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Carbon Dioxide Removal, Planetary Waste Management & Carbon Pricing: A Public Economics Perspective

GTAP Events: 26th Annual Conference on Global Economic Analysis

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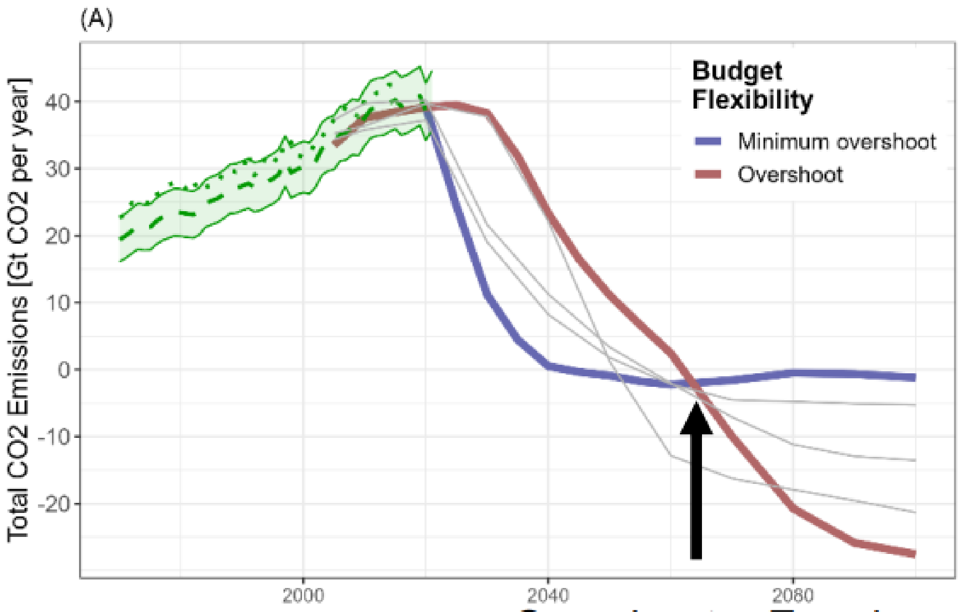
Climate targets and carbon dioxide removals

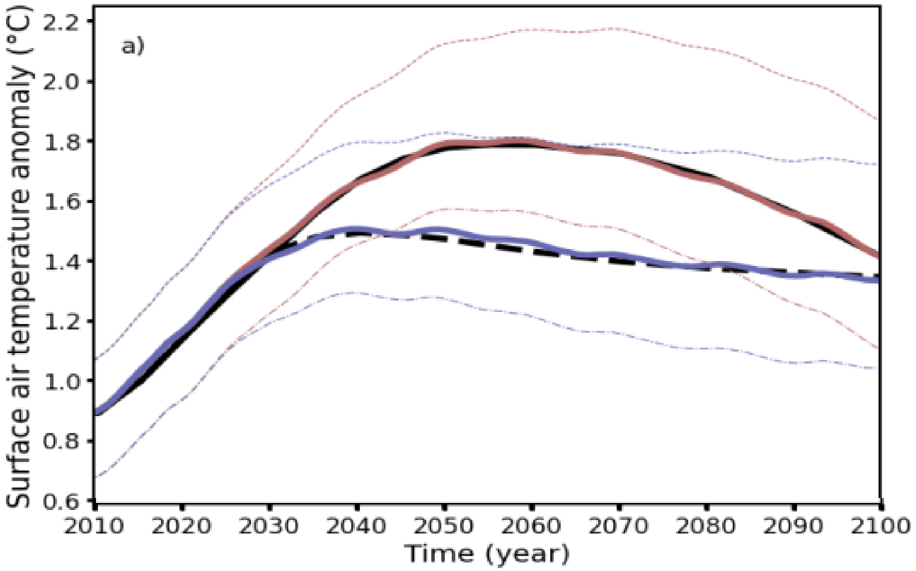
Window to 1.5°C rapidly closing. "Overshoot" very likely while very risky

Markedly different emission pathways fulfill same carbon budget



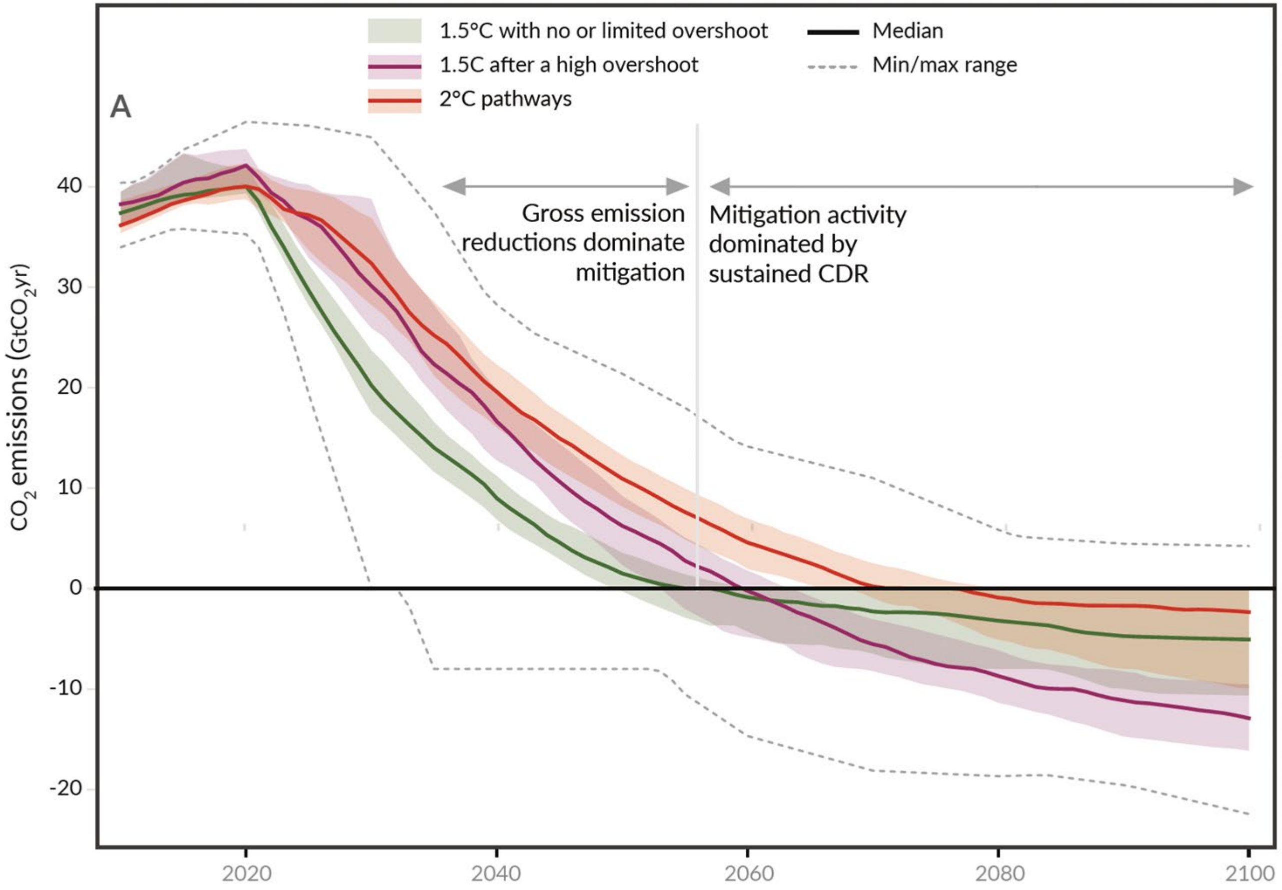
Overshoot = Zero by 2050 and Negative emissions thereafter

Peak difference in global warming 0.35°C



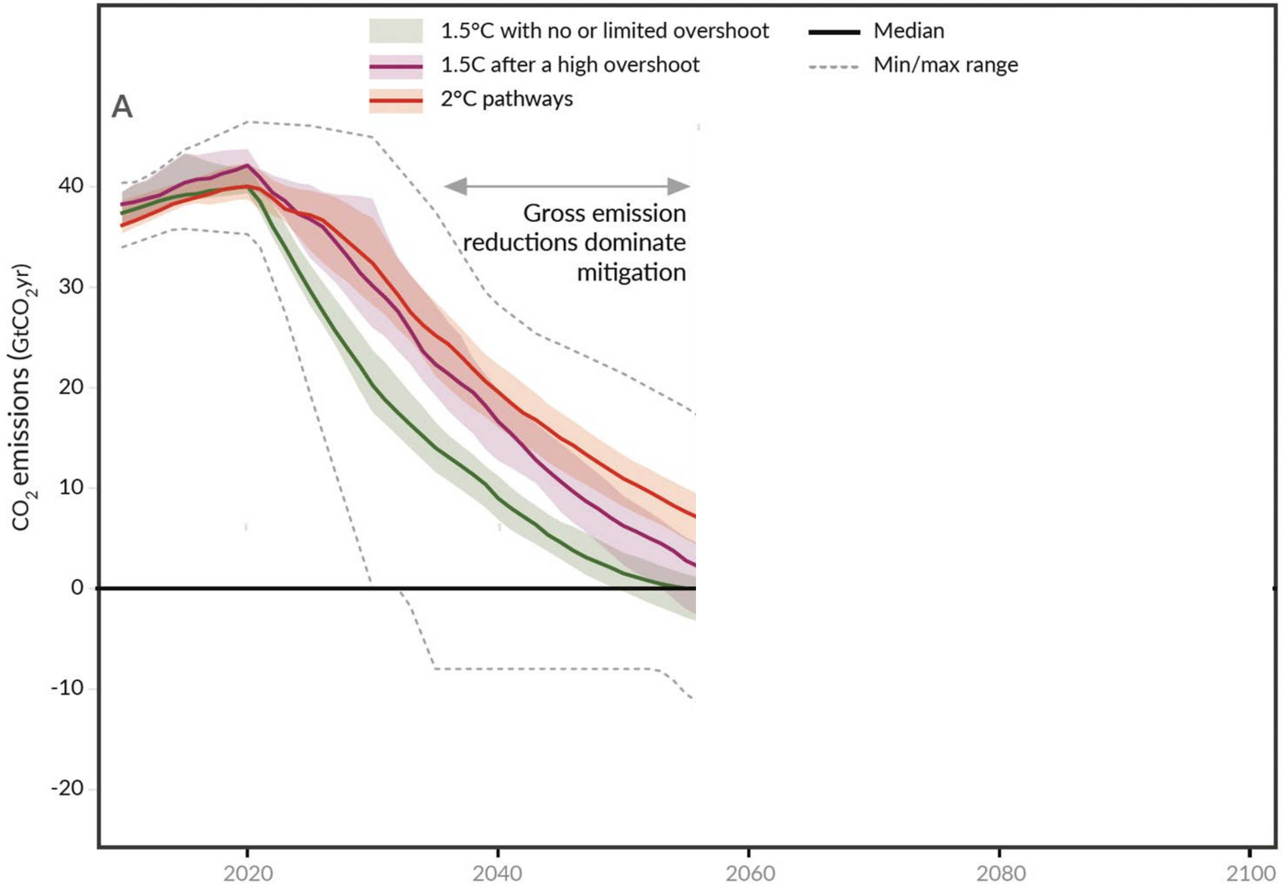
Source: Bauer et al. (2023, in revision)

No mitigation strategy meets the Paris temperature goal without carbon dioxide removal (CDR)



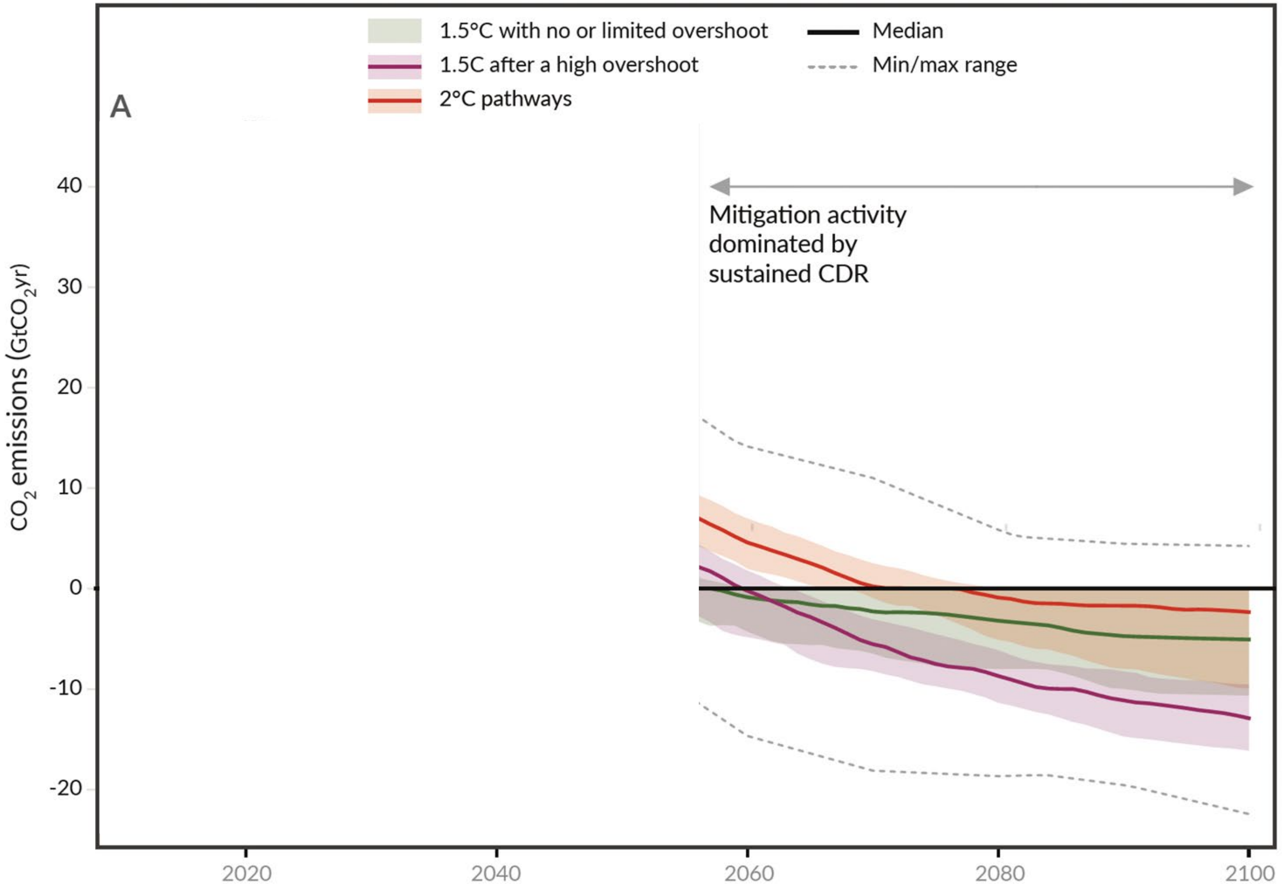
Source: Smith, Geden, Nemet et al. (2023). *The State of Carbon Dioxide Removal*

The first half of the 21st century is dominated by GHG emission reductions



Source: Smith, Geden, Nemet et al. (2023). *The State of Carbon Dioxide Removal*

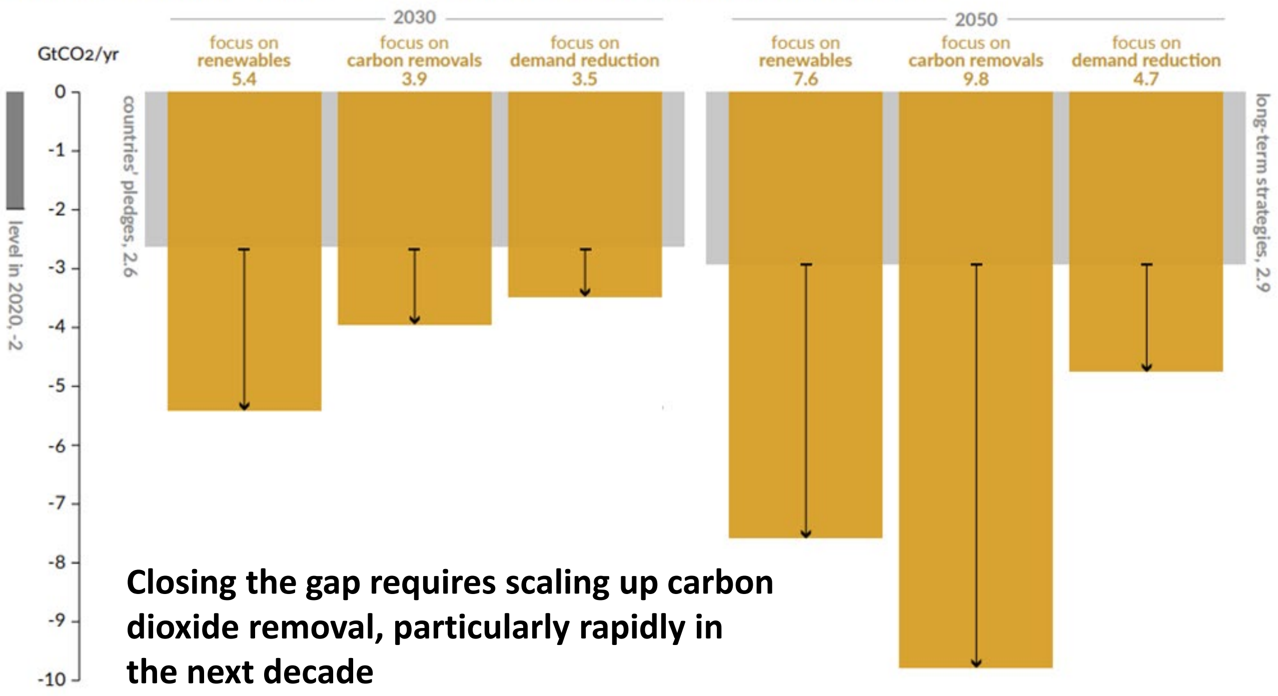
The second half of the 21st century is dominated by CDR



Source: Smith, Geden, Nemet et al. (2023). *The State of Carbon Dioxide Removal*

Huge gap between proposed levels of CDR and actual needs

Carbon dioxide removal (GtCO2/yr), proposed levels compared to three Paris-relevant scenarios in 2030 and 2050



Closing the gap requires scaling up carbon dioxide removal, particularly rapidly in the next decade

Source: Smith, Geden, Nemet et al. (2023). *The State of Carbon Dioxide Removal*

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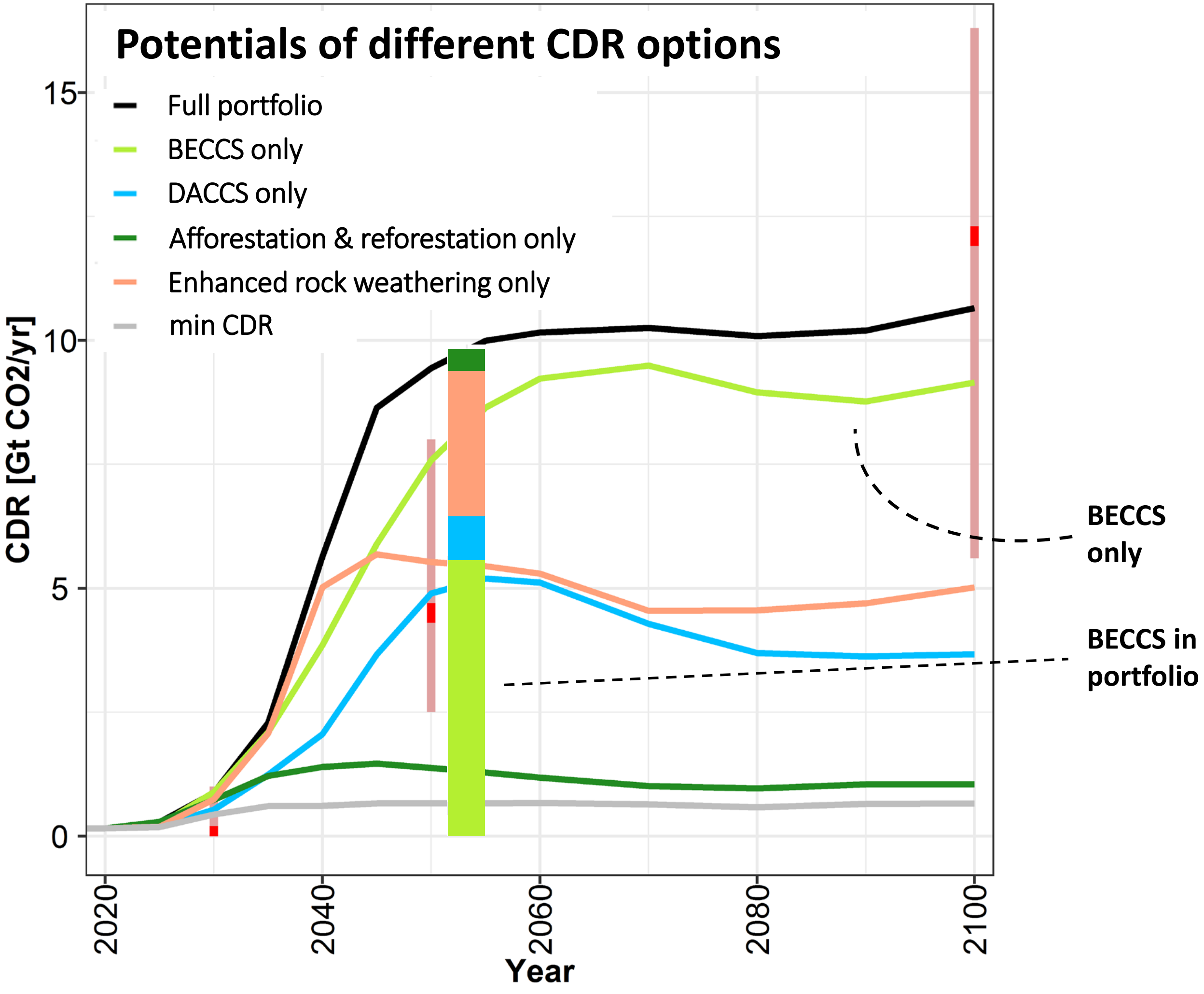
There is no CDR silver bullet. Portfolios have multiple benefits



- **Higher CDR availability** can lead to lower levels of net emissions and hence **enable earlier emission neutrality**
- Limit contribution of each options, thus **reducing risks and tradeoffs**
- Portfolios **balance regional CDR deployment**

Source: Strefler et al. (2021). *Carbon dioxide removal technologies are not born equal*

Optimal Carbon Pricing

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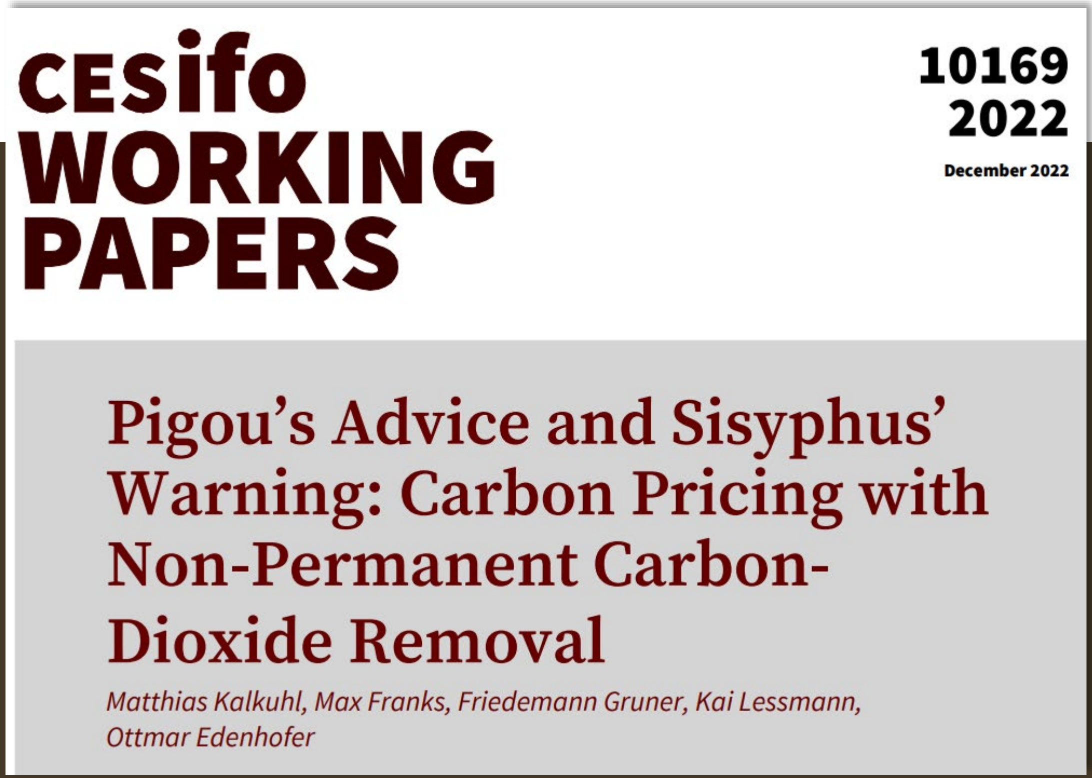
Carbon dioxide removal needs good governance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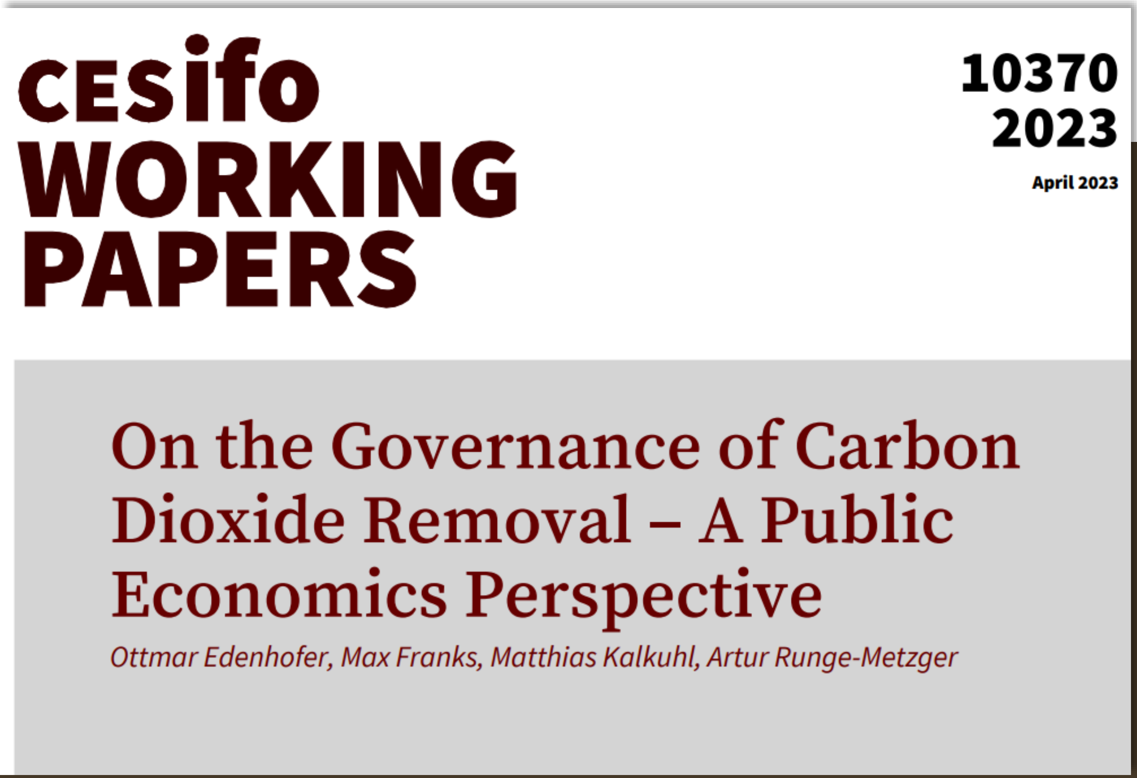
Pigou's Advice and Sisyphus' Warning: Carbon Pricing with Non-Permanent Carbon-Dioxide Removal

Matthias Kalkuhl, Max Franks, Friedemann Gruner, Kai Lessmann, Ottmar Edenhofer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On the Governance of Carbon Dioxide Removal – A Public Economics Perspective

Ottmar Edenhofer, Max Franks, Matthias Kalkuhl, Artur Runge-Metzger

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

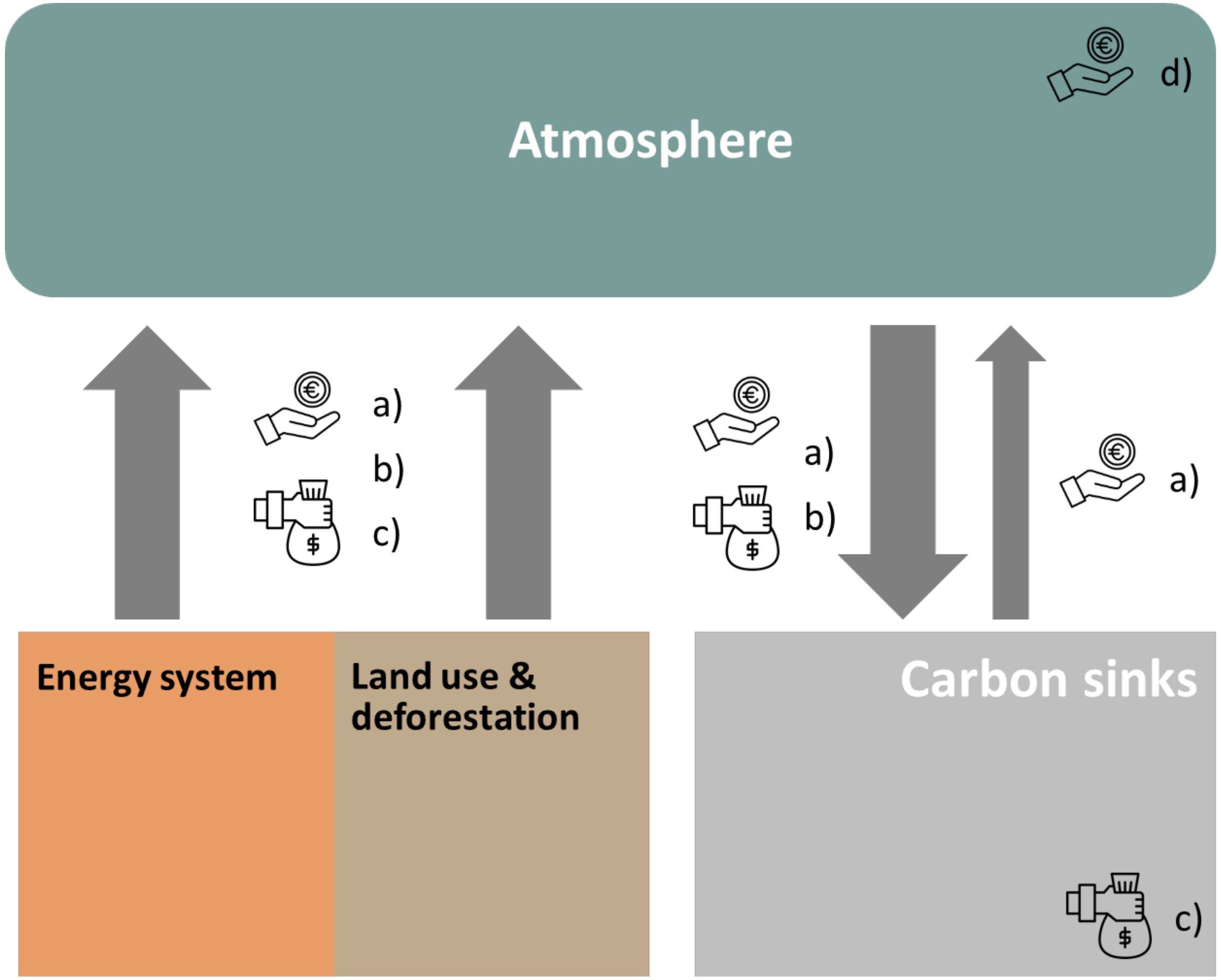
Technology	Potentials ($Gt\ CO_2\ yr^{-1}$)	Costs ($)	Storage duration (half-life)
Afforestation/reforestation	0.5-3.6	0-50	Decades to centuries
BECCS	0.5-5	100-200	Millenia
Ocean alkalinisation	0.1-10	14-500	Centuries
Enhanced weathering	2-4	50-200	Centuries
Biochar	0.5-2	30-120	Centuries
Modified patterns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

- The conventional **social cost of carbon emissions (SCC-E)** is a measure of the marginal climate change damages from one ton of carbon emitted into the atmosphere
- The new metric **social costs of carbon removal (SCC-R)** is a measure of climate change damages resulting from releasing emissions from storage
- The SCC-E and SCC-R metrics are **central concepts for the design of tax and subsidy policies**

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



a) **Downstream pricing**
   Price all removals *and* all occurring leakage/releases at the same carbon price

b) **Downstream pricing**
   Carbon tax on emissions from economic activity and a subsidy adjusted for the social cost of carbon removal

c) **Storage stock subsidy**
   Annual subsidy on carbon reservoir

d) **Pricing of carbon stock in atmosphere**
   Taxation of cumulative net CO_2 emissions / 'carbon shares'

Optimal pricing for carbon dioxide removal depends on inter-regional leakage

Under inter-regional carbon leakage, the optimal CDR subsidy should exceed the price for carbon (reducing emissions by a ton of CO_2 domestically causes more inter-regional leakage than removing a ton).

This wedge may be exacerbated or reversed, depending on the resource trade balance of a country.

A net exporter of fossil resources increases the price differential to increase rents of their carbon resource producers.

A net importer sets a carbon tax above the CDR subsidy to appropriate the resource rents from resource exporters.

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Optimal pricing for carbon dioxide removal under inter-regional leakage ☆

Max Franks [a, b], Matthias Kalkuhl [c, d], Kai Lessmann [a, c]

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Abstract

Carbon dioxide removal (CDR) moves atmospheric carbon to geological or land-based sinks. In a first-best setting, the optimal use of CDR is achieved by a removal subsidy that equals the optimal carbon tax and marginal damages. We derive second-best policy rules for CDR subsidies and carbon taxes when no global carbon price exists but a national government implements a unilateral climate policy. We find that the optimal carbon tax differs from an optimal CDR subsidy because of carbon leakage and a balance of resource trade effect. First, the optimal removal subsidy tends to be larger than the carbon tax because of lower supply-side leakage on fossil resource markets. Second, net carbon exporters exacerbate this wedge to increase producer surplus of their carbon resource producers, implying even larger removal subsidies. Third, net carbon importers may set their removal subsidy even below their carbon tax when marginal environmental damages are small, to appropriate producer surplus from carbon exporters.

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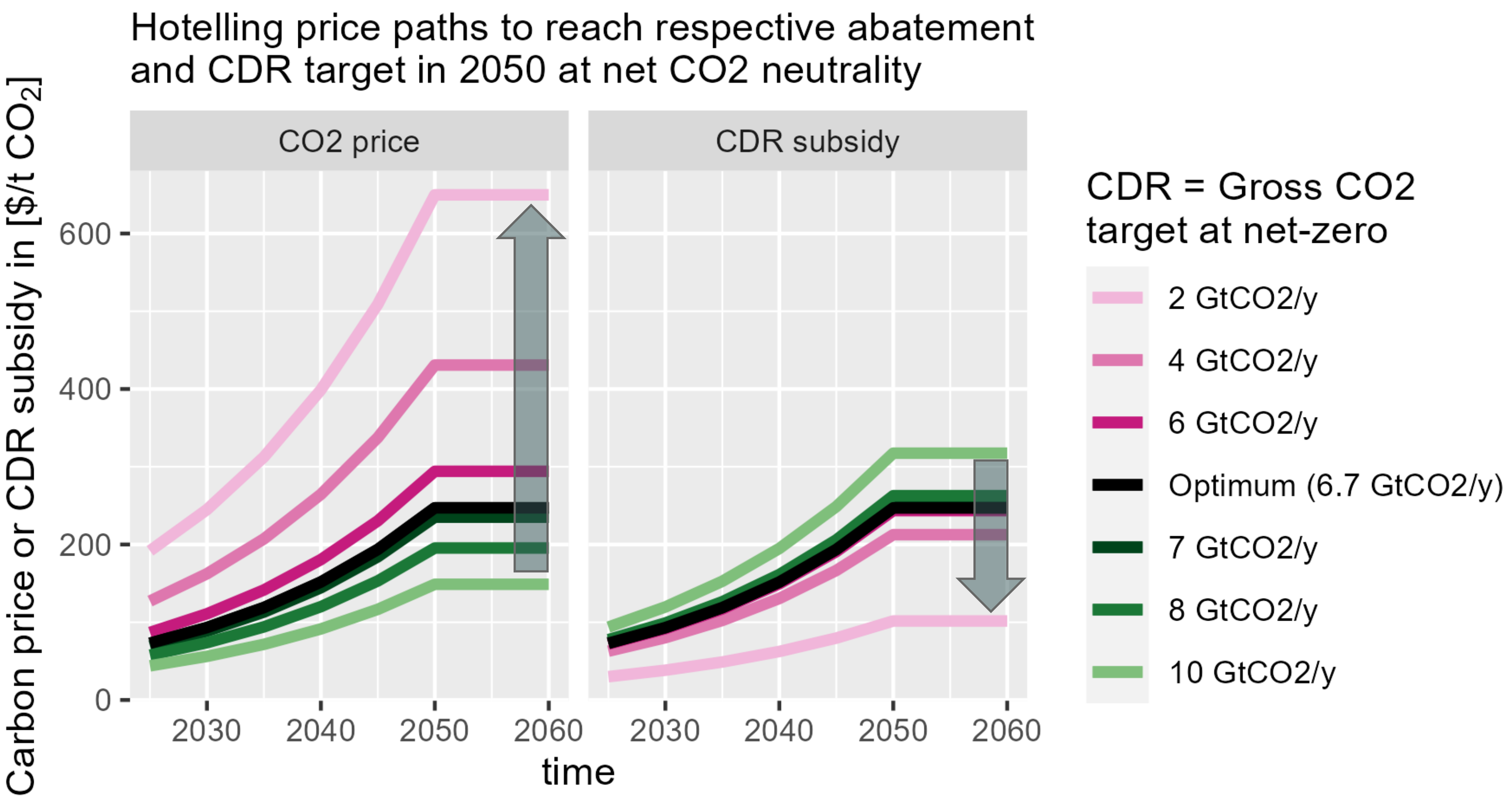
Separate quantity targets for residual emissions and CDR lead to diverging prices



Decreasing residual emissions and reliance on CDR at net-zero

Source: Merfort & Strefler, in prep.

Governing CDR in the European Union

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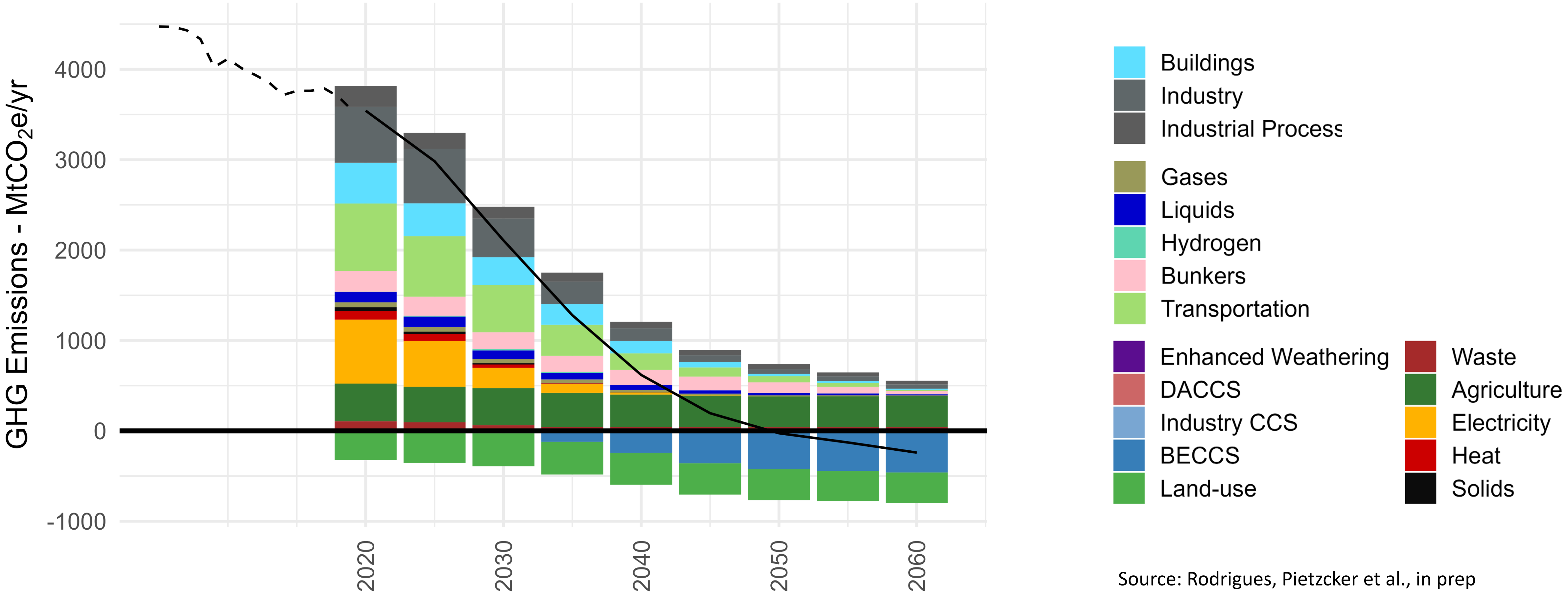
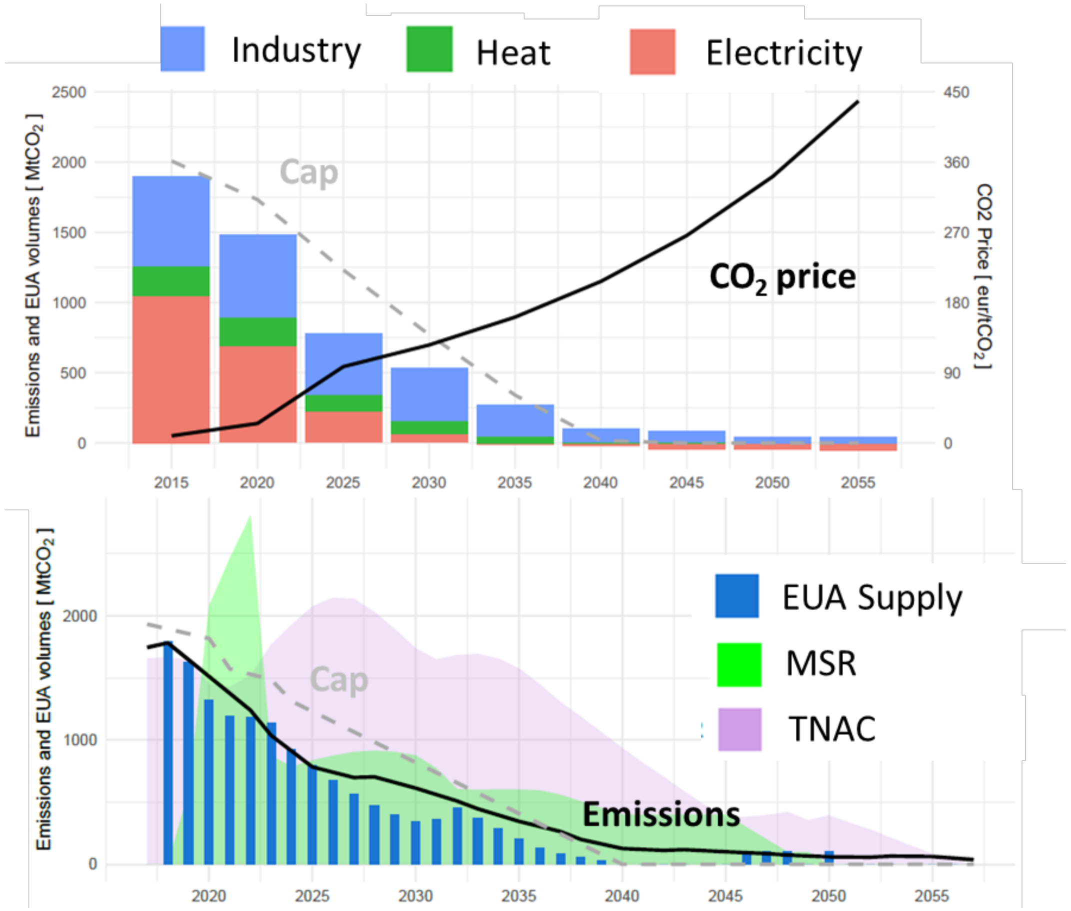
Climate neutrality implies that residual emissions are balanced by carbon dioxide removals

Residual Greenhouse Gas Emissions in EU Green Deal Scenario



Source: Rodrigues, Pietzcker et al., in prep

“Fit for 55” revision: The EU ETS endgame could start in 2039 already



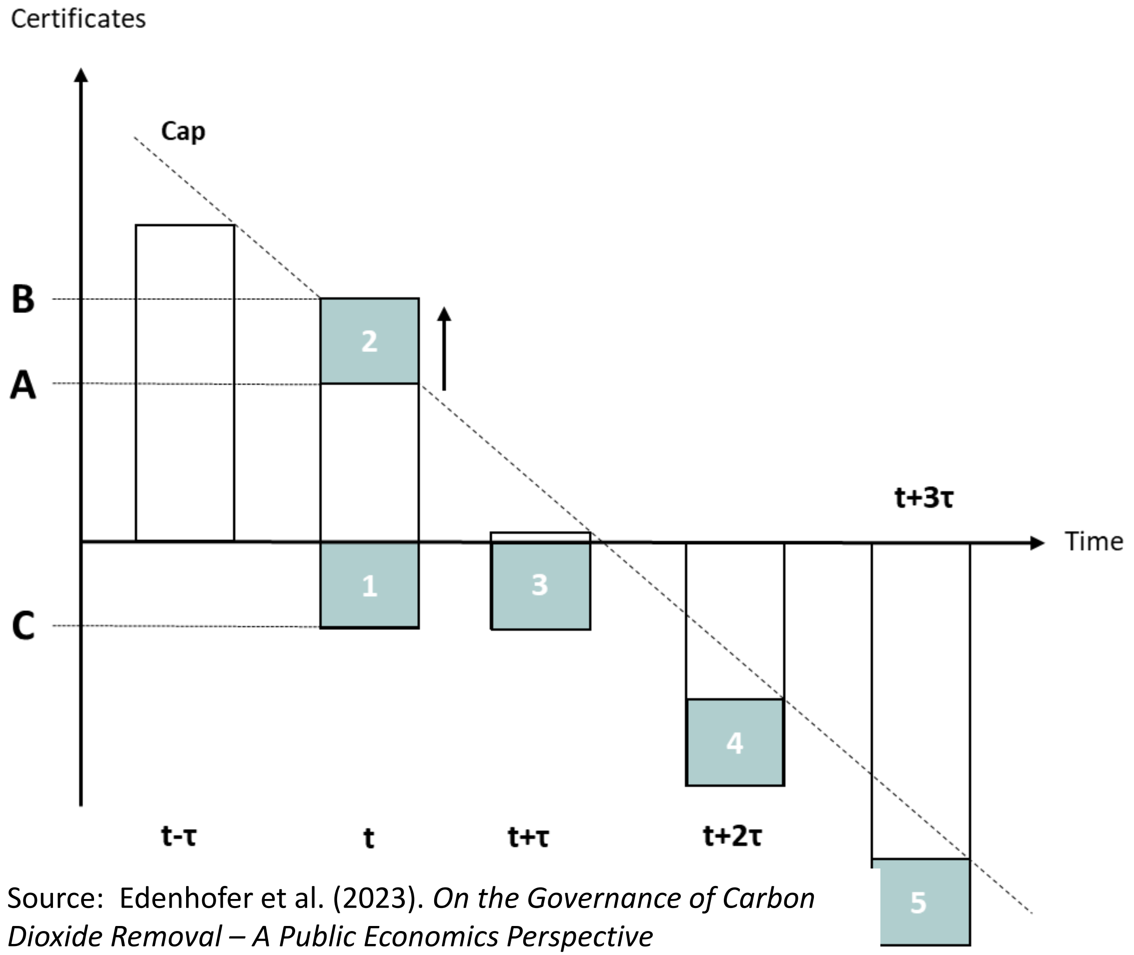
Source: Pahle et al. (2023). *The Emerging Endgame: The EU ETS on the Road Towards Climate Neutrality*

› Increasingly scarce allowance supply will **heavily alter price formation** and the **functioning of the market**

› “Endgame” characterized by transition from positive to **negative supply equilibrium** (ie. balancing of rest emission via CO_2 removals)

› This raises the question whether the ETS is fit for climate neutrality and how **governance must be adjusted to account for the changes**

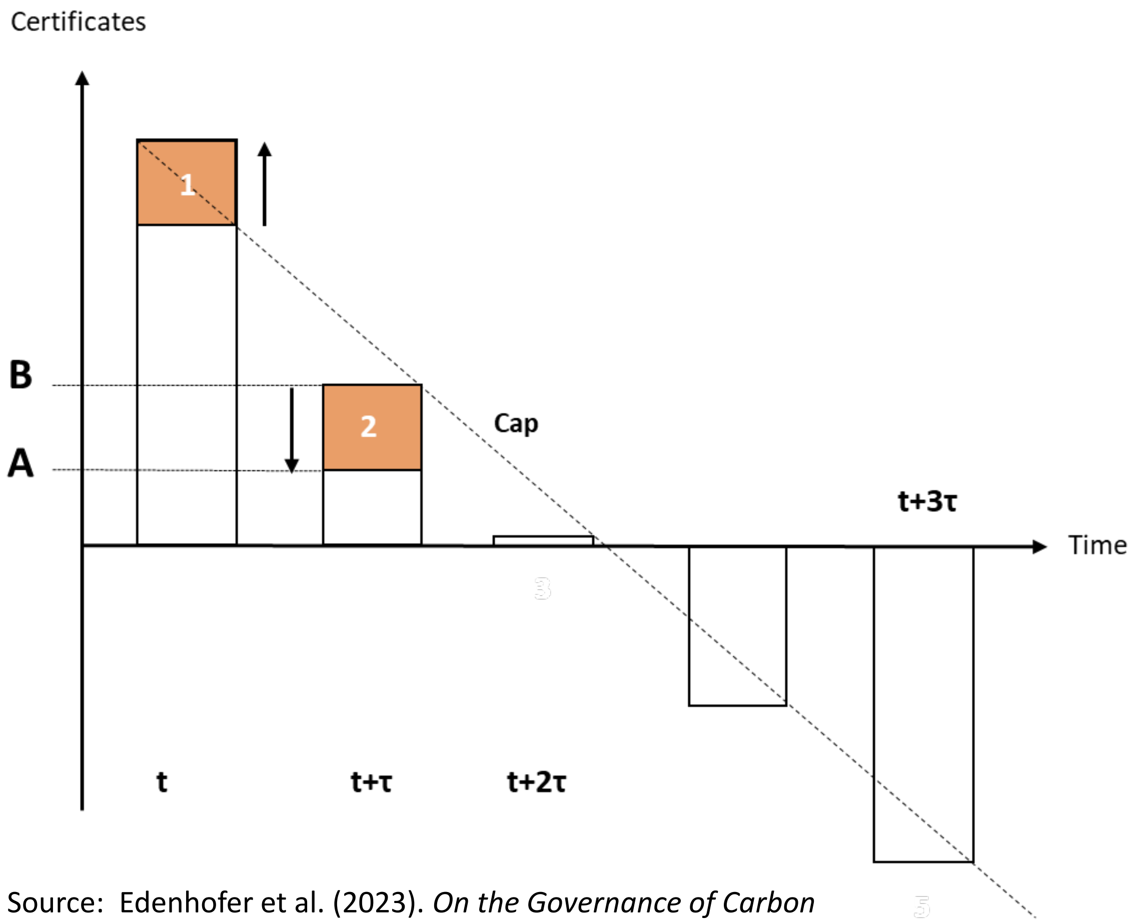
‚Managing the ETS cap': emissions from non-permanent removal need to be compensated by further removals



Source: Edenhofer et al. (2023). *On the Governance of Carbon Dioxide Removal – A Public Economics Perspective*

- Initial removal of C non-permanent units (1) creates additional ETS certificates (2)
- Released emissions from reservoir have to be compensated by additional removals (3)
- This goes on in perpetuity (4,5,..)

Released emissions can also be compensated by regular ETS certificate



Source: Edenhofer et al. (2023). *On the Governance of Carbon Dioxide Removal – A Public Economics Perspective*

- Non-permanent removal (1) is compensated by a regular ETS certificate (2)
- Perpetual renewal of removals becomes a financial liability in the ETS

The carbon debt from non-permanent removal activities might be very large or even infinite

		Storage time [τ years]				
γ_R	r	5	10	20	50	100
	1%	19.6	9.6	4.5	1.6	0.6
0	**2%**	9.6	**4.6**	2.1	0.6	0.2
	3%	6.3	2.9	1.2	0.3	0.1
	5%	3.6	1.6	0.6	0.1	0.0
	1%	∞	∞	∞	∞	∞
2%	**2%**	∞	$\boldsymbol{\infty}$	∞	∞	∞
	3%	20.0	9.8	4.6	1.6	0.6
	5%	6.4	3.0	1.3	0.3	0.1

$\boldsymbol{\gamma_R}$ = growth rate of marginal removal costs

$\boldsymbol{r}$ = discount rate

Source: Edenhofer et al. (2023). *On the Governance of Carbon Dioxide Removal – A Public Economics Perspective*

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A way forward: A governance proposal for CDR in the EU

Carbon Removal Certification Authority	European Carbon Central Bank	Green Leap Innovation Authority

Key takeaways

- **Climate targets cannot be met without CDR**. Sustainably managing the carbon cycle is a core challenge of climate action in the 21st century (“*planetary waste management system*”).

- The **CDR gap needs to be addressed swiftly**. Early years of technology deployment are decisive for upscaling and successfully meeting demand in the coming decades.

- Without **good governance**, the CDR gap won’t close and mitigation efforts might be jeopardized. Deployment at scale requires a consistent policy framework and solid incentive schemes.

- A **governance framework for carbon dioxide removal** and **a mandate for a European Carbon Central Bank** should find its way into EU legislation.

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