Potsdam Institute for Climate Impact Research

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Carbon Removals, Pricing & Planetary Waste Management

A Governance Perspective on Negative Emissions

IEO Webinar Series (IMF)
9 May 2024

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Leibniz Gemeinschaft

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Climate impacts, the world economy and overshoot

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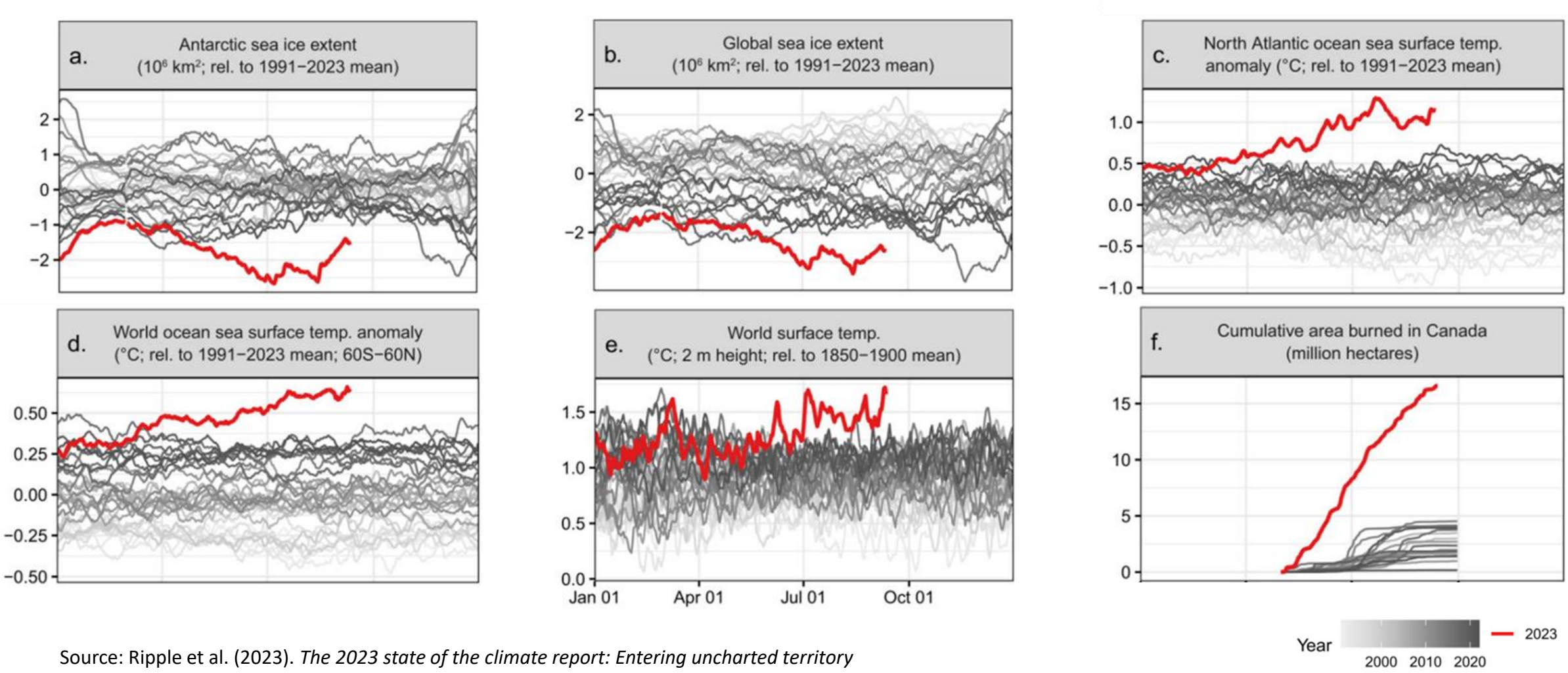
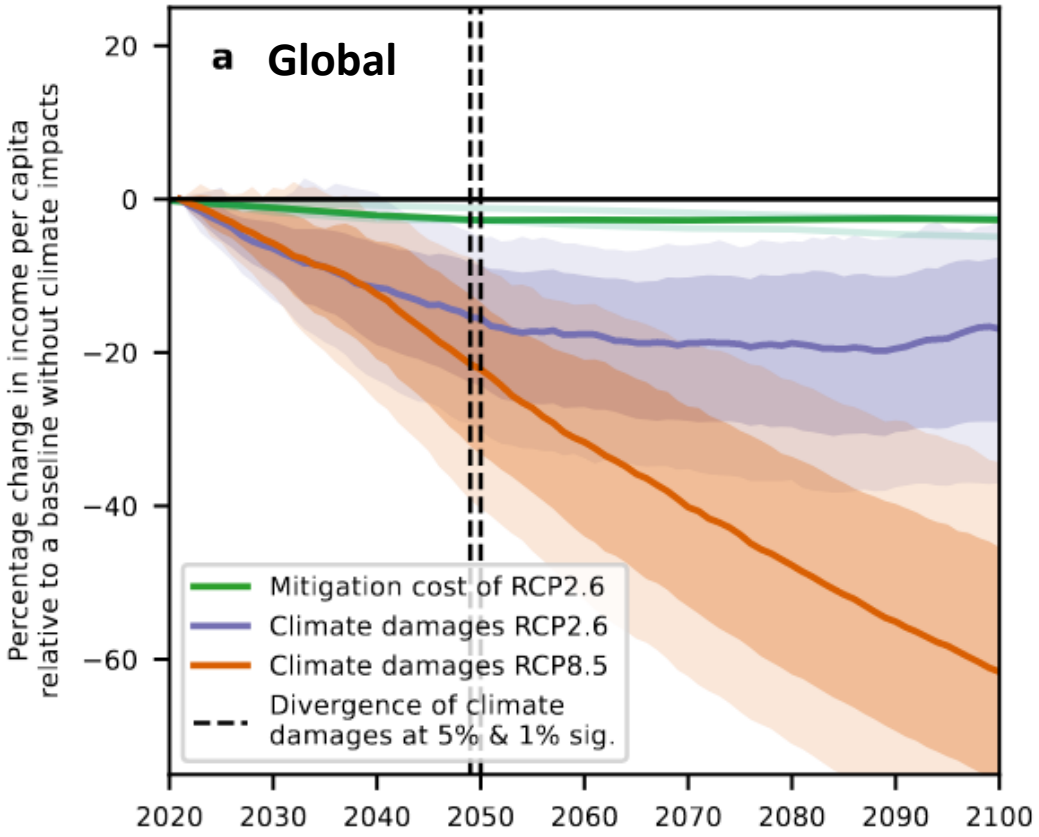
Record year 2023: Venturing into uncharted climate territory



Source: Ripple et al. (2023). *The 2023 state of the climate report: Entering uncharted territory*

The economic commitment of climate change



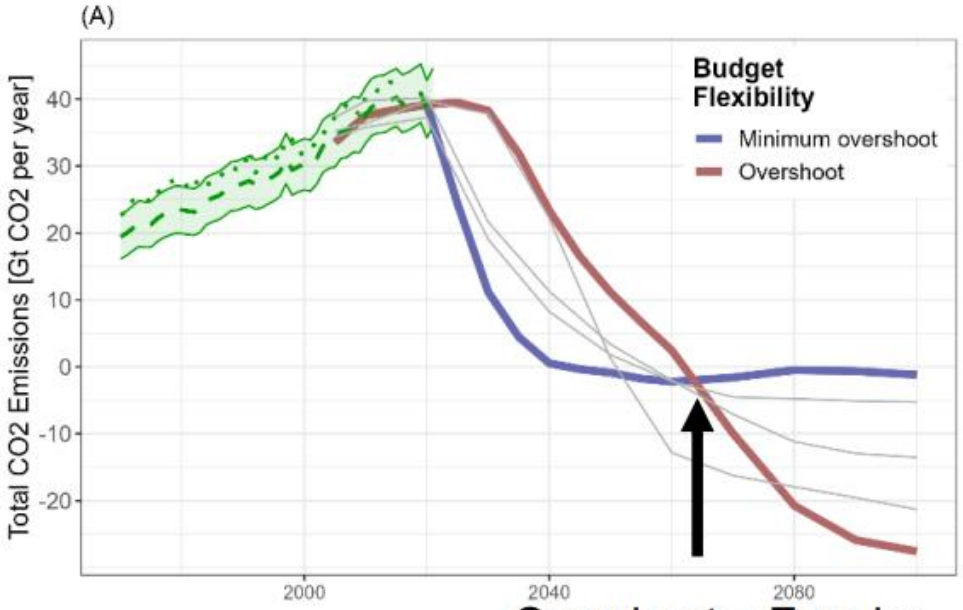
Source: Kotz, Levermann, Wenz (2024).
The economic commitment of climate change

- World economy is committed to an income reduction of 19% until 2050 - independent of emission choices*
- Damages outweigh the mitigation costs required to limit global warming to 2°C by a factor of six
- The largest losses are committed in regions with lower cumulative historical emissions and lower income

* relative to a baseline without climate impacts [range: 11–29%]

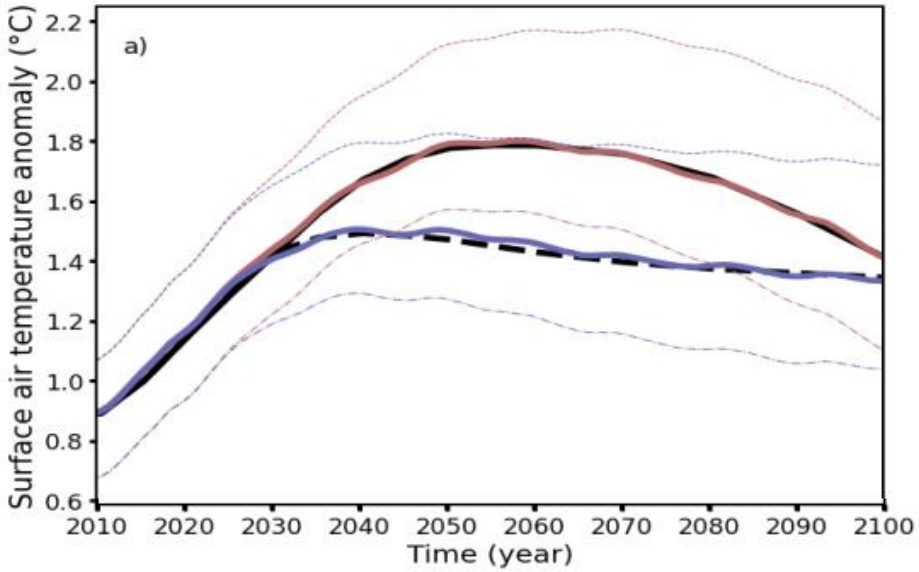
Window to 1.5°C rapidly closing. “Overshoot” very likely while very risky

Markedly different emission pathways fulfill same carbon budget



Overshoot = Zero by 2050 and Negative emissions thereafter

Peak difference in global warming 0.35°C

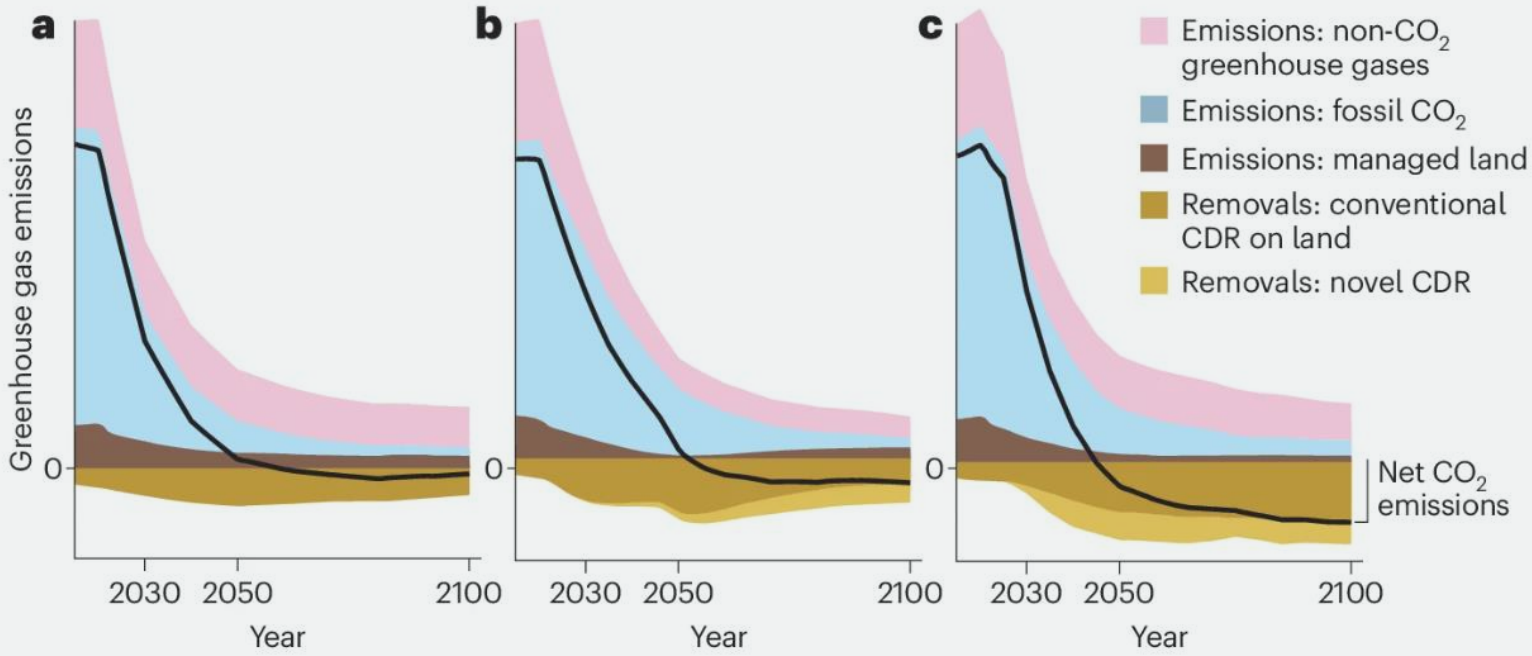


Source: Bauer et al. (2023). *Exploring risks and benefits of overshooting a 1.5 °C carbon budget over space and time*

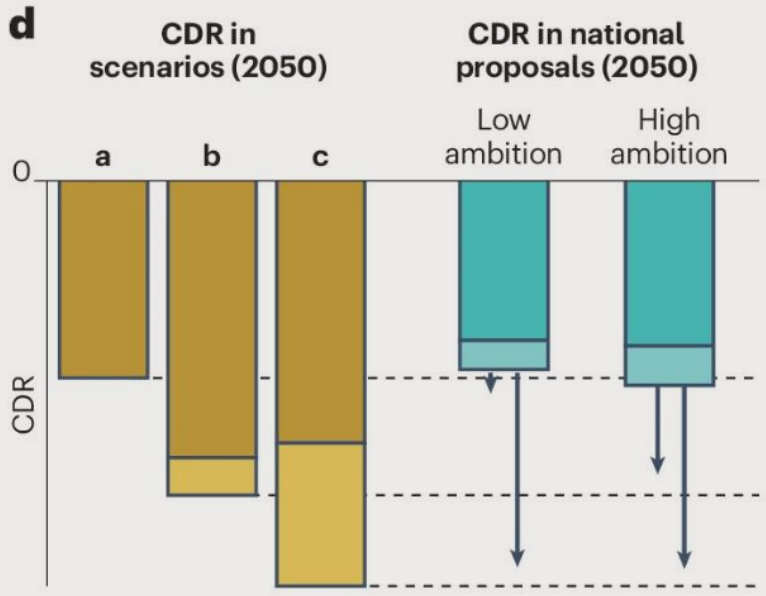
Current national proposals are off track to meet carbon dioxide removal needs

Three scenarios focused on

Demand reduction *Renewables* *Carbon removal*



The carbon dioxide removal gap



Source: Lamb et al. (2024). *Current national proposals are off track to meet carbon dioxide removal needs*

Optimal pricing regimes

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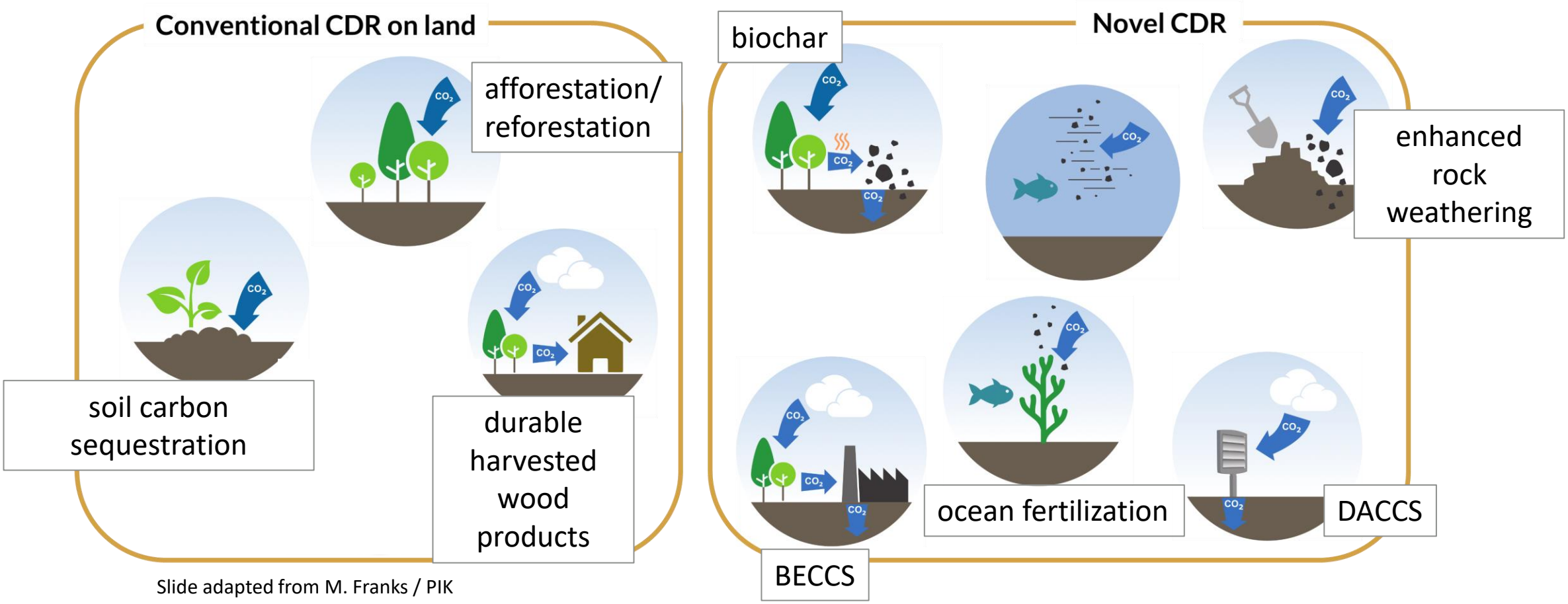
Novel CDR methods need to be developed and deployed



Slide adapted from M. Franks / PIK

To infinity and beyond? Storage times of CDR methods vary significantly

Technology	Potentials (Gt CO_2 yr-1)	Costs ($)	Storage duration (half-life)
Afforestation/reforestation	0.5-3.6	0-50	Decades to centuries
BECCS	0.5-5	100-200	Millenia
Ocean alkalinisation	0.1-10	14-500	Centuries
Enhanced weathering	2-4	50-200	Centuries
Biochar	0.5-2	30-120	Centuries
Modified patterns of agriculture	2-5	0-100	Years to decades
DACCS	0.5-5	100-300	Millennia

Source: Kalkuhl et al. (2023). *Pigou's Advice and Sisyphus' Warning: Carbon Pricing with Non-Permanent Carbon-Dioxide Removal*

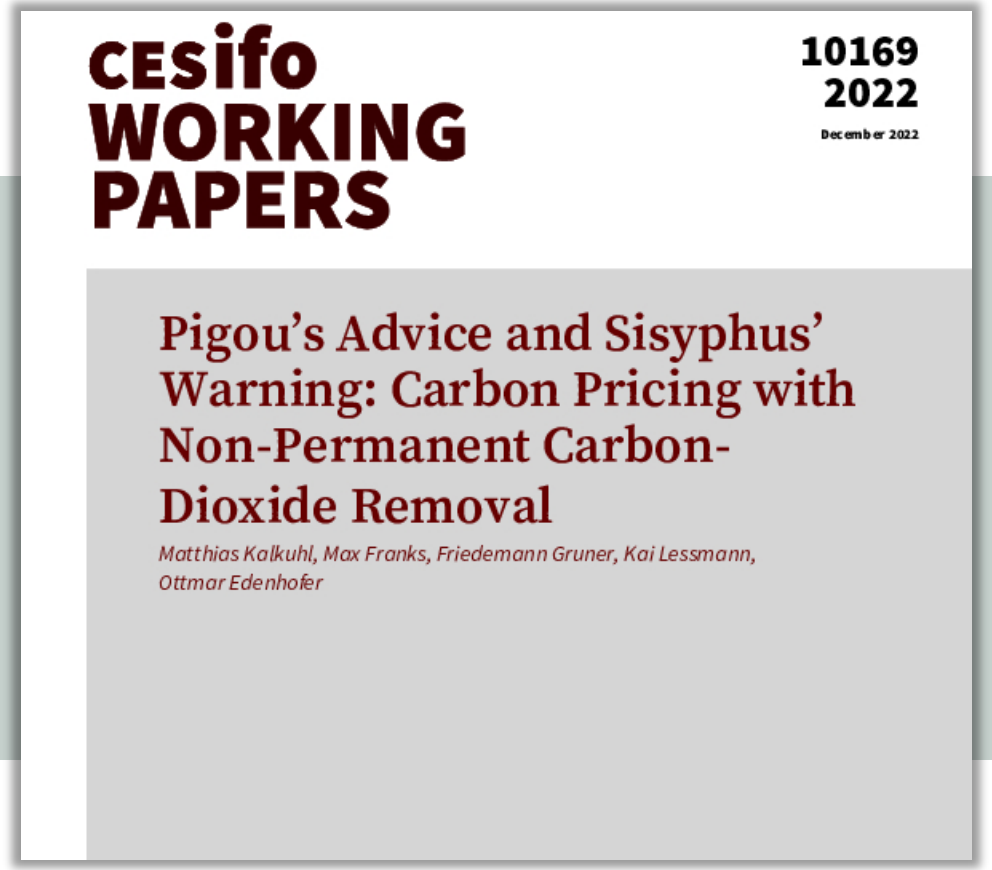
Non-permanent carbon removal introduces a new social cost of carbon metric: the social cost of carbon removal

Social cost of carbon emissions (SCC-E)

› Measure of the marginal climate change damages from carbon emitted into the atmosphere

Social costs of carbon removal (SCC-R):

› Measure of climate change damages resulting from emission release from storage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Pigou's Advice and Sisyphus' Warning: Carbon Pricing with Non-Permanent Carbon-Dioxide Removal

Matthias Kalkuhl, Max Franks, Friedemann Gruner, Kai Lessmann, Ottmar Edenhofer

Technische Universität Berlin · MCC · PIK · Leibniz Association

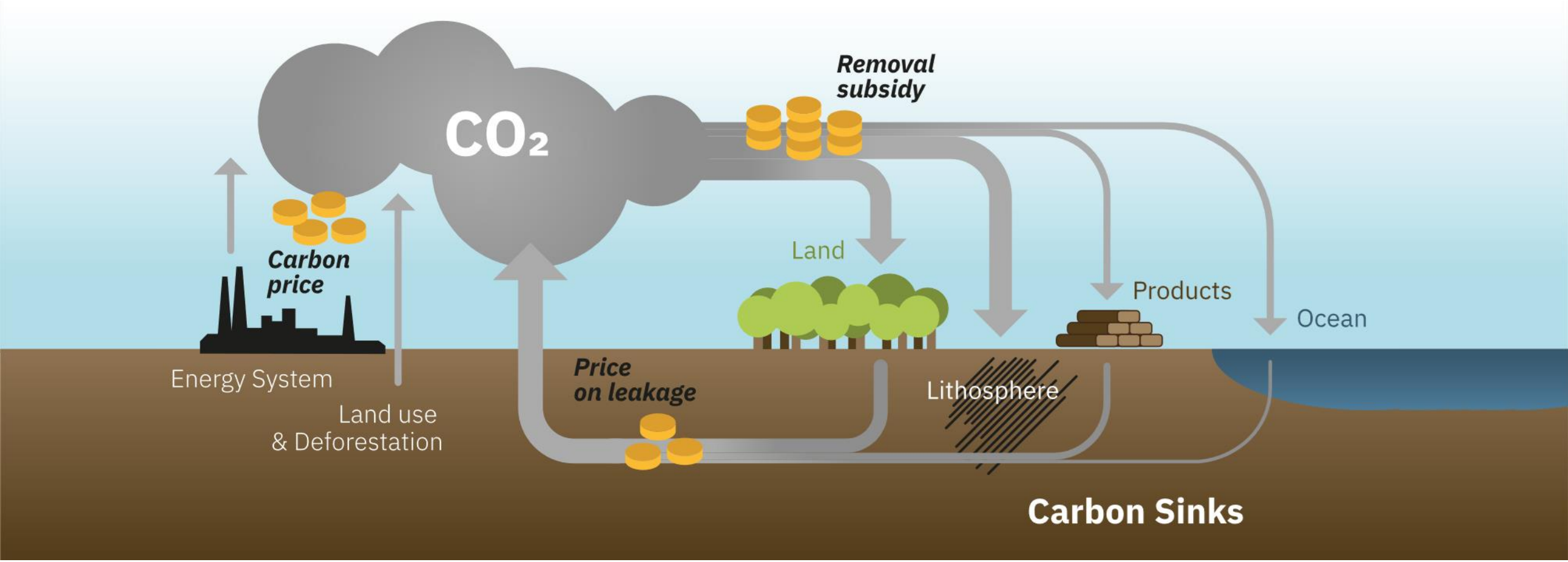
Carbon pricing regimes for optimally incentivizing removals

Downstream pricing	Upstream pricing	Storage stock subsidy	Pricing of carbon stock in atmosphere*
Price all removals *and* all occurring leakage/releases at the same carbon price (e.g. Social Cost of Carbon)	Carbon tax on emissions from economic activity and a subsidy adjusted for the social cost of carbon removal	Annual subsidy on carbon reservoir (e.g. standing forest)	Taxation of cumulative net CO_2 emissions / 'carbon shares'
MRV of all carbon flows (in/out)	MRV of removal flows + regulation on diligence to secure expected half-life of carbon storage	MRV of carbon stocks	MRV of carbon stocks + estimated costs of realized climate damages

Based on Kalkuhl et al. (2022); J. Minx / MCC Berlin

* Lemoine (2020). *Incentivizing Negative Emissions Through Carbon Shares*

„Planetary waste management“ will become core task of the 21st century



A CDR governance proposal for Europe

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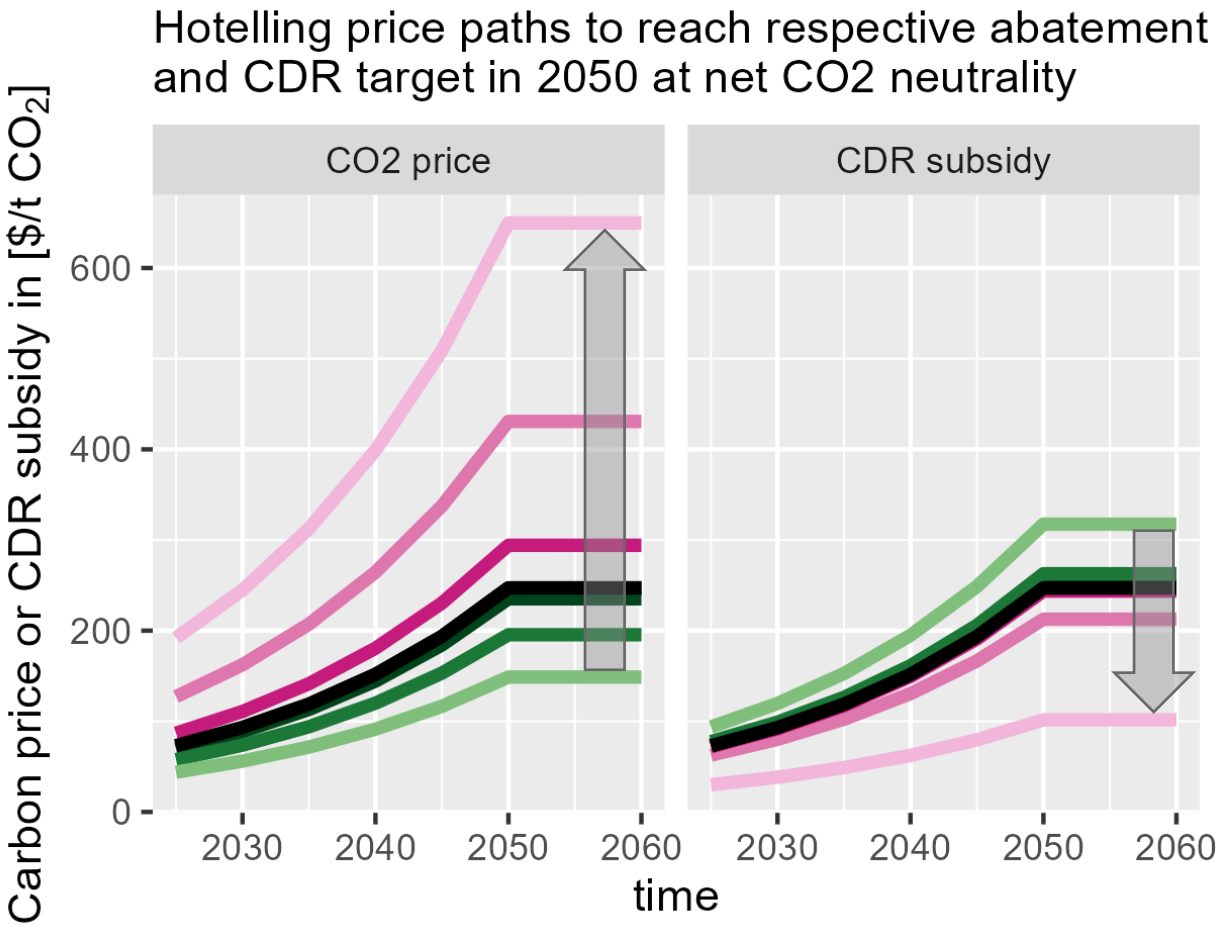
Separate quantity targets for residual emissions and CDR lead to diverging prices



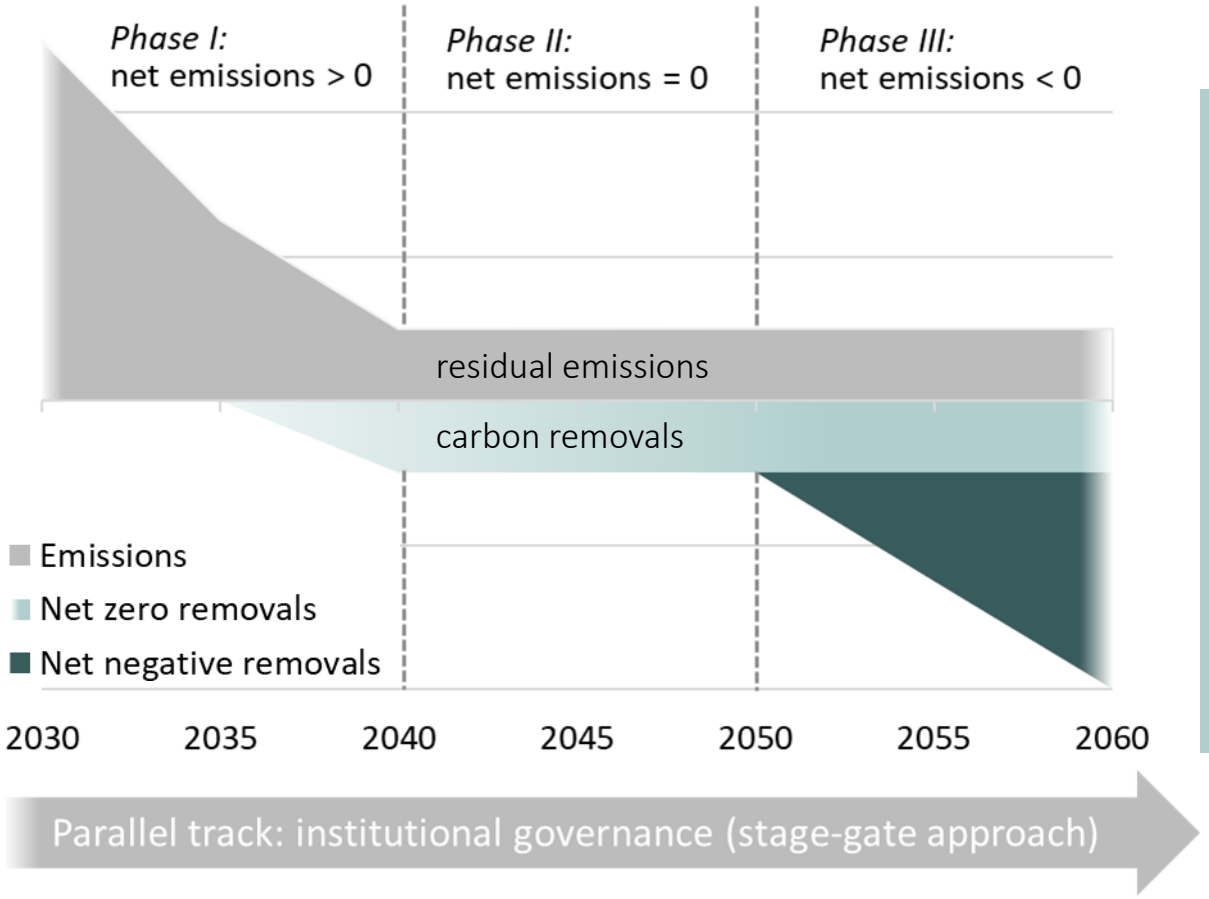
CDR = Gross CO2 target at net-zero

- 2 GtCO2/y
- 4 GtCO2/y
- 6 GtCO2/y
- Optimum (6.7 GtCO2/y)
- 7 GtCO2/y
- 8 GtCO2/y
- 10 GtCO2/y

Decreasing residual emissions and reliance on CDR at net-zero

Source: Merfort et al. / PIK (in prep.). *Separate targets for residual emissions and CDR to achieve net-zero*

Net zero as inflection point: Governments stop selling allowances and start buying removal credits



Source: based on M. Pahle & D. Sultani / PIK

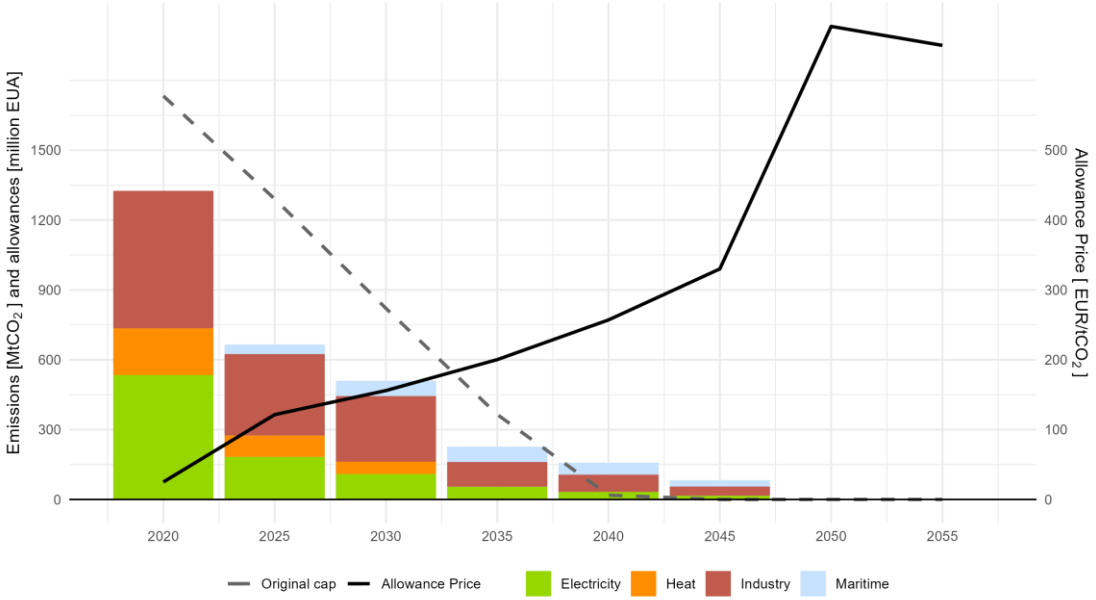
The ETS "endgame" could start in the 2030s

- „Fit for 55" revision: EU ETS cap to go down to zero by 2039 (excl. aviation/maritime sectors)
- ETS-industries will only be able to use EUA banked/bought from other market participants
- ETS "endgame" (Pahle et al., 2024) characterized by transition to negative supply equilibrium

CDR integration leads to hoteling rule until 2045, MAC equals marginal cost of removal afterwards

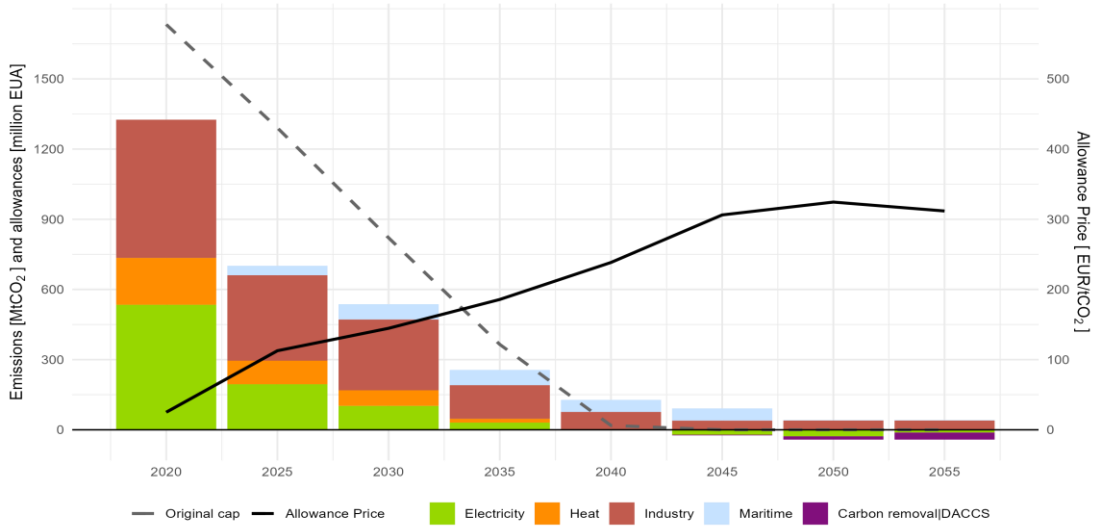
Status quo

*BECCS and DACCS excluded**



CDR integration

BECCS and DACCS integrated into the EU ETS



Source: Sultani et al. / PIK (in prep.). *Sequencing CDR into the EU ETS*

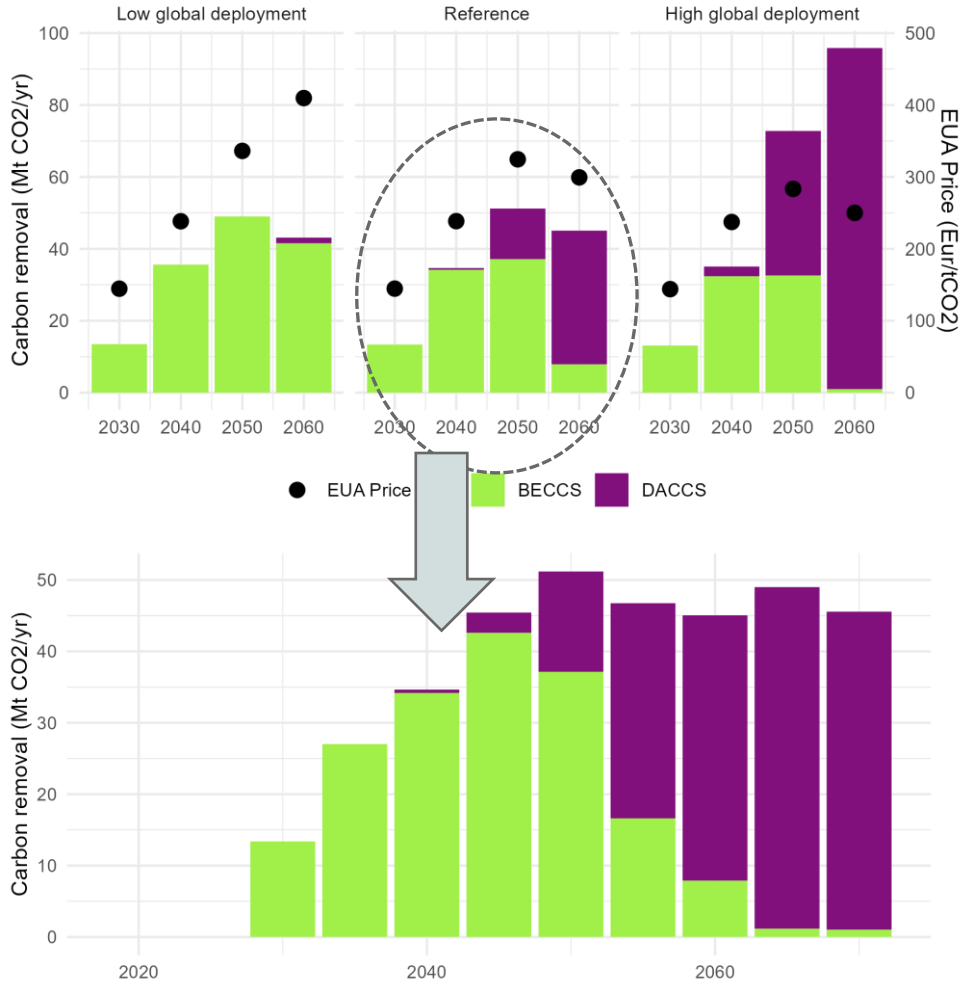
* Assumption: Banking constrained by from 2050 onwards

DACCS takes over BECCS in the long run - if expectations on global deployment (and cost reductions) materialize

BECCS/DACCS deployment and EUA prices for three global DACCS deployment scenarios

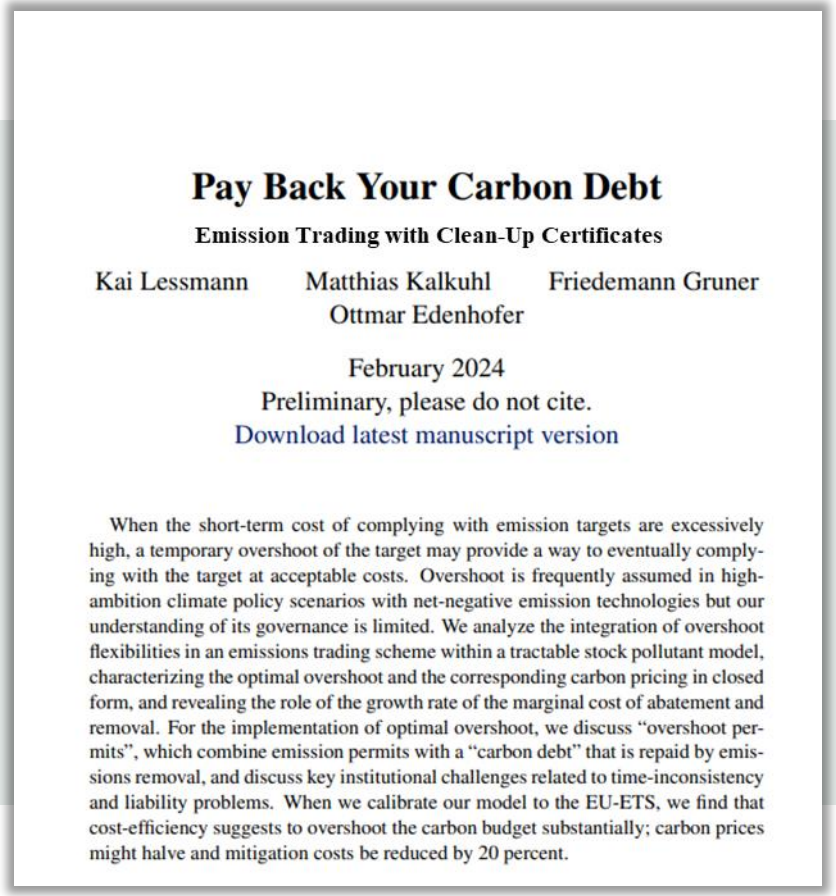
- Potential to incentivize BECCS and DACCS deployment depends on amount of residual emissions in ETS sectors
- Here: residual in relative terms, i.e. more "expensive-to-abate" than to remove permanently
- ETS first incentivizes BECCS, then DACCS as technological learning progresses and bioenergy becomes scarce (moderate DACCS costs / reference scenario)

Source: Sultani et al. / PIK (in prep.). *Sequencing CDR into the EU ETS*



Pay back your carbon debt

- Overshoot implies risks. Yet, robust overshoot management might be better than breaching climate targets due to policy failure
- To implement optimal overshoot, the regulator could issue new Clean-Up Certificates (= commitment to repay a “carbon debt”)
- Firms purchase Clean-Up Certificates, if CDR costs are anticipated to decline, or abate otherwise (reveals firms’ expectations on technological progress)
- Clean-Up Certificates could help reduce near-term mitigation costs while simultaneously promoting greater long-term ambition



Pay Back Your Carbon Debt

Emission Trading with Clean-Up Certificates

Kai Lessmann Matthias Kalkuhl Friedemann Gruner
Ottmar Edenhofer

February 2024
Preliminary, please do not cite.
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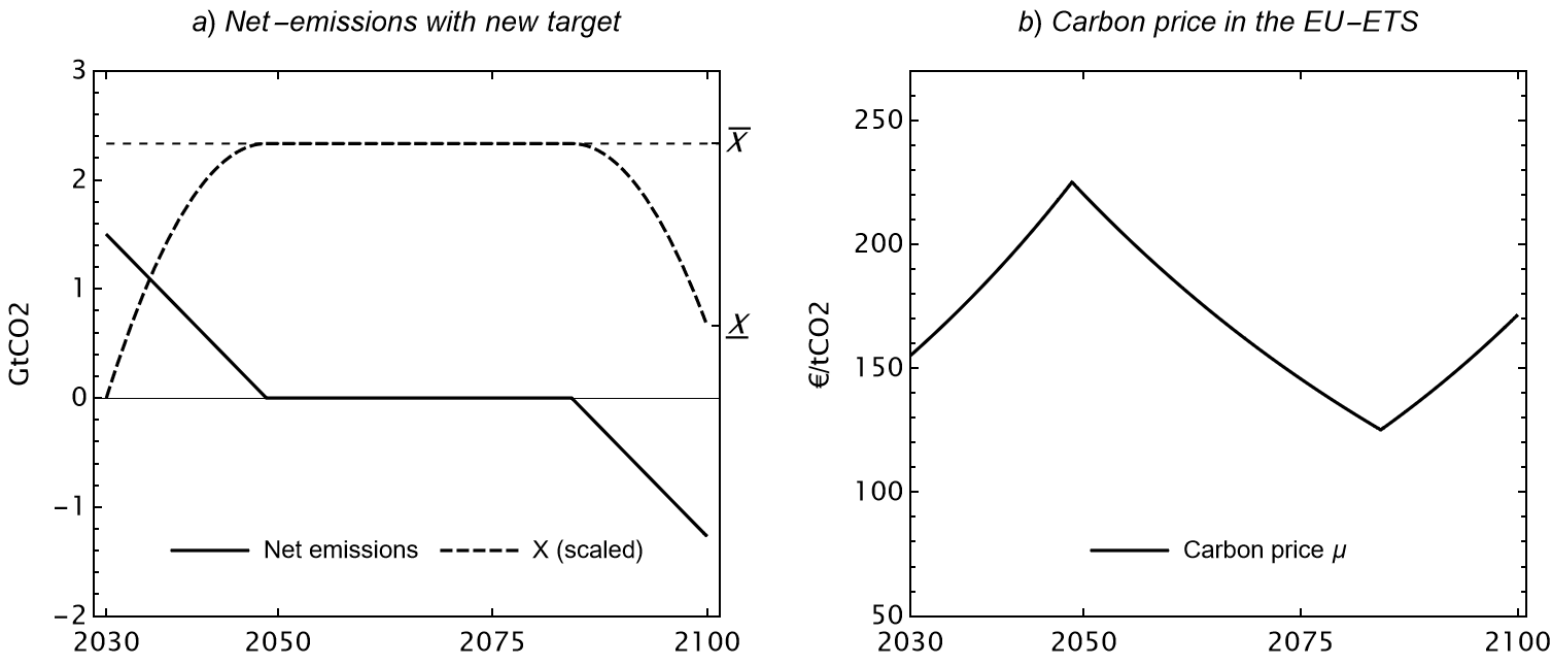
When the short-term cost of complying with emission targets are excessively high, a temporary overshoot of the target may provide a way to eventually complying with the target at acceptable costs. Overshoot is frequently assumed in high-ambition climate policy scenarios with net-negative emission technologies but our understanding of its governance is limited. We analyze the integration of overshoot flexibilities in an emissions trading scheme within a tractable stock pollutant model, characterizing the optimal overshoot and the corresponding carbon pricing in closed form, and revealing the role of the growth rate of the marginal cost of abatement and removal. For the implementation of optimal overshoot, we discuss “overshoot permits”, which combine emission permits with a “carbon debt” that is repaid by emissions removal, and discuss key institutional challenges related to time-inconsistency and liability problems. When we calibrate our model to the EU-ETS, we find that cost-efficiency suggests to overshoot the carbon budget substantially; carbon prices might halve and mitigation costs be reduced by 20 percent.

Emission trading with Clean-Up Certificates

Illustration EU-ETS

EU to remove 10GtCO2 by 2100



Source: Lessmann et al. / PIK (in prep.). *Pay Back Your Carbon Debt: Emissions Trading with Clan-Up Certificates*

Implementation

- Clean-Up Certificate = EUA + carbon debt (CD)
- CD must be paid back by removing carbon before the end of period T
- CD requires a collateral to ensure coverage of future removal cost
- Clean-Up Certificates require institutional governance

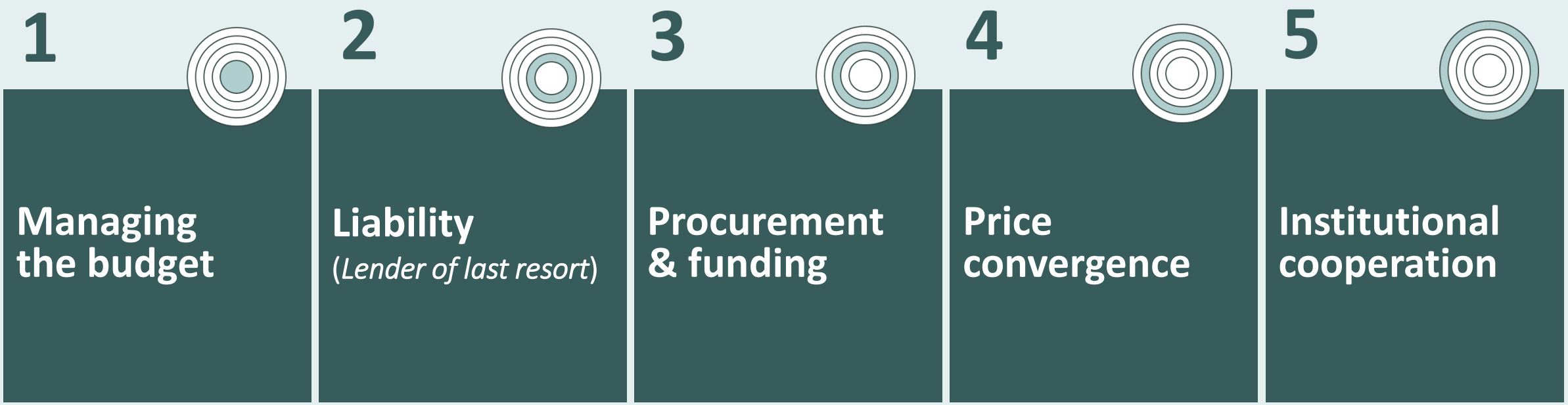
New EU institutions and authorities

Carbon Removal Certification Authority

European Carbon Central Bank

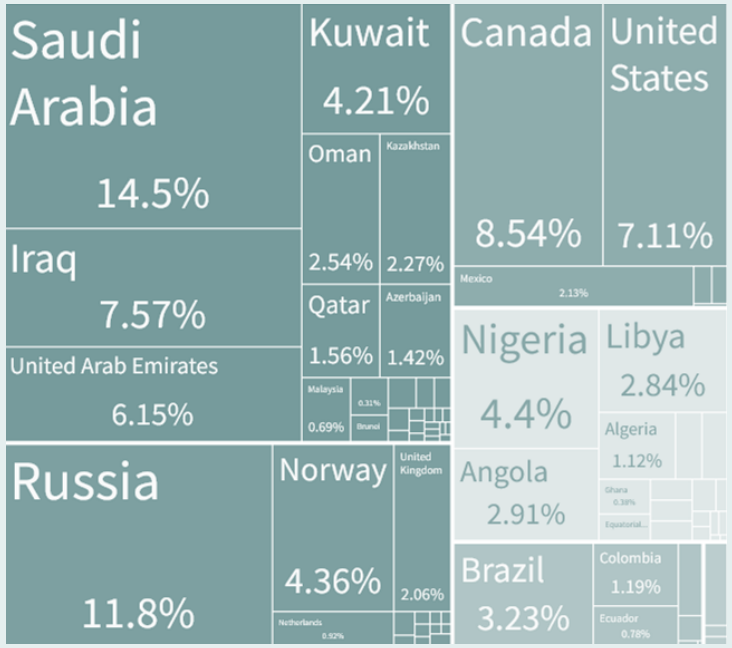
Green Leap Innovation Authority

Mandate of a European Carbon Central Bank



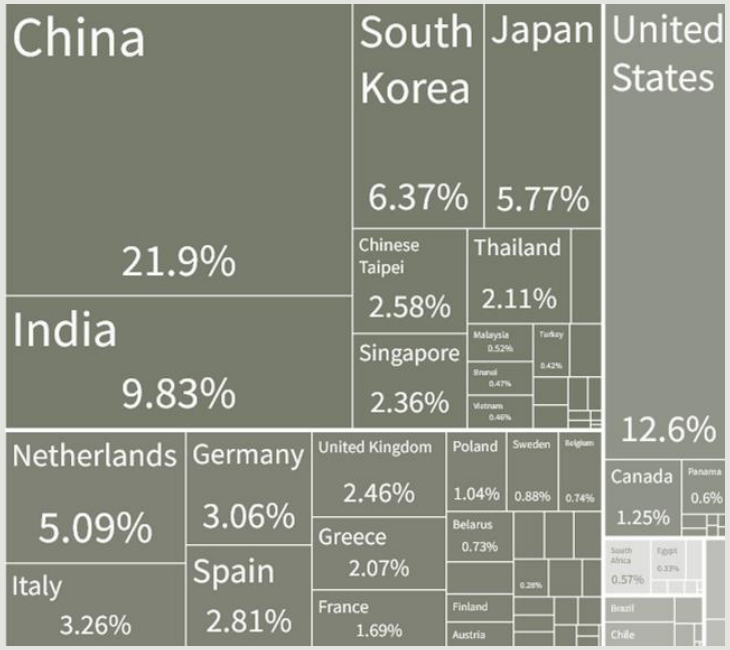
New incentives for carbon market diplomacy

CDR subsidy > CO_2 price



Crude oil exporters

CDR subsidy < CO_2 price



Crude oil importers

Source: OEC (2023). *Which countries export Crude Petroleum?* (2021);
Franks et al. (2022). *Optimal pricing for carbon dioxide removal under inter-regional leakage*

Conclusion

› **Rapid and significant emission reductions are critical** to limit global warming
- not in a few years, but immediately

› **CDR is essential for achieving climate neutrality and managing the overshoot**. This requires coherent incentive schemes and new institutions to meet net-zero / net-negative commitments

› A **European Carbon Central Bank** could mitigate the regulator's commitment problem (time inconsistency) and address specific liability risks associated with CDR (“lender of last resort”)

› **Sustainably managing the carbon cycle and establishing a planetary waste management system** are fundamental challenges for 21st-century climate policy

Thank you

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