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Follow the flows:
Pitfalls to avoid in LCA for [bio]CCUS

S.E. Tanzer / 7 March 2024

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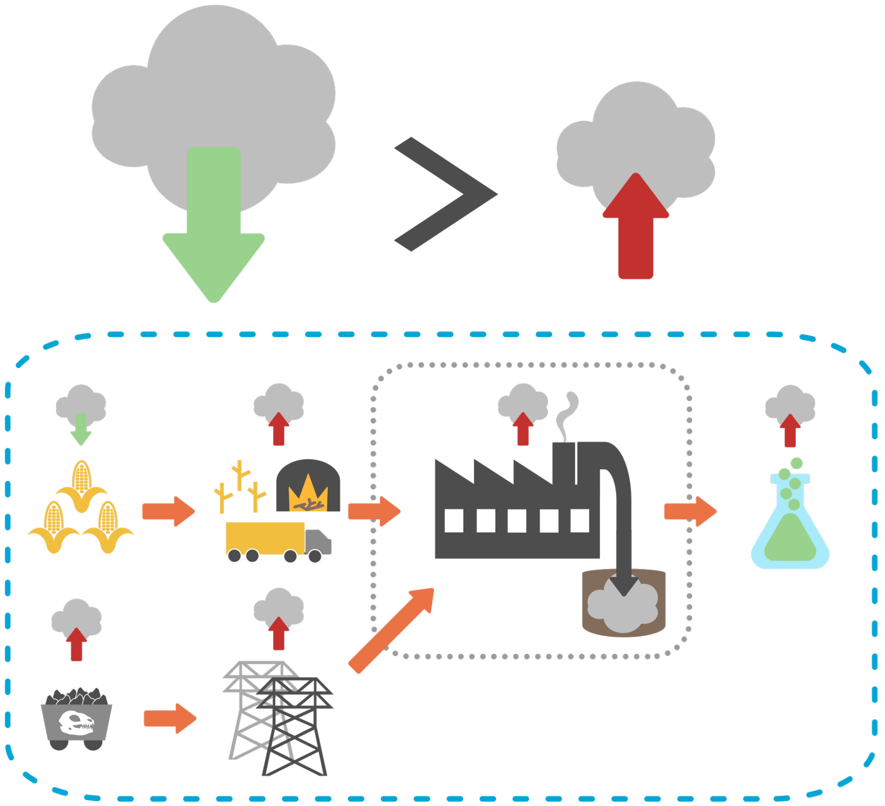
What am I going to tell you today?

6 ½ common issues I have seen regarding:

- System boundary choices
- Overclaiming
- Unhelpful aggregation



First, in case you weren’t aware…

DG ENER has published guidelines specifically for LCA for CCU.

doi: 10.2833/161308


European Commission

LCA4CCU

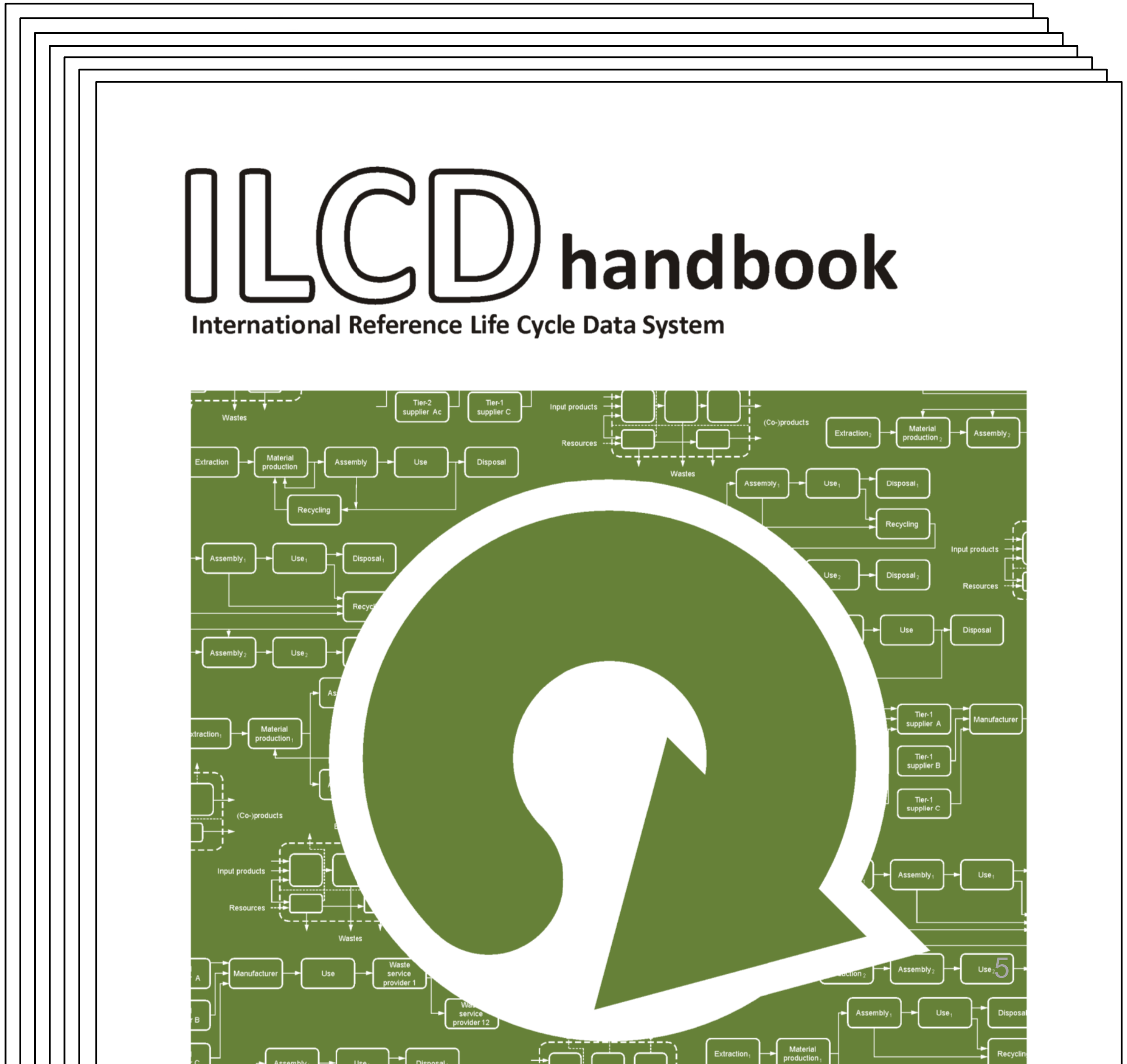
Guidelines for Life Cycle Assessment of Carbon Capture and Utilisation

Written by **Andrea Ramirez Ramirez, Aïcha El Khamlichi, Georg Markowz, Nils Rettenmaier, Martin Baitz, Gerfried Jungmeier, and Tom Bradley**
March – 2020

First, in case you weren't aware…

and the JRC has general guidelines for LCA, too

doi: 10.2788/38479



#1

Cutting off your carbon source

The feedstock should always be within your system boundaries

If CO_2 is captured from the atmosphere or a waste stream:
start from the flue-gas stack (or air contactor)

cleaning, capture, compression, transport, losses

and all associated energy use, chemicals, infrastructure, &c

If the carbon is produced directly for your system (e.g., syngas):

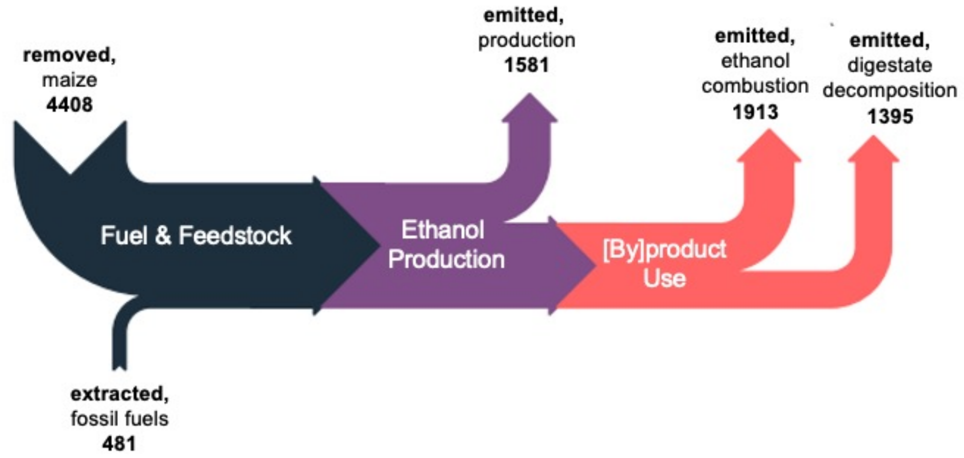
include the extraction, processing, and transport of that carbon source

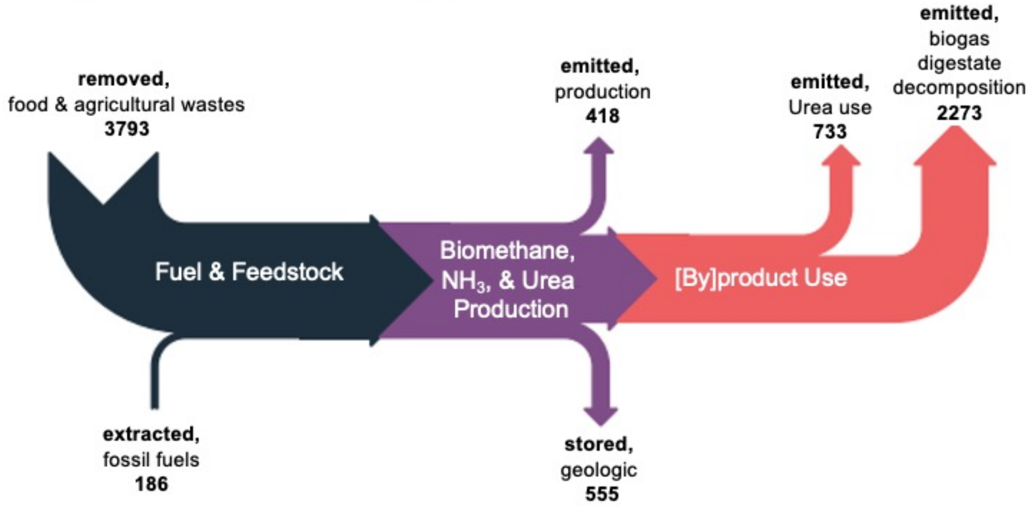
#2

Cutting off your carbon fate

Cradle-to-gate is not enough

- Cutting off use and end-of-life distorts the perception of impacts
- which propogates to any downstream metrics (e.g. cost of avoidance)
- Also: No such thing as “carbon neutral carbon storage”



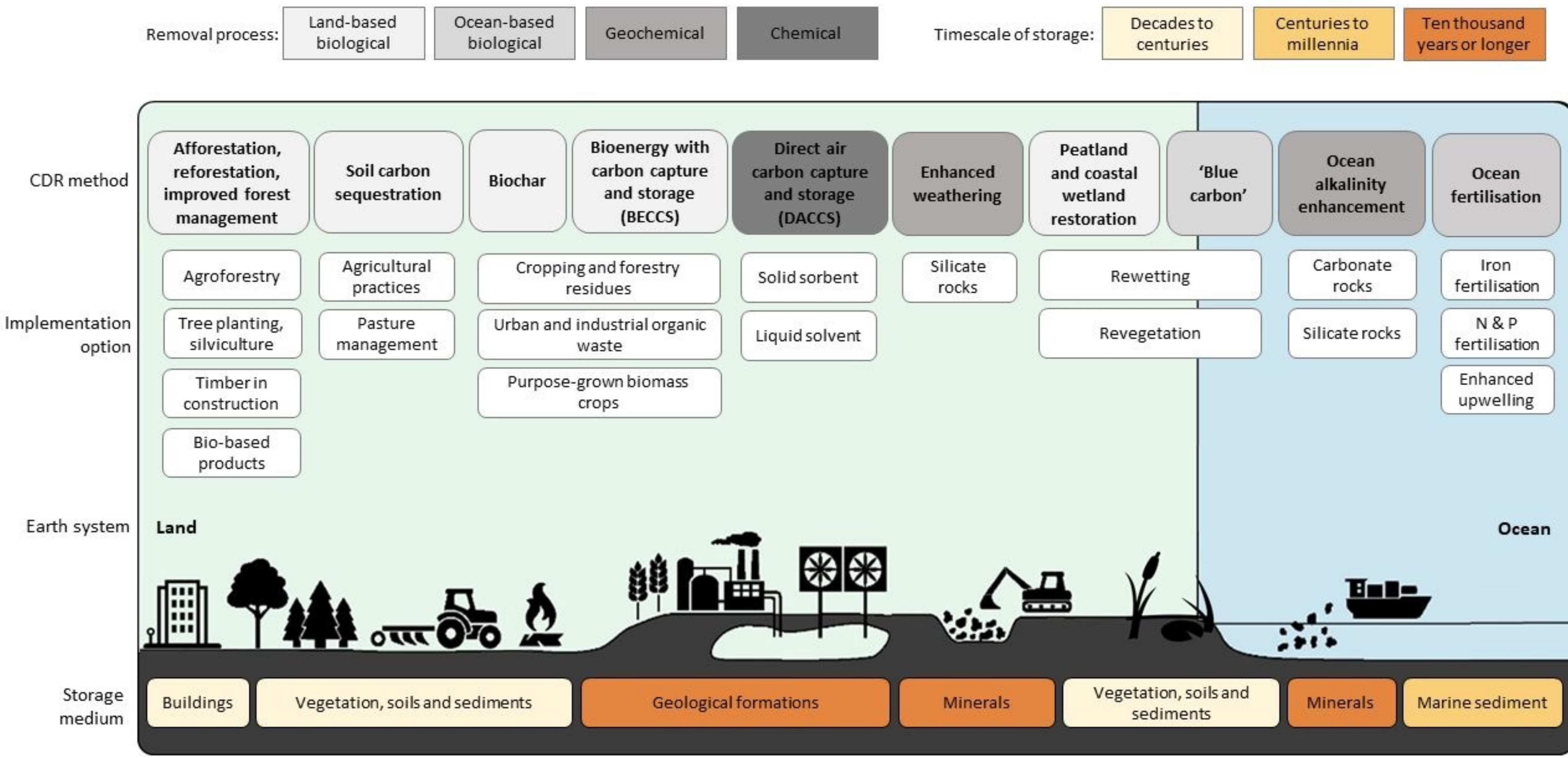


Tanzer et al (2021) doi: 10.2139/ssrn.3819778

#3a

Claiming negative emissions without an atmospheric CO_2 source *and* long-term CO_2 sink

There are many forms of CDR…

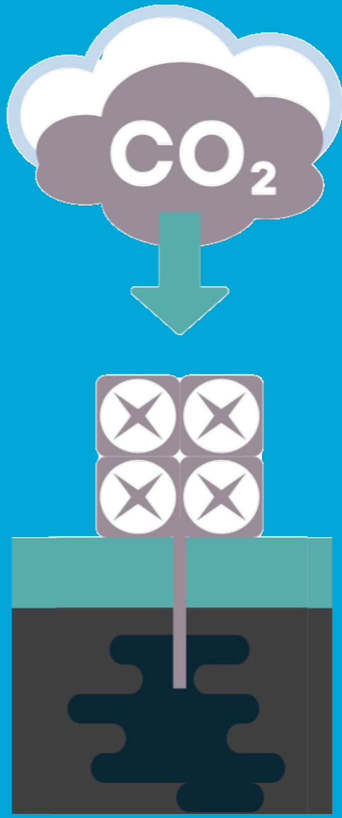


Source: IPCC AR6 WGIII, Chapter 12 (Box 8, Figure 1)

…with two things in common

Source: CO_2 is **physically extracted** from the atmosphere.

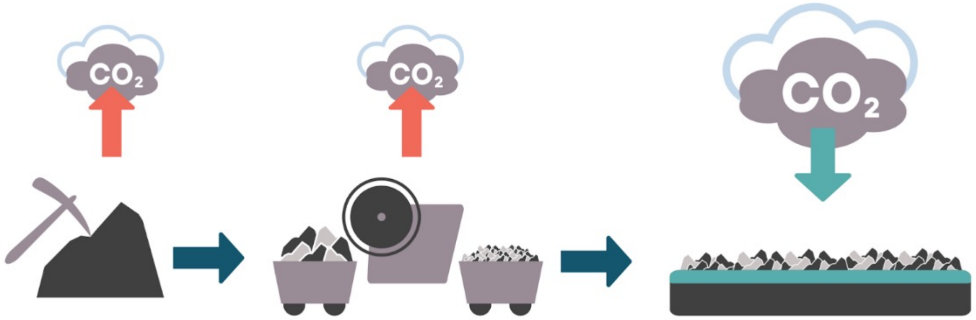
Sink: The extracted atmospheric CO_2 is **stored** out of the atmosphere.



Direct Air Capture + Storage

Atmospheric CO_2 extracted by chemicals

Storage in geology



Enhanced weathering

Grinding and spreading of rocks

Atmospheric CO_2 extracted by dissolution

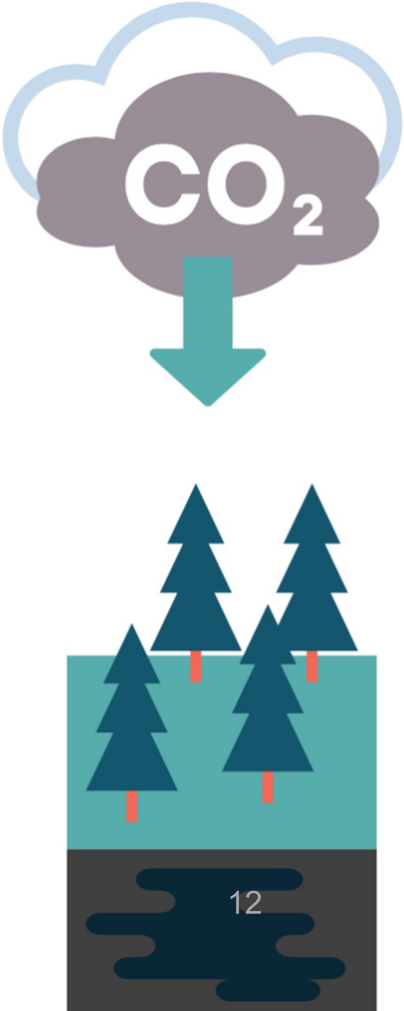
Storage in dissolved minerals in soils and oceans

Afforestation

Atmospheric CO_2 extracted by photosynthesis

Storage in biomass

Ongoing management



#notallsinks

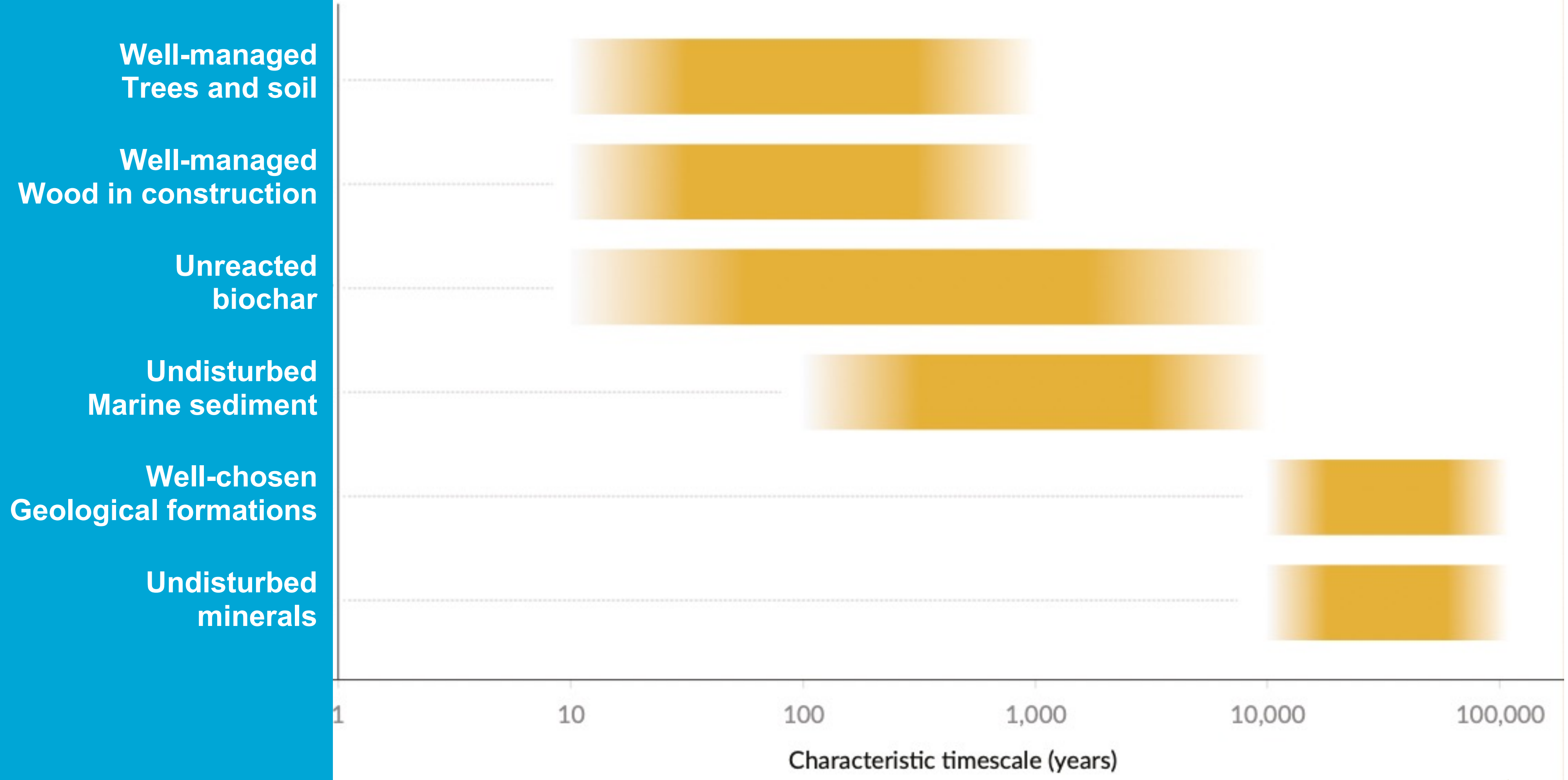


Figure 1.3. *The durability of different carbon storage pools ranges from decades to tens of millennia. Note that these timescales are indicative, assuming no premature disturbance. Source: IPCC WG3 AR6 Chapters 7 & 12*[13,19].

Source: The State of CDR Report (2023)

#3b

Claiming negative emissions without a cradle-to-grave LCA

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The **fundamental purpose** of carbon dioxide removal is to **decrease** the amount of greenhouse gases in the atmosphere.

Therefore, the fundamental purpose of CDR accounting is to establish how much the amount of greenhouse gases in the atmosphere decreased.

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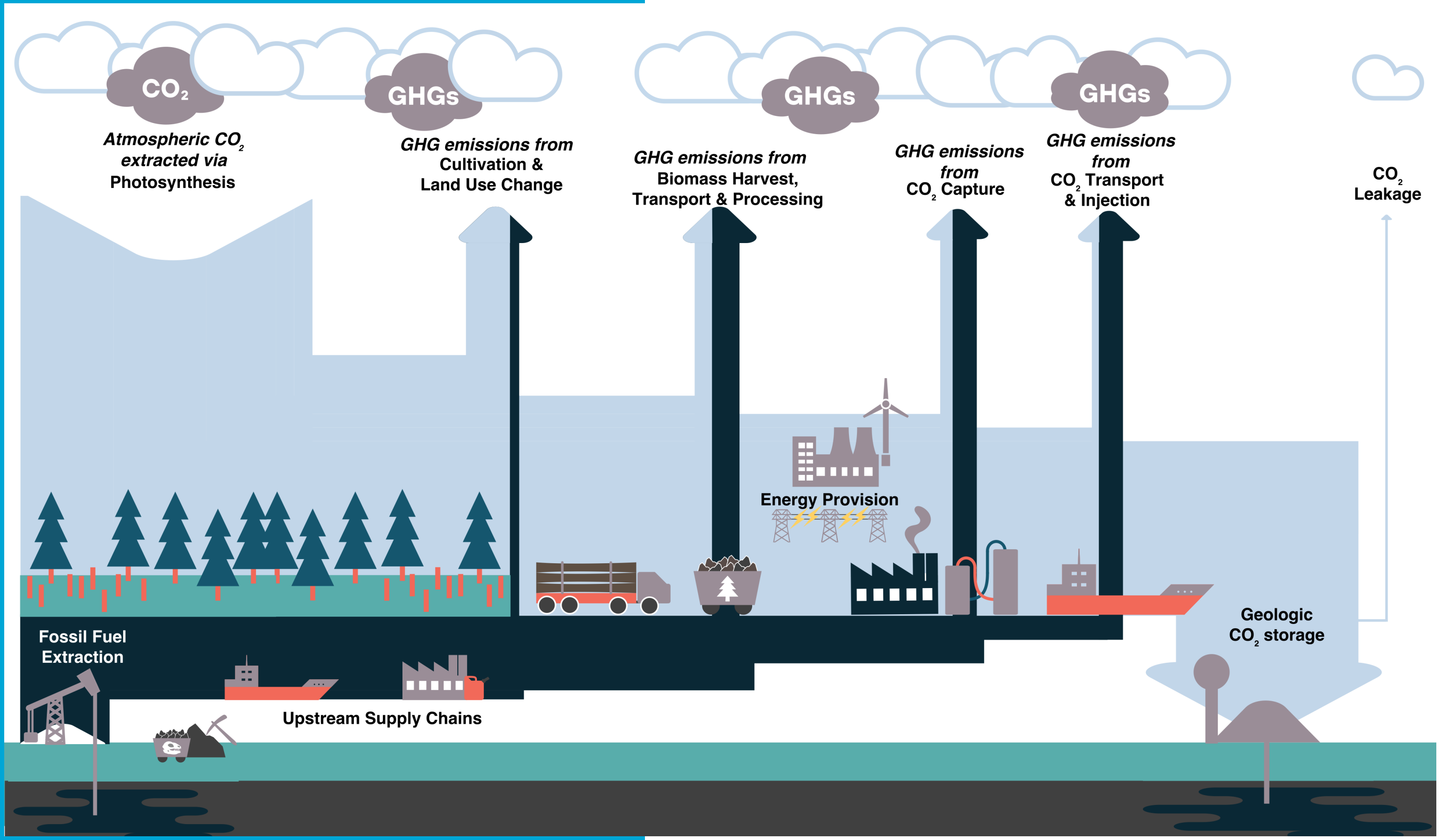
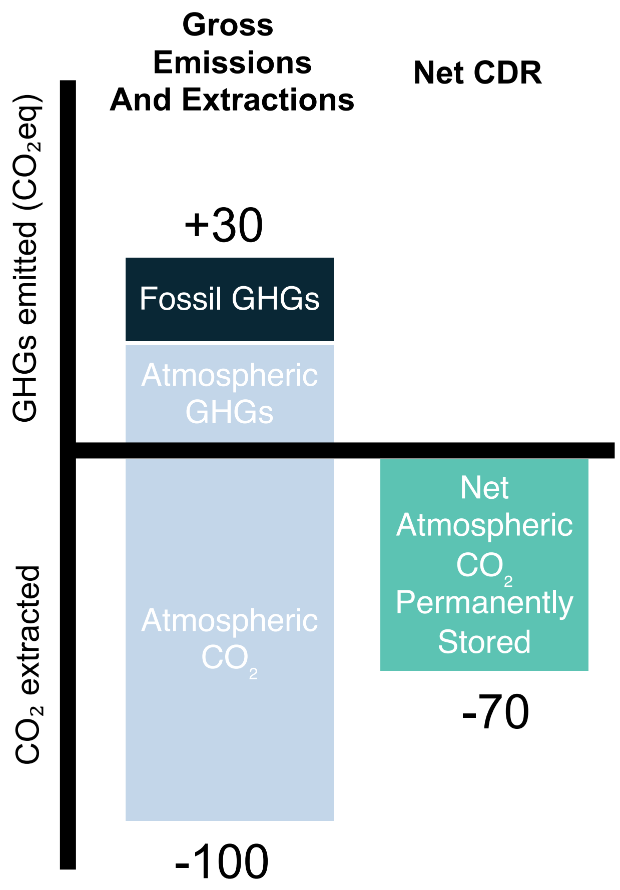
CDR requires knowing source, sink, *and* system





CDR requires knowing source, sink, *and* system

Energy & Environmental Science

ROYAL SOCIETY OF CHEMISTRY

PERSPECTIVE

Check for updates

Cite this: *Energy Environ. Sci.*, 2019, **12**, 1210

When are negative emissions negative emissions?†

Samantha Eleanor Tanzer * and Andrea Ramirez

Negative emission technologies (NETs) have seen a recent surge of interest in both academic and popular media and have been hailed as both a saviour and false idol of global warming mitigation. Proponents hope NETs can prevent or reverse catastrophic climate change by permanently removing greenhouse gases from the atmosphere. But there is currently limited agreement on what "negative emissions" are. This paper highlights inconsistencies in negative emission accounting in recent NET literature, focusing on the influence of system boundary selection. A quantified step-by-step example provides a clear picture of the impact of system boundary choices on the estimated emissions of a NET system. Finally, this paper proposes a checklist of minimum qualifications that a NET system and its emission accounting should be able to satisfy to determine if it could result in negative emissions.

Received 13th November 2018,
Accepted 20th February 2019

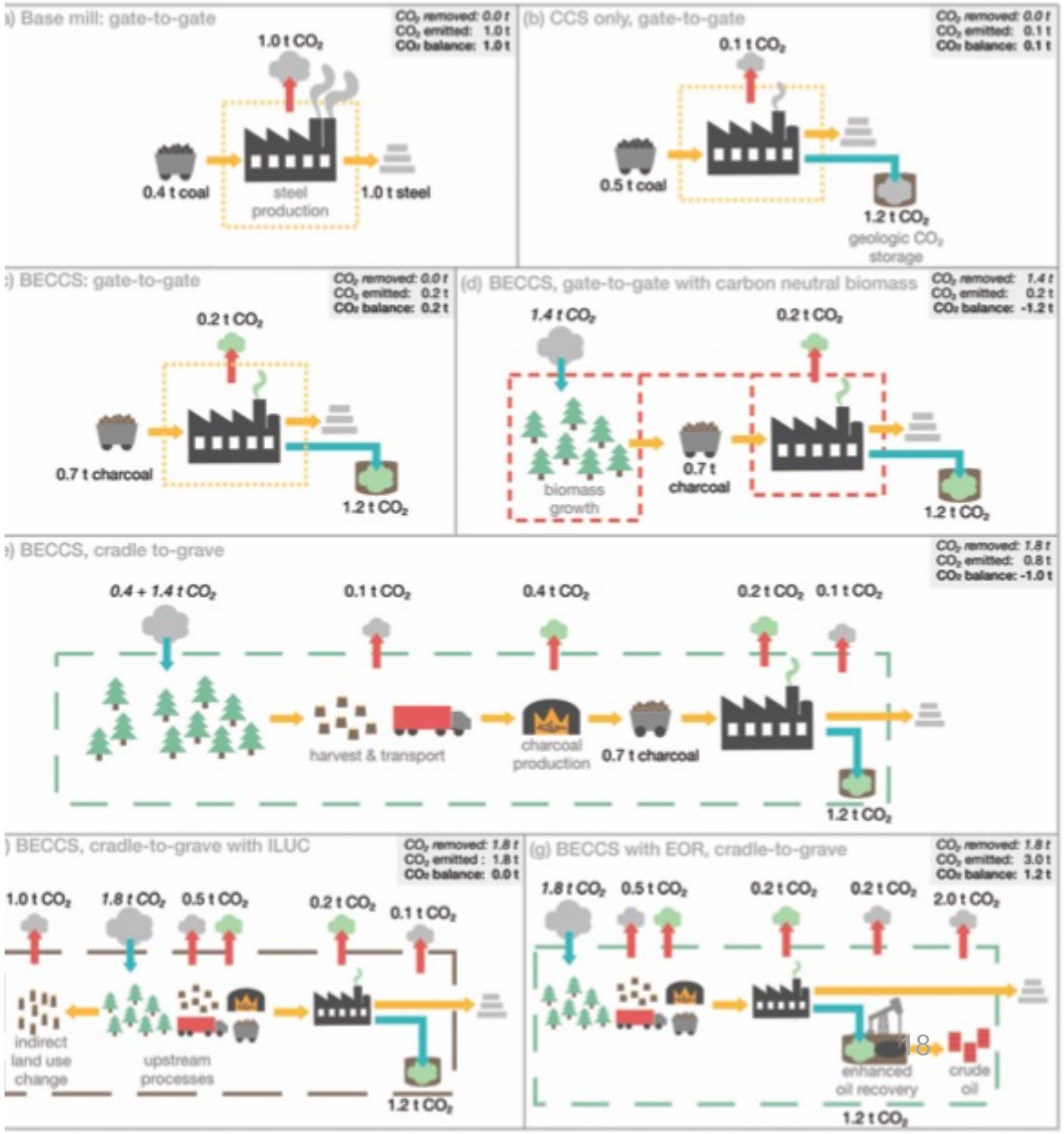
DOI: 10.1039/c8ee03338b

rsc.li/ees

Table 1 Summary of results from the literature review on the usage of the term "negative emissions"

Features of usage	Number of reviewed papers with feature	(% of total)
States that the goal of negative emissions[a] is to reduce global warming or the atmospheric concentration of greenhouse gases	199	(70%)
Provides an explicit definition of negative emissions[a] that includes:		
The removal of greenhouse gas from the atmosphere	143	(50%)
The storage of the removed gases	82	(29%)
And specifying permanent storage	58	(20%)
An accounting of greenhouse gas emissions to the atmosphere that result from the use of negative emission technology	5	(2%)
Uses the term negative emissions[a] to include:		
The capture and/or storage of non-atmospheric greenhouse gases (*e.g.* from the combustion of fossil fuels)	17	(6%)
Greenhouse gases that are explicitly re-emitted to the atmosphere	23	(9%)
Greenhouse gases that would be prevented from being emitted to the atmosphere when compared to a reference scenario (avoided emissions)[b]	16	(6%)

For the full article list with usage features marked per article, please refer to the ESI. [a] Including the alternate terms: "negative CO_2", "negative greenhouse gas", "CO_2 negative", and "carbon negative". [b] Including 11 of the 27 (41%) life cycle assessments papers that are in the literature review.

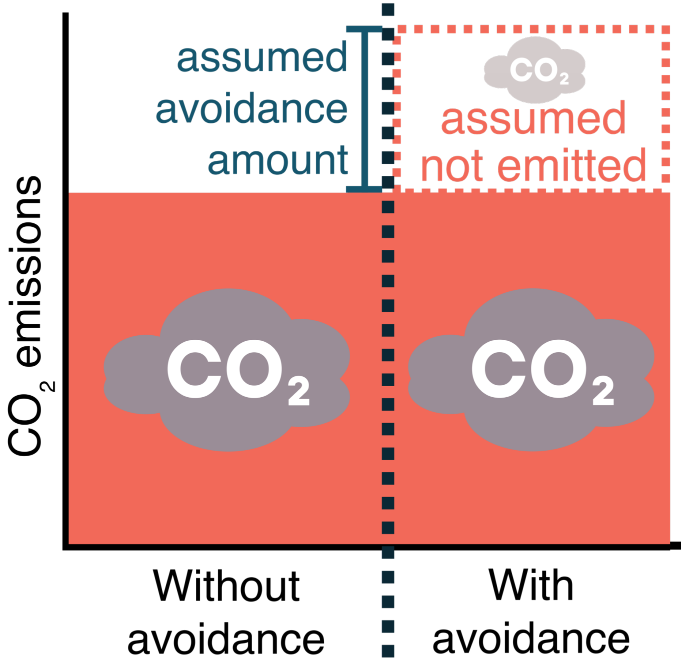


#4

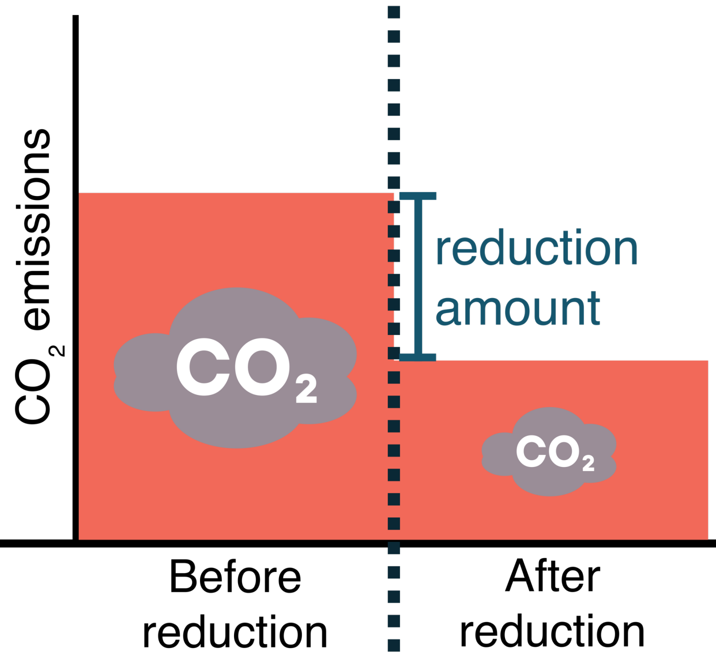
Adding together incommutable tonnes of CO_2eq

Three distinct types of climate action

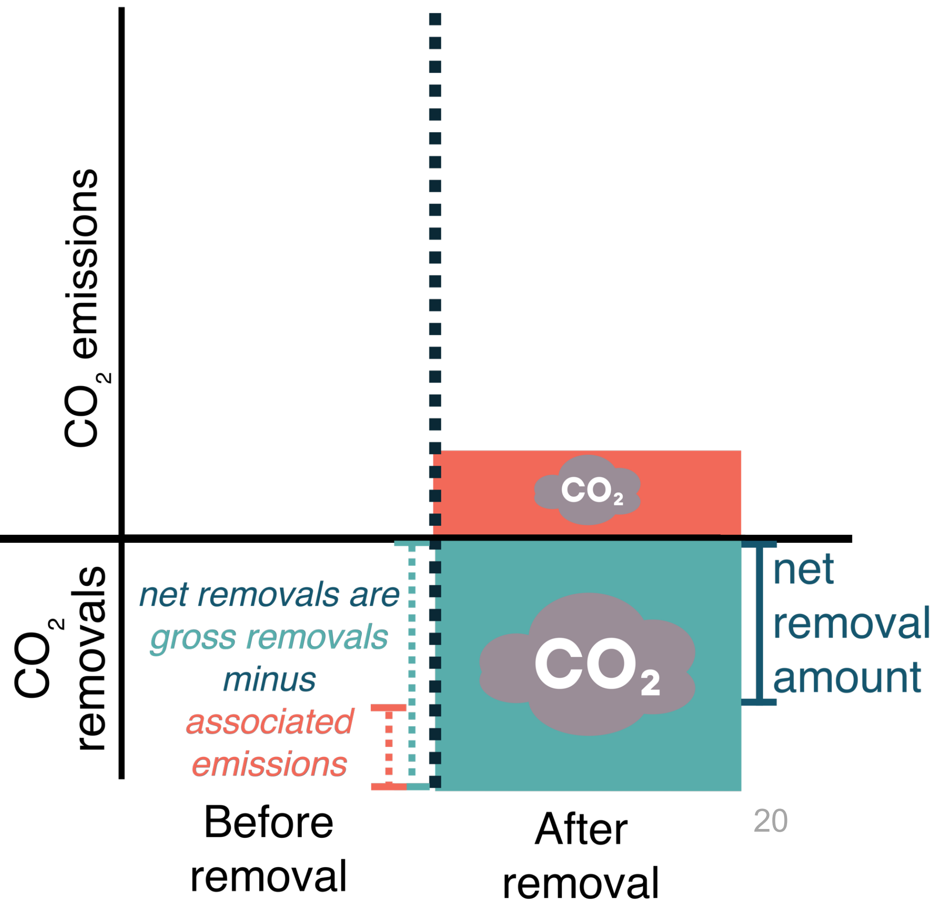
CO_2 Avoidance:
Emitting less CO_2 than an alternate scenario.



CO_2 Reduction:
Emtting less CO_2 than in the past.



CO_2 Removal:
Physically extracting and permanently storing CO_2 out of the atmosphere.



Source:
Bellona (2022) “The Carbon Credits Conundrum”
https://tiny.cc/bellona_ccc

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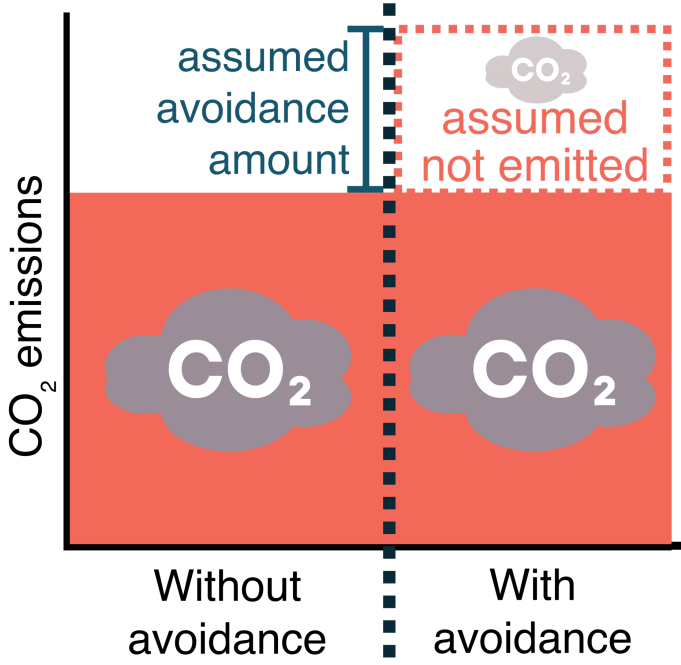
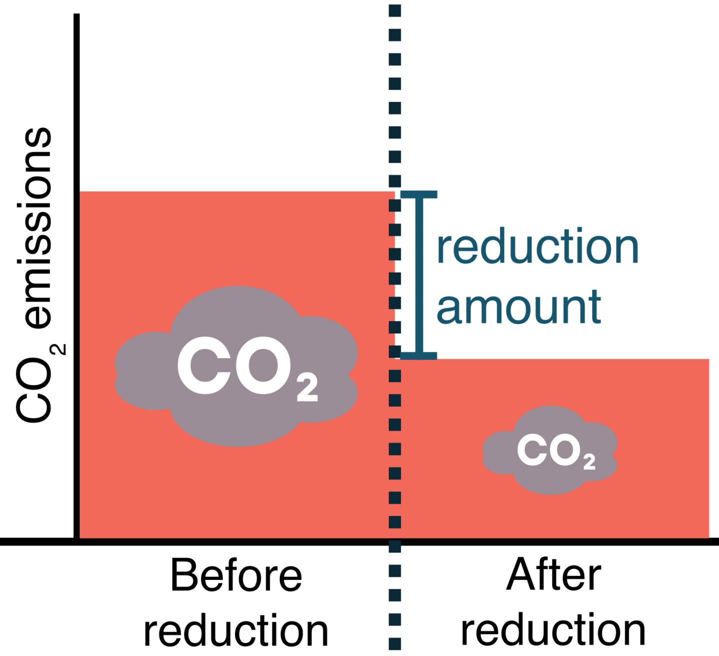
Three distinct types of results

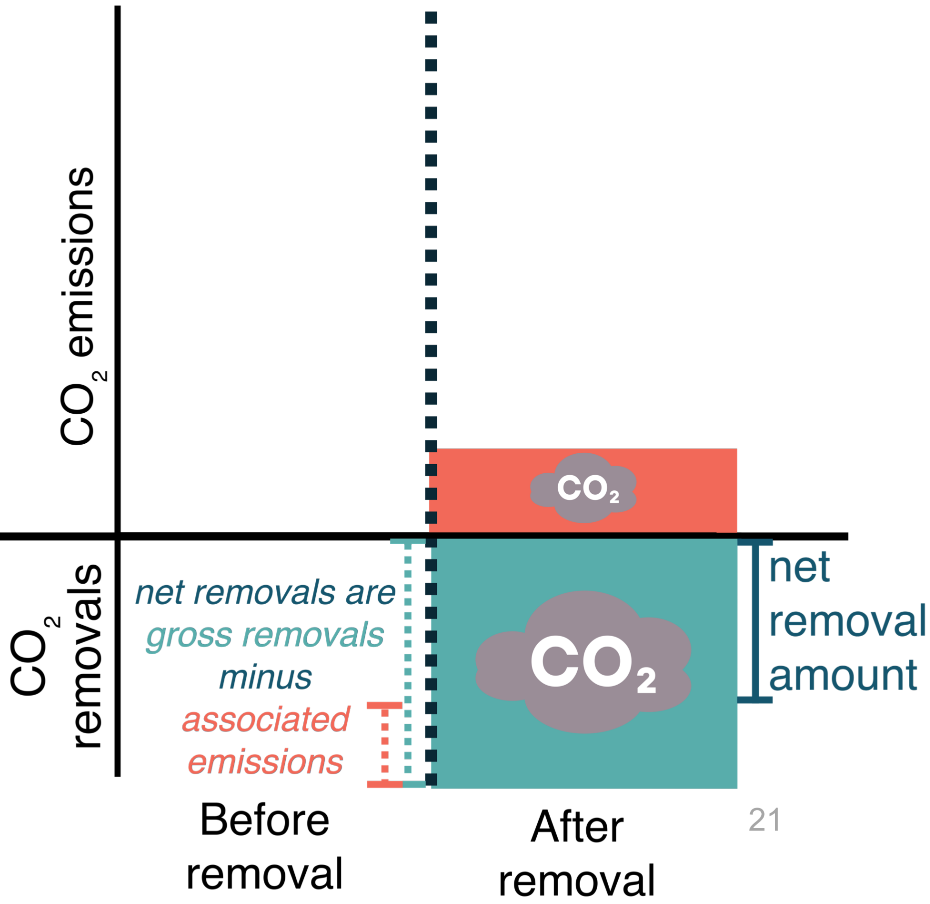
CO_2 Avoidance:
Atmospheric CO_2 doesn't increase even faster than it already is



CO_2 Reduction:
Atmospheric CO_2 increases less quickly than in the past (or even stops increasing)



CO_2 Removal:
Atmospheric CO_2 decreases



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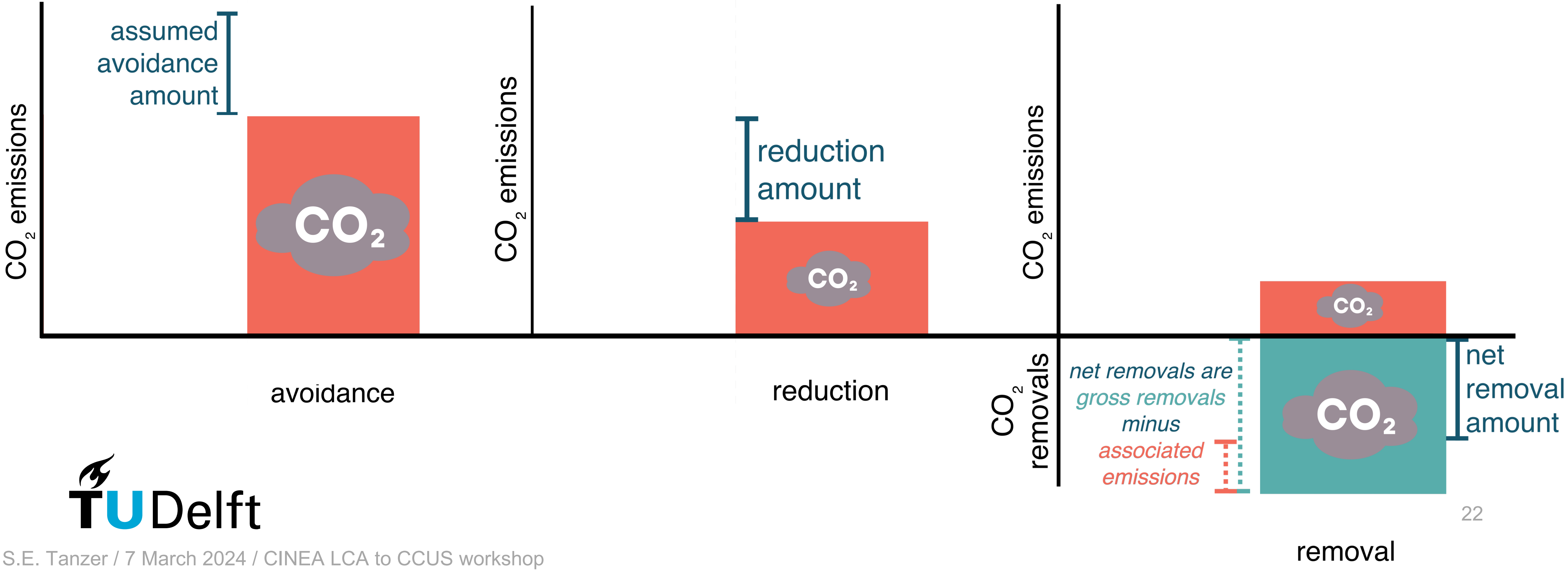
Three distinct units of measurement

CO_2 Avoidance measures a **non-emission** in *t CO_2 assumed to be avoided*

CO_2 Reduction measures a **non-emissions** in *t CO_2 less than before*

CO_2 Removal measures **net physical flows** in *t CO_2 removed from the atmosphere minus t CO_2 associated emissions*



Avoidance, reductions, and removals are **not commutable nor fungible**, no matter how tempting it is to add things counted in “tonnes of CO_2eq” together

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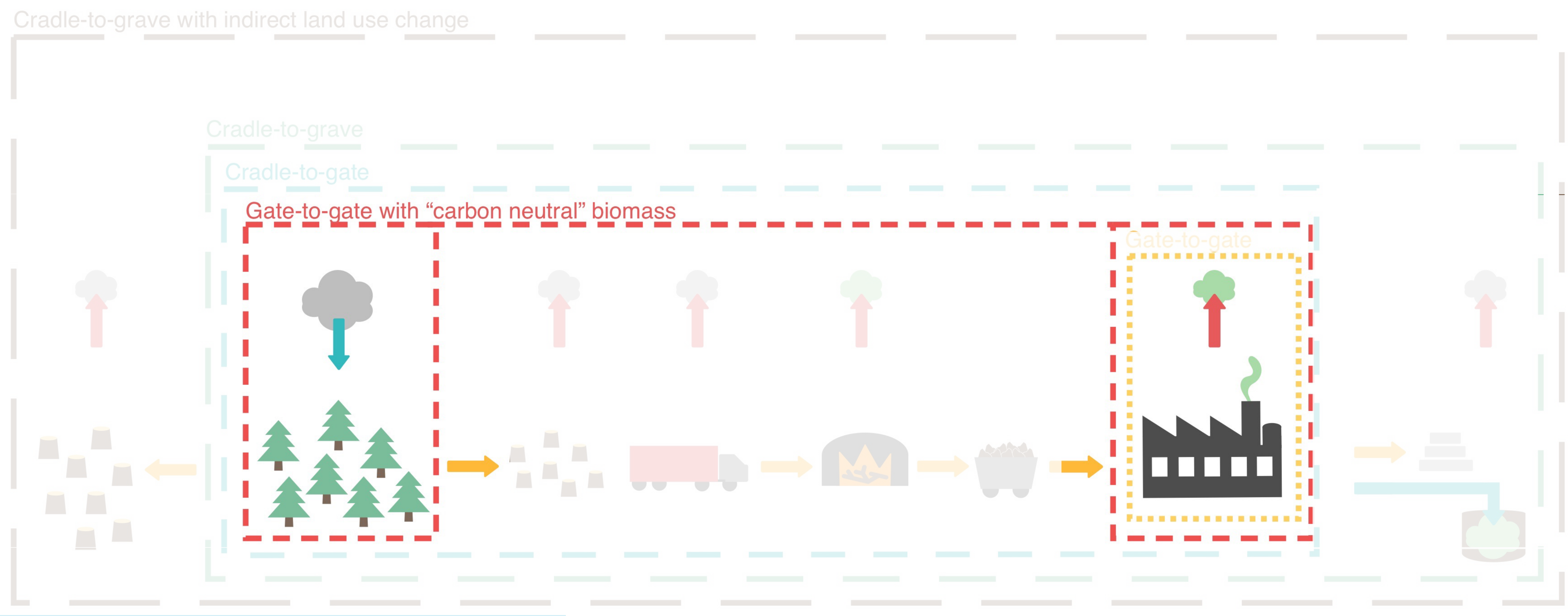
#5

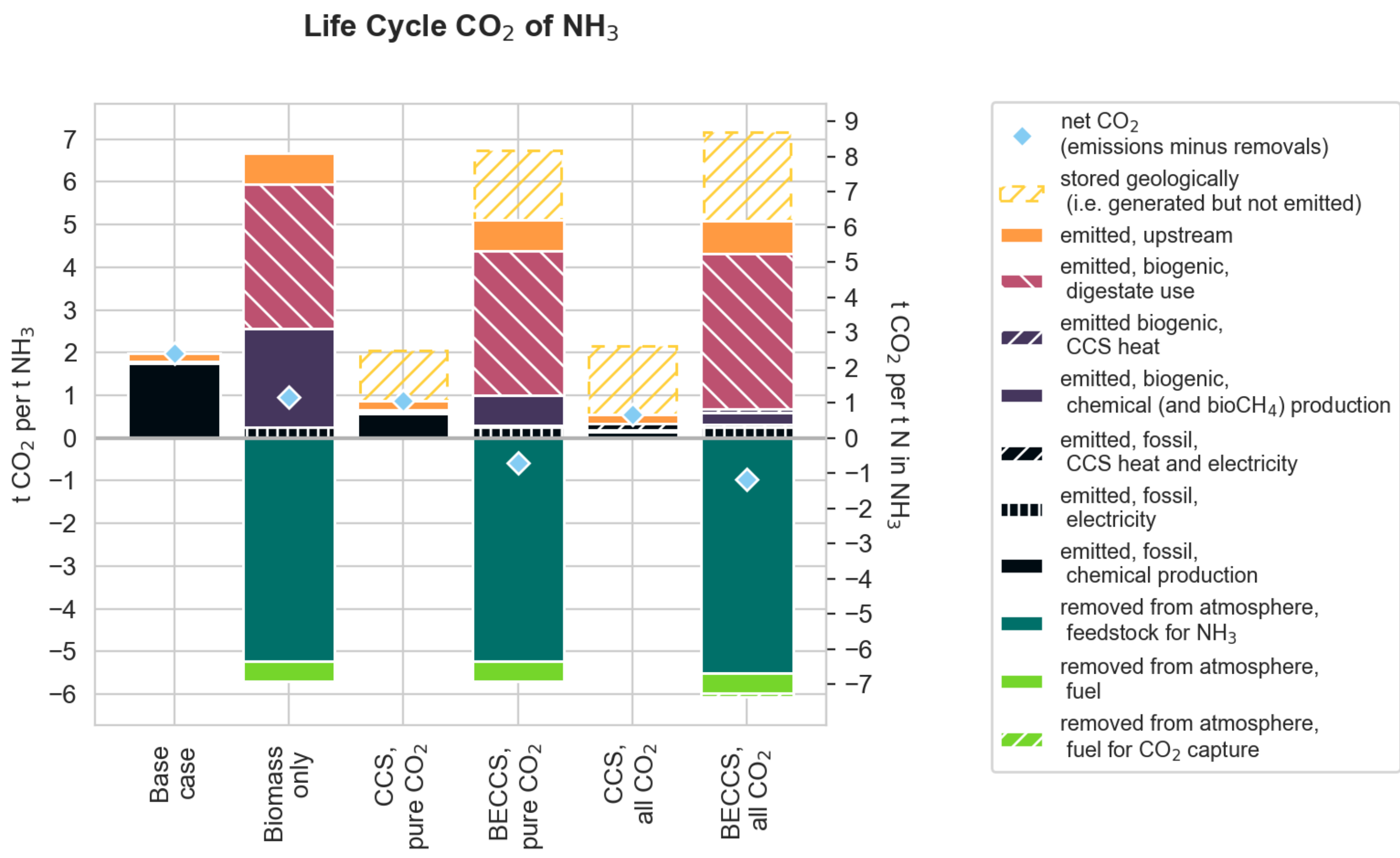
"Carbon neutral" biomass

the worst possible system boundary choice



“net zero CO_2” hides the carbon intensity of biomass

e.g., in this BioCCS study on ammonia, he use of biomass lowers the net CO_2 while tripling the amount of carbon in the system



Tanzer et al (2021) doi: 10.2139/ssrn.3819778

#6
Disregarding Temporality

Time matters.

- "Circular" CO_2 use still has (temporary) global warming impacts (both "sustainable" biogenic carbon and DAC CO_2)
- The background and reference systems will also change over time
- Availability of CO_2 waste streams will change over time
- Applications and demand of products will change over time
- Be critical of the age of your data and assumption sources
- Be critical of LCA's inherent temporal "flattening" and 100-year GWP default
  - LCA4CCU: if released within 500 years, counted as normal emission
  - Von der Assen et al (2013): 100-year cut off with adjusted GWPs for delayed emissions (10.1039/c3ee41151f)
  - Guest et al (2013): adjusted GWPs for temporary C-storage (10.1016/j.eiar.2013.05.002)
  - Tanzer et al (2021): 2-dimensional emission profiles (10.1039/D0FD00139B)

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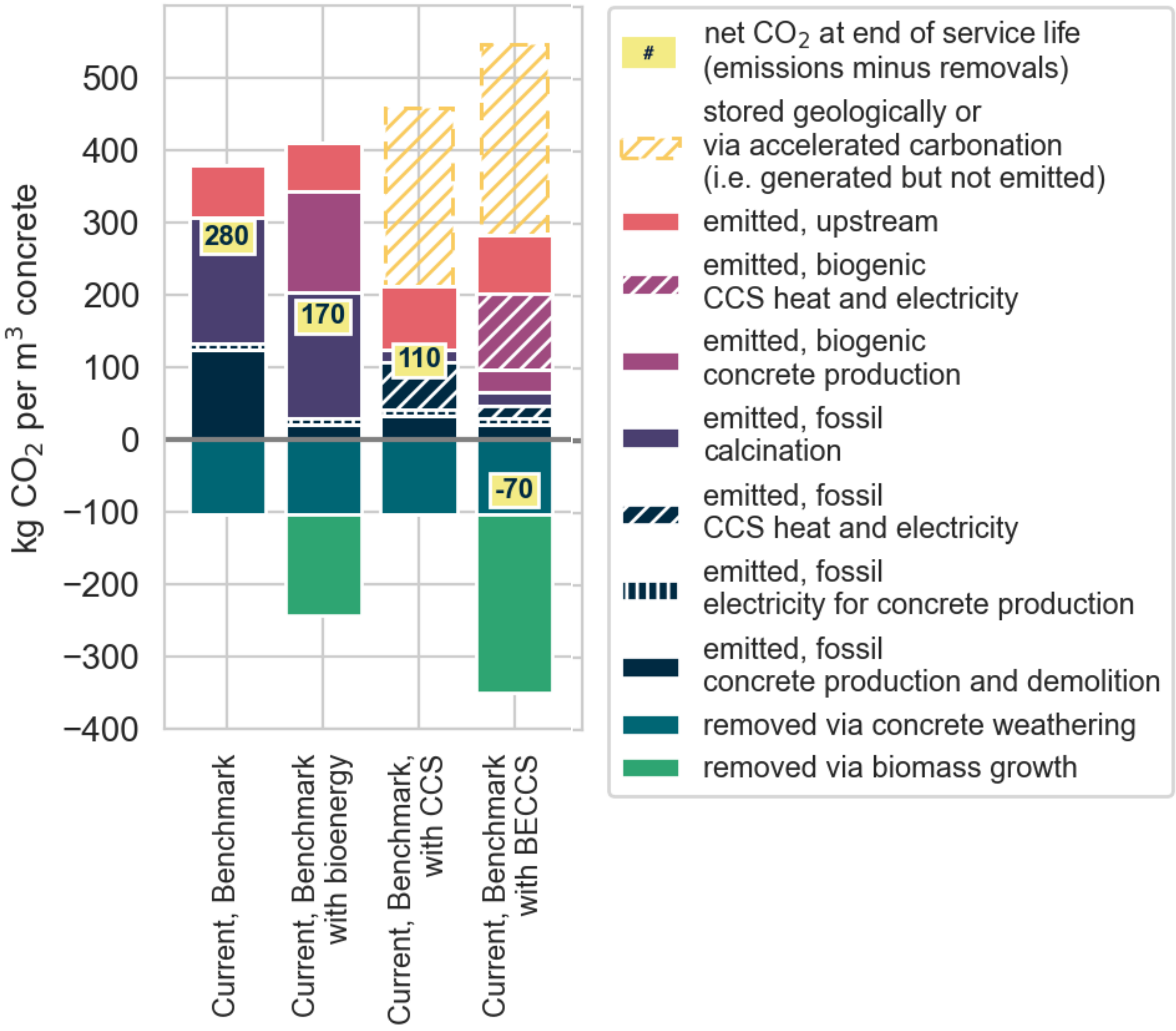
example: BECCS-in-concrete

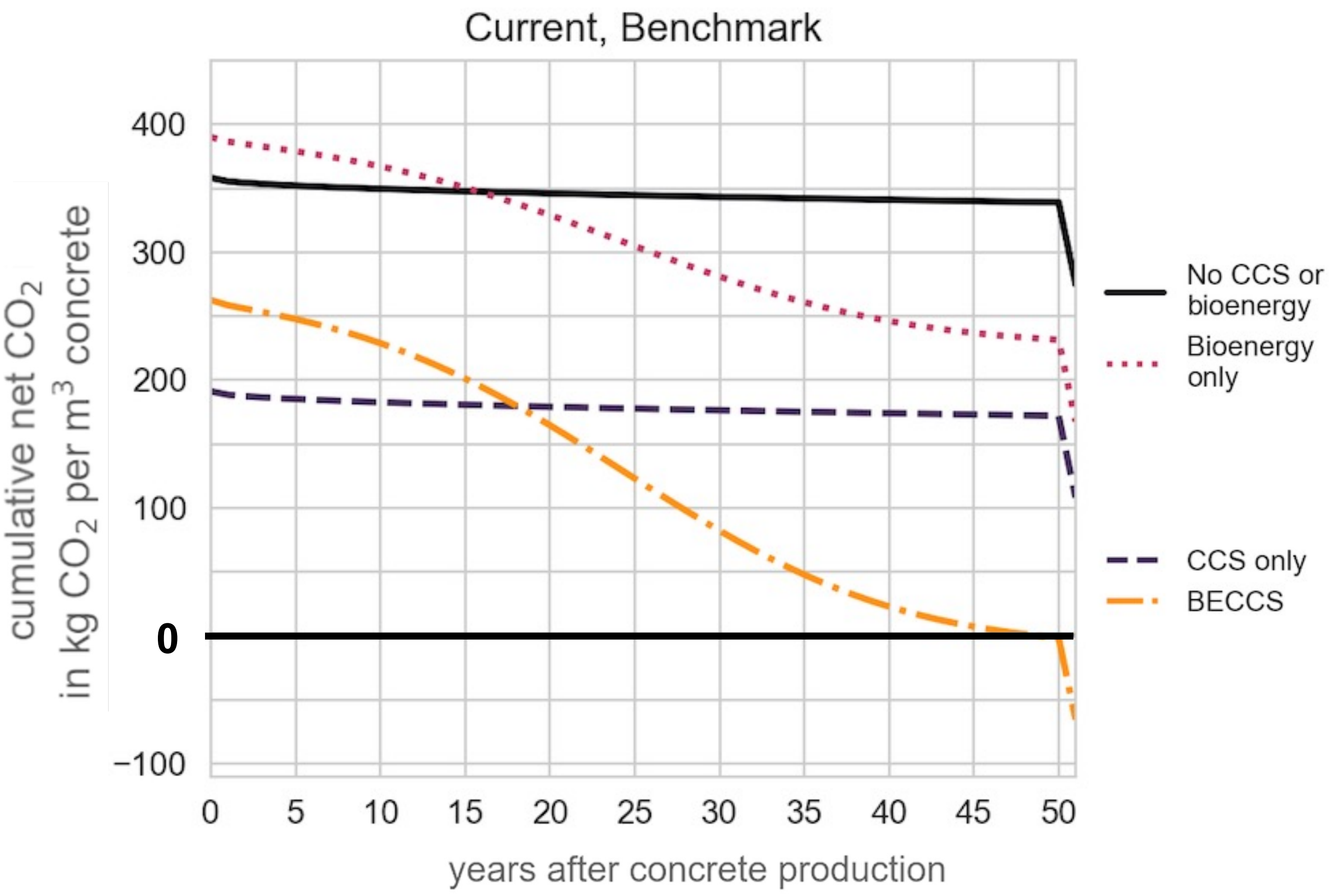
Standard Results:
single-point metric of
all impacts over time



Tanzer et al (2021) doi: 10.1039/D0FD00139B

example: BECCS-in-concrete

Temporally Explicit Results:
50-year time horizon
Includes biomass regrowth



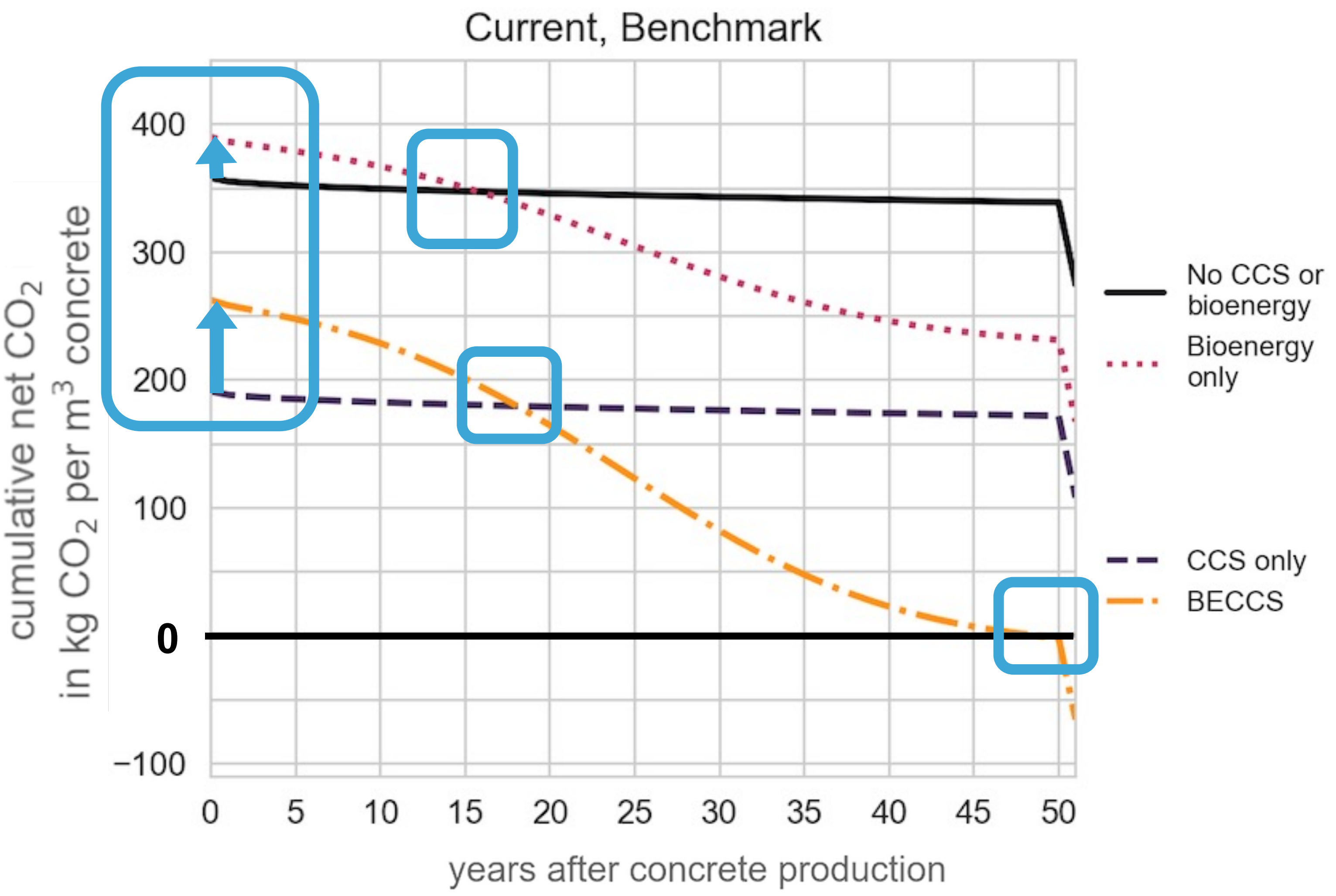
Tanzer et al (2021) doi: 10.1039/D0FD00139B

example: BECCS-in-concrete

Biofuels emit more carbon than fossil fuels…

…only reach carbon parity as the biomass starts to regrow….

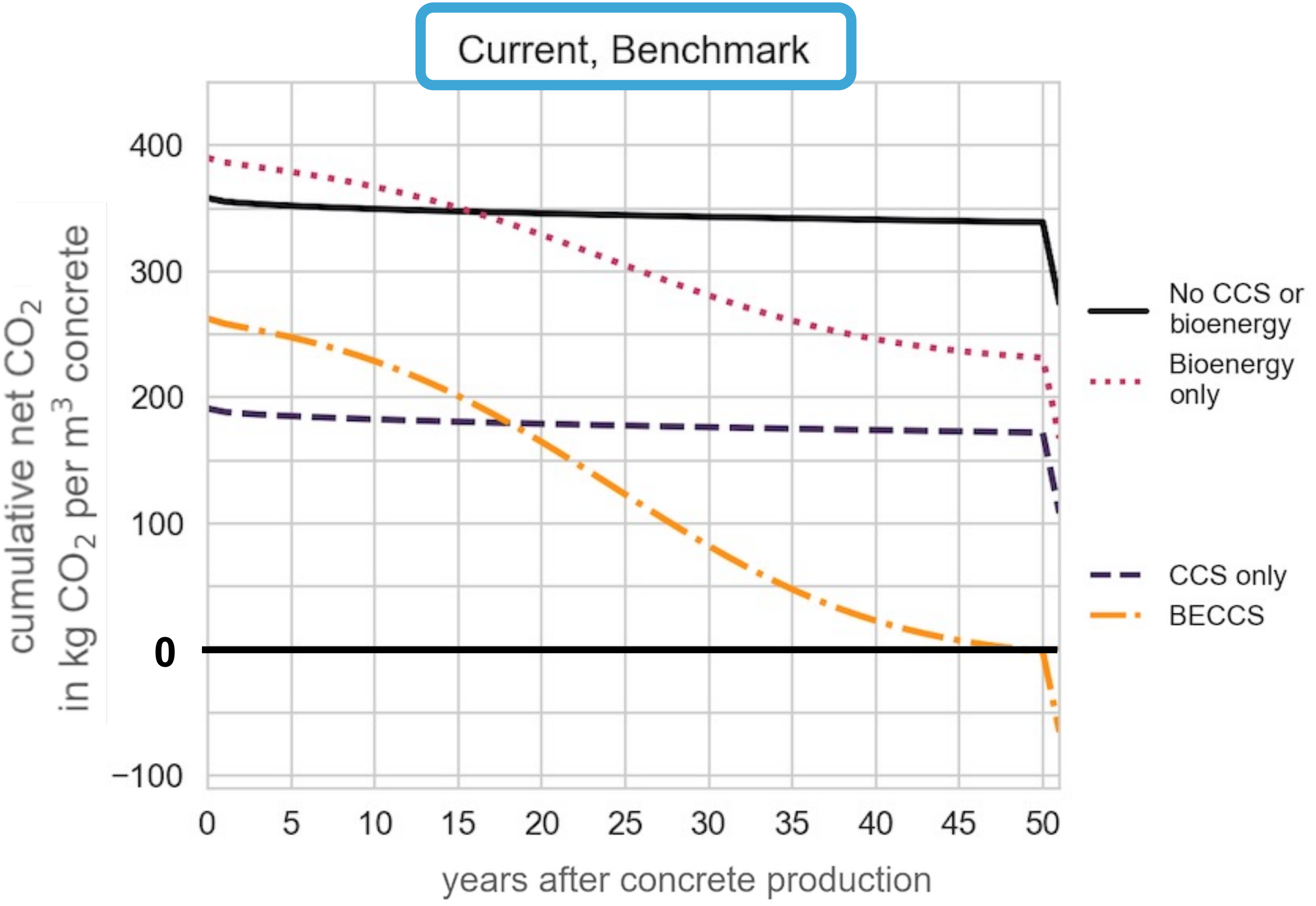
…and carbon neutrality after the full rotation period.



Tanzer et al (2021) doi: 10.1039/D0FD00139B

example: BECCS-in-concrete

The background system also changes over time



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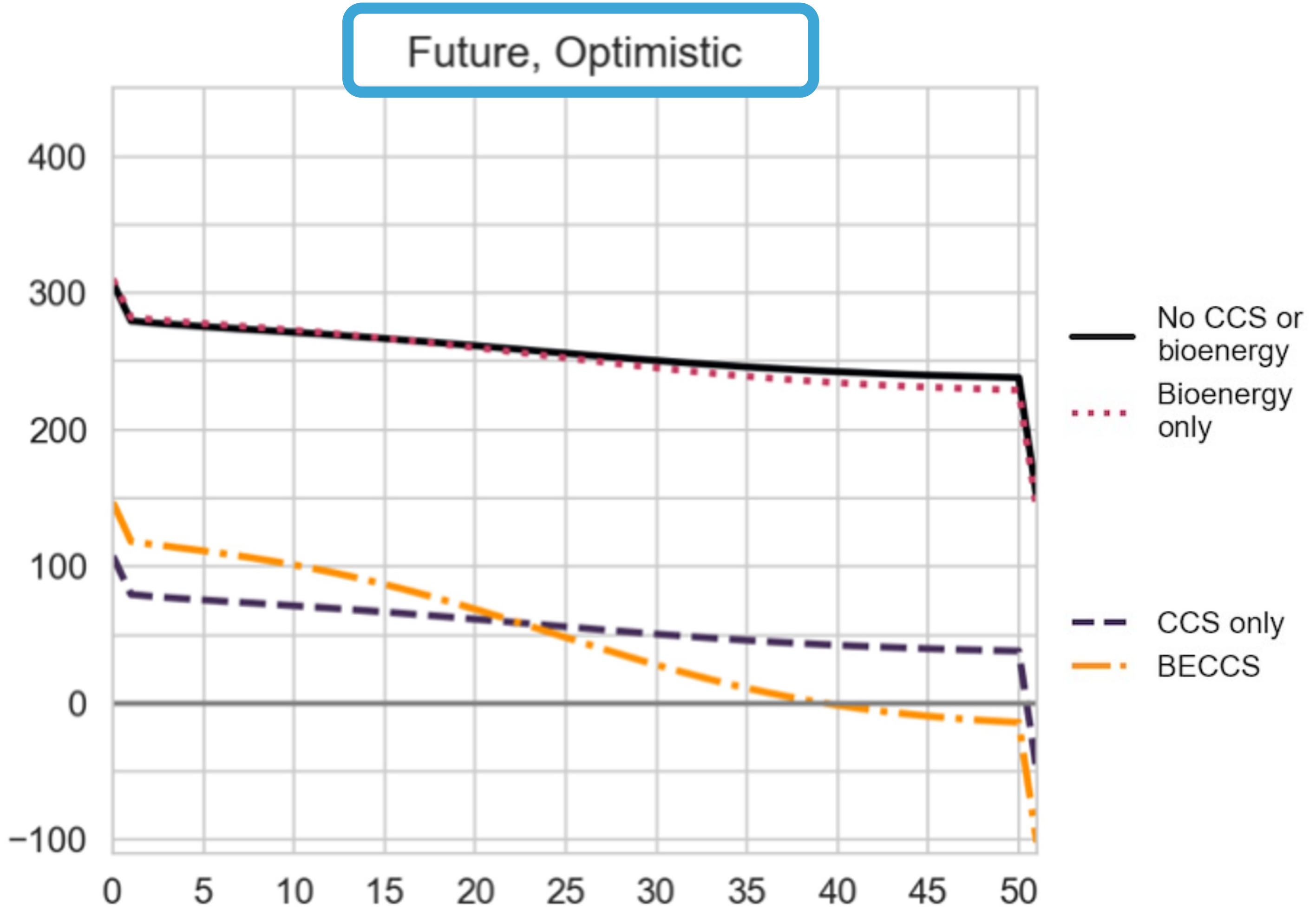
example: BECCS-in-concrete

which impacts the performance of both the potential technology system *and* the reference system



Tanzer et al (2021) doi: 10.1039/D0FD00139B

Avoid unintended time travelling – make sure your **temporal boundaries** are **defined** and **aligned**.

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So, in short…

- Follow your carbon from **source to sink**.
- Be **explicit**, especially for
  - system boundaries
  - temporal alignment
- Don’t **overaggregate**.
  - Avoidance ≠ Reduction ≠ Removal
  - Don’t rely only on net metrics
- Don’t **overclaim**.
  - Be true to your boundaries, data quality, and assumptions.

Thank you for your attention

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