture and storage

Future generations would bear the burden of failure to scale up negative emissions.

3 demonstration plants exist today

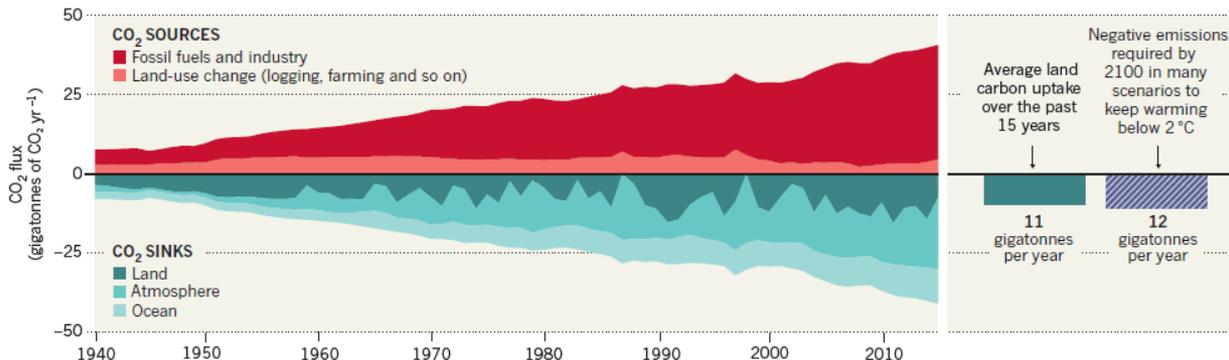
700

5,000

16,000

DEMANDS UNPRECEDENTED SINK

The scale of negative emissions required in many scenarios would mean controlling a massive carbon sink (purple bar) — larger than the entire current natural land sink.



Lenzi et al. (2018), Weigh the ethics of plans to mop up carbon dioxide, *Nature*