GGR: permanence and efficiency

Niall Mac Dowell

Imperial College London

niall@imperial.ac.uk

@niallmacdowell

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Research and analysis

Monitoring, reporting and verification of greenhouse gas removals (GGRs): Task and Finish Group report

Academic and industry recommendations on how the government should approach the monitoring, reporting and verification of negative emissions resulting from various greenhouse gas removal (GGR) methods.

From: **Department for Business, Energy & Industrial Strategy**
Published 19 October 2021

Documents

Monitoring, reporting and verification of greenhouse gas removals - Task and Finish Group report

PDF, 1.45MB, 33 pages

Related content

Greenhouse gas removal methods: technology assessment report

Investable commercial frameworks for 'power-BECCS'

Net Zero Research and Innovation Framework

https://www.gov.uk/government/publications/monitoring-reporting-and-verification-of-ggrs-task-and-finish-group-report

Contributors

The Department for Business, Energy and Industrial Strategy

- Niall Mac Dowell - Expert Policy Advisor – GGR & CCUS - Chair
- Laura Hurley - Head of Greenhouse Gas Removals
- Sam Bradley - Science Advisor, Climate Science – GGR
- Pierre Brender - Science Advisor, Climate Science – LULUCF
- Jonathan Baker-Brian - Senior Policy Advisor – Clean Electricity
- Luke Jones - Senior Policy Advisor – GGR
- Celine Turner - Policy Advisor – GGR

The Department for the Environment, Food and Rural Affairs

- Florence Benn - Senior Climate Science Advisor

Her Majesty's Treasury

- Julie Sorensen - Senior Policy Advisor
- Alix Green - Policy Advisor

External to Her Majesty's Government

- Luke Warren – Chief Executive, Carbon Capture and Storage Association
- Jonathan Scurlock - Chief Adviser, Renewable Energy and Climate Change, National Farmers Union
- Katie Sullivan – Managing Director, International Emissions Trading Association
- Dalia Majumder-Russell – Partner, CMS Cameron McKenna Nabarro Olswang LLP
- Francis Sullivan - Corporate Sustainability Advisor, HSBC
- Stuart Haszeldine – Professor of Carbon Capture and Storage, University of Edinburgh
- David Reiner – Senior Lecturer in Technology Policy, University of Cambridge
- Peter Vis – Senior Research Associate, European University Institute
- Tim Dixon - Director and General Manager, IEA Greenhouse Gas R&D Programme
- Olivia Powis - Head of UK Office, Carbon Capture and Storage Association
- Danial Sturge - Carbon Policy Practice Manager, Energy Systems Catapult

What follows is just Niall's opinion

What is GGR?

1. Carbon dioxide is physically removed from the atmosphere.
2. The removed carbon dioxide is stored out of the atmosphere in a manner intended to be permanent.
3. Upstream and downstream greenhouse gas emissions, associated with the removal and storage process, are comprehensively estimated and included in the emission balance.
4. The total quantity of atmospheric CO_2 removed and permanently stored is greater than the total quantity of CO_2 emitted to the atmosphere.

ZEP, "Europe needs a definition of carbon dioxide removal", 2020

What is GGR?

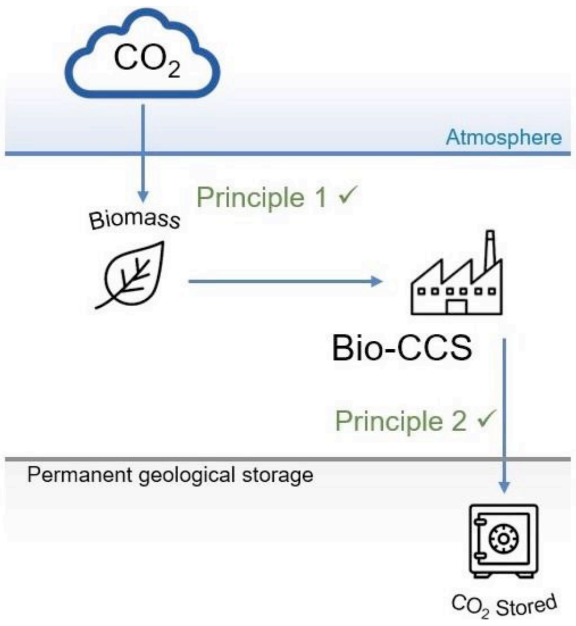
In order to “do” GGR, we need to know:

1. When CO_2 removal starts,
2. How much CO_2 gets removed, at what rate, and for how long,
3. When the project gets concluded.

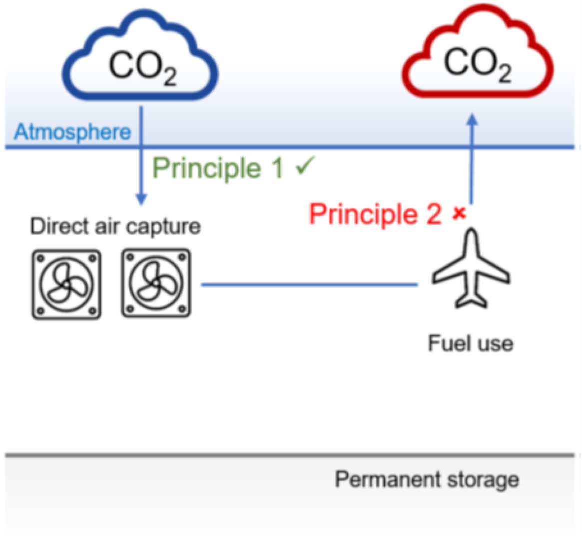
This requires

1. Thorough up- and down-stream lifecycle analysis to identify, and quantify, potential sources of carbon leakage across the GGR value chain.
2. Baselining background carbon/carbon dioxide levels – this will necessarily vary depending on the GGR approach employed.
3. Developing project completion and abandonment protocols and MRV plan (to be potentially revised and updated as the project progresses).

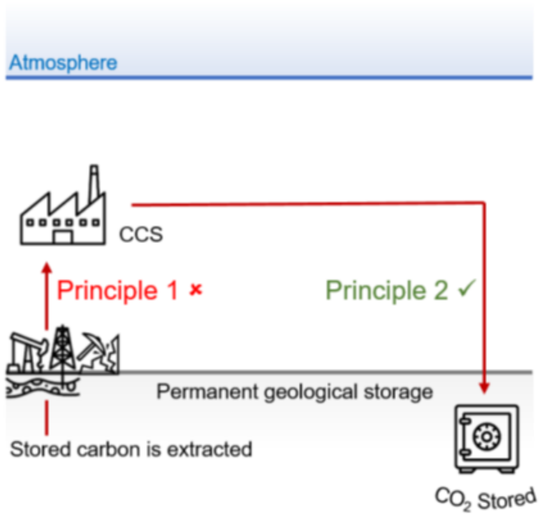
What is GGR?



Removing CO_2



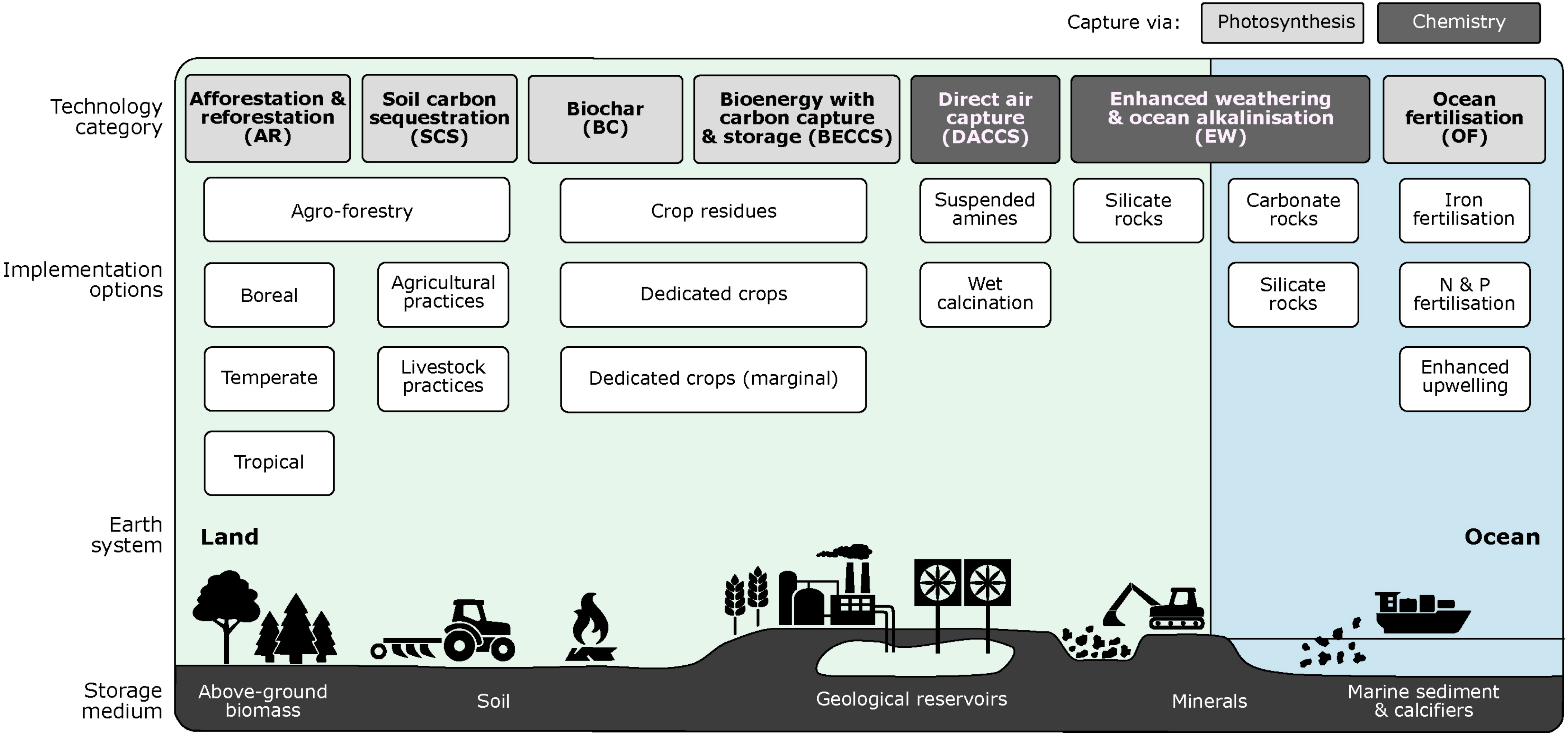
Using CO_2



Avoiding CO_2

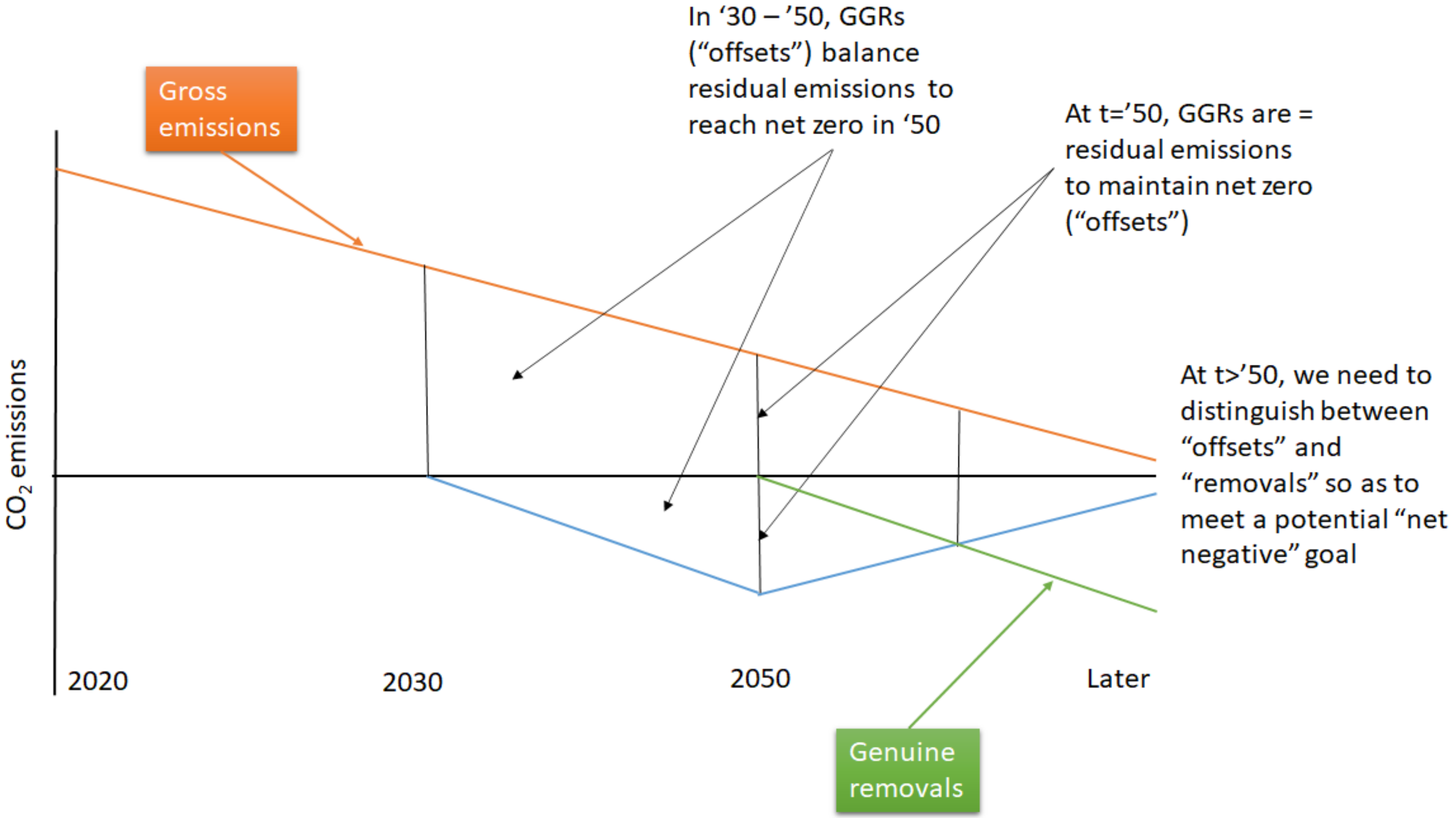
ZEP, "Europe needs a definition of carbon dioxide removal", 2020

What is GGR?

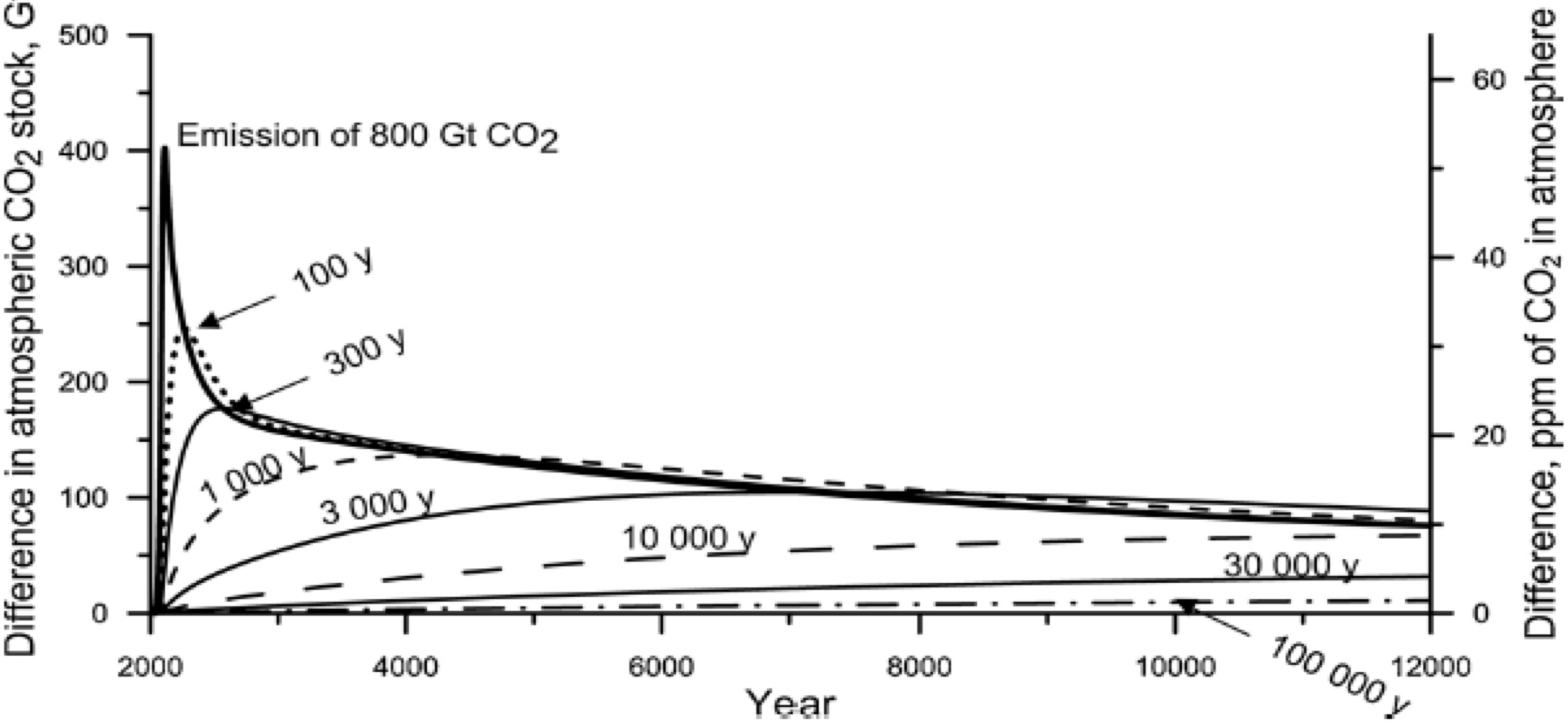


Minx *et al*, Environ. Res. Lett., 2018

Need to distinguish between “offsets” and “removals”

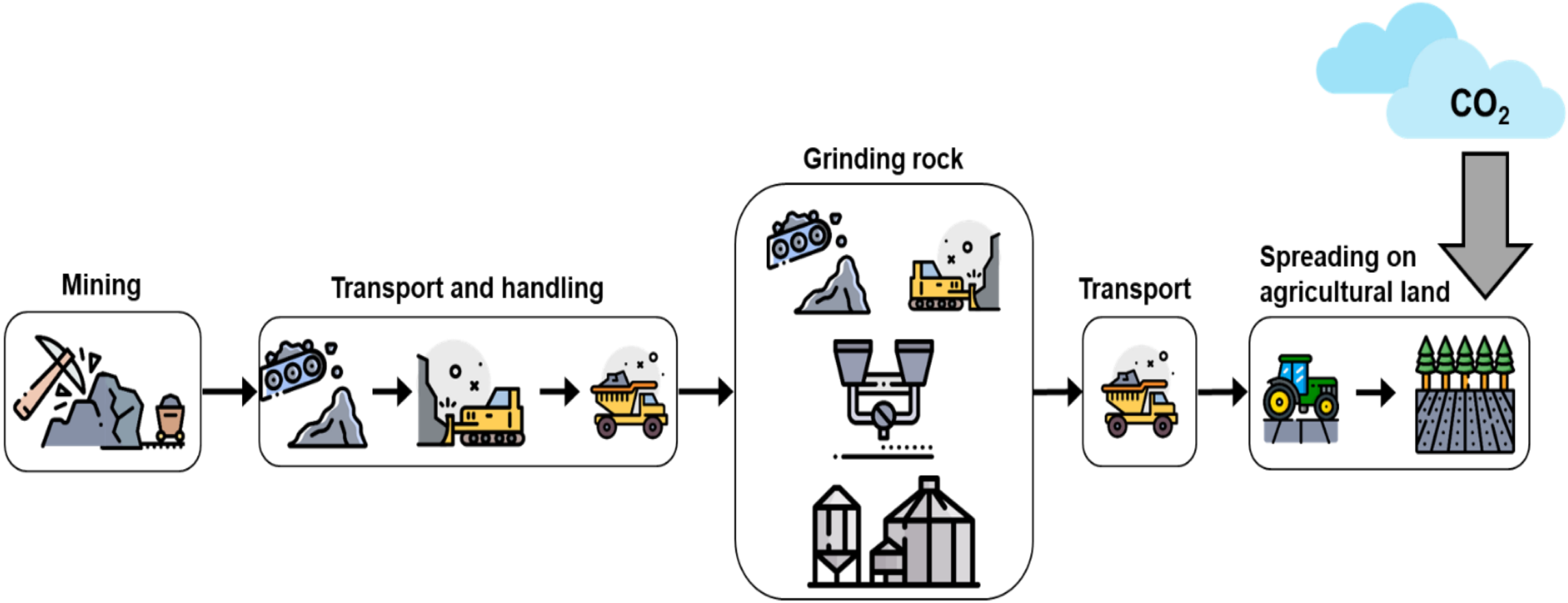


Temporary removals do not solve this problem

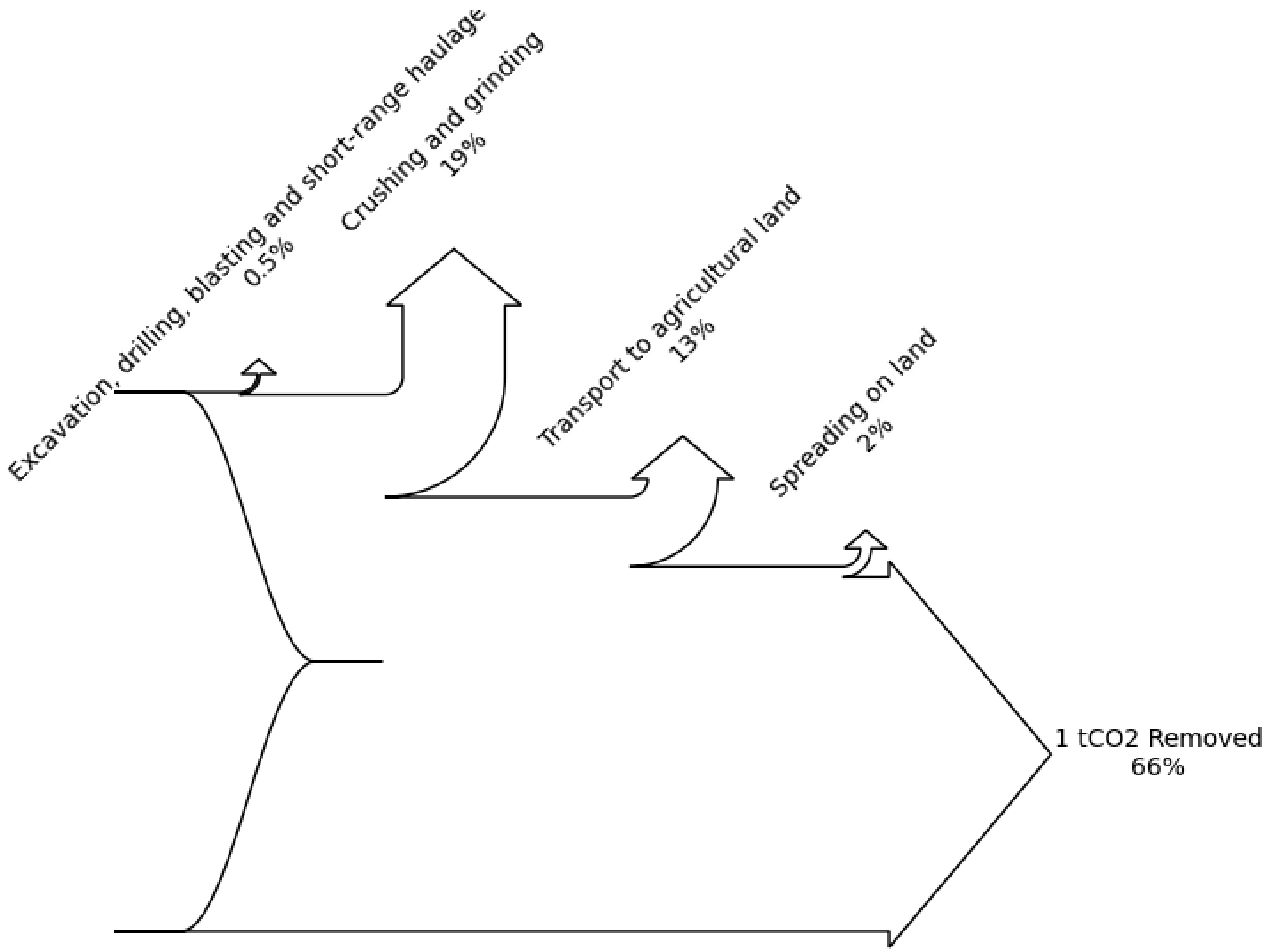


Lyngfelt, et al., Int J GHG Con, 2019

Enhanced Weathering



Enhanced Weathering



Illustrative carbon efficiency of passive enhanced weathering process. Here it is assumed that the mineral material is available in the UK. It can be observed that the primary sources of carbon leakage are the energy required for mineral size reduction, transport, and spreading on land. Calculation performed with the MONET Framework.

Enhanced Weathering

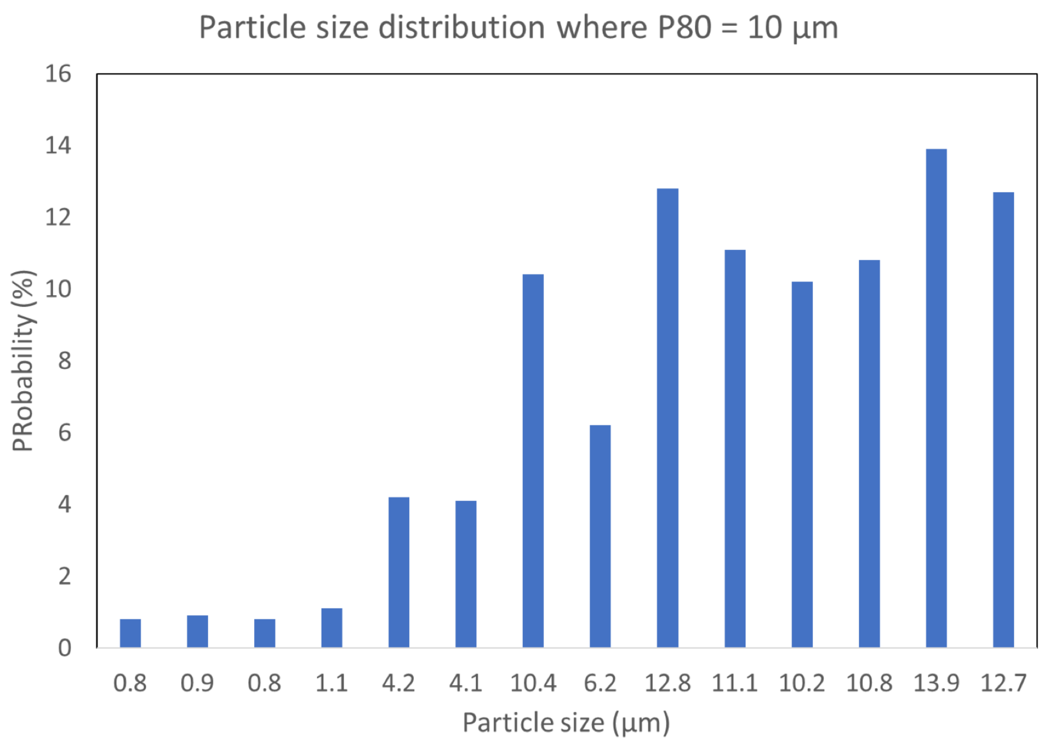
- Recall; this process involves exposing pulverised rock to the atmosphere, and waiting for it to carbonate
- This carbonation reaction, C_R, can be described via the “shrinking core” model, and proceeds as a function of soil pH, soil temperature, soil hydrology and crop net primary productivity….

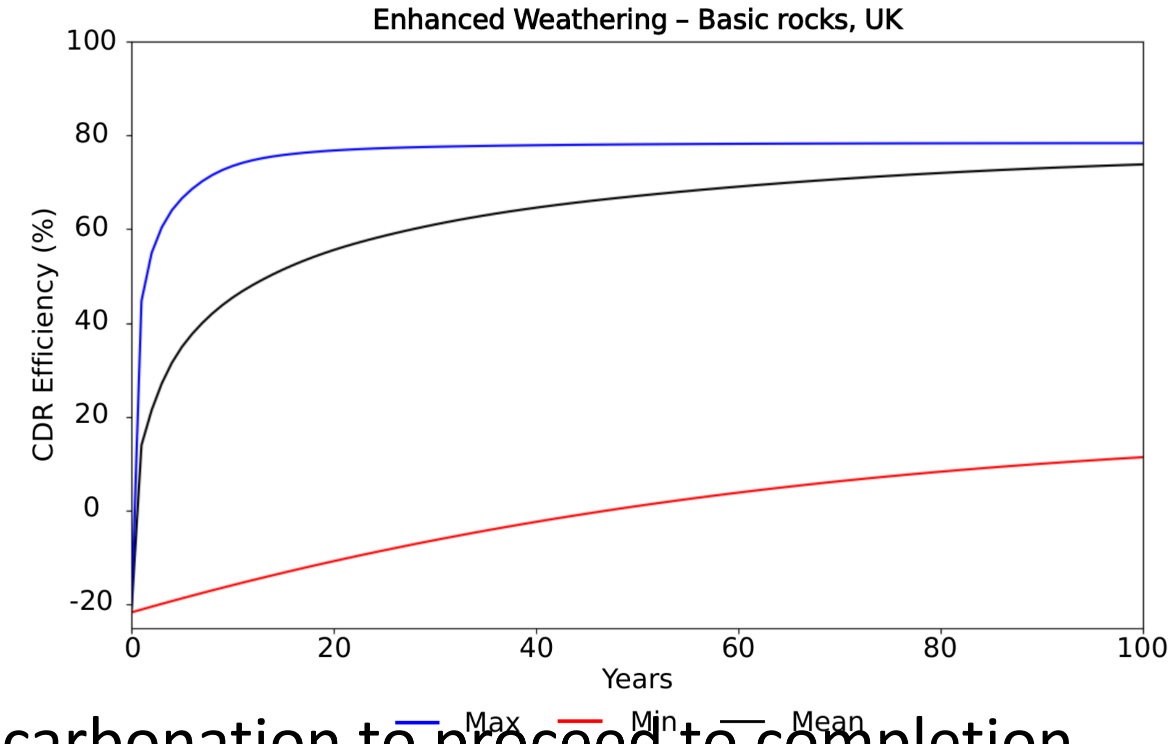
$$C_R(x,t) = \frac{x^3 - (x - 2W_R V_M t)^3}{x^3}$$

$$W_R = \sum_i k_i \exp\left[\frac{-E_i}{R}\left(\frac{1}{T} - \frac{1}{298.15}\right)\right] a_j^{n_i}$$

- Key point: carbon removal is not coincident with application

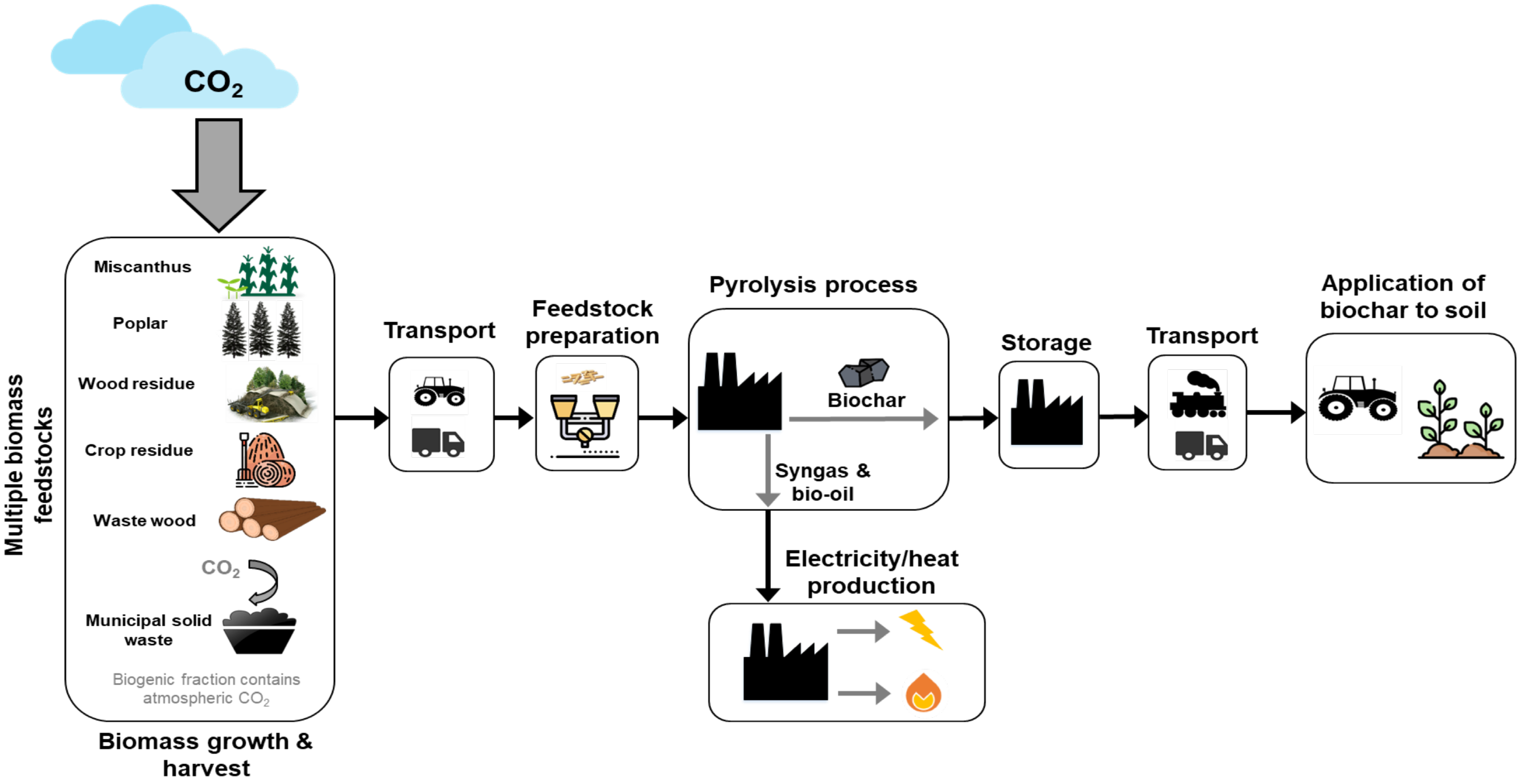
Carbonation is not an instantaneous process…





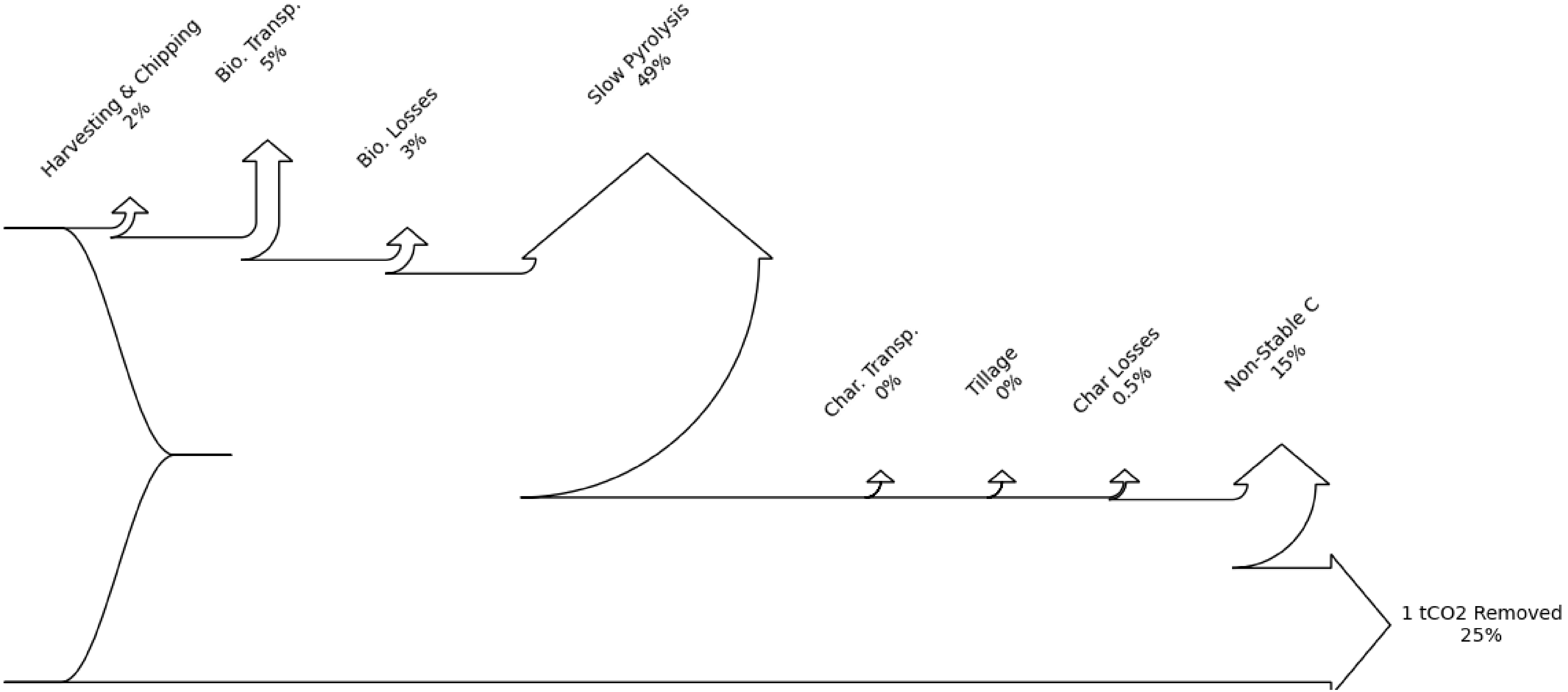
- It may take a significant period for carbonation to proceed to completion
- What does this mean for project economics?

Biochar



CO_2
Multiple biomass feedstocks
Miscanthus
Poplar
Wood residue
Crop residue
Waste wood
CO_2
Municipal solid waste
Biogenic fraction contains atmospheric CO_2
Biomass growth & harvest
Transport
Feedstock preparation
Pyrolysis process
Biochar
Syngas & bio-oil
Electricity/heat production
Storage
Transport
Application of biochar to soil

Biochar



Illustrative carbon removal efficiency diagram for biochar application in the UK using forest residue from Scotland with char application in the midlands. Calculation performed with the MONET Framework.

Think next about biochar…

- Biochar degrades with time

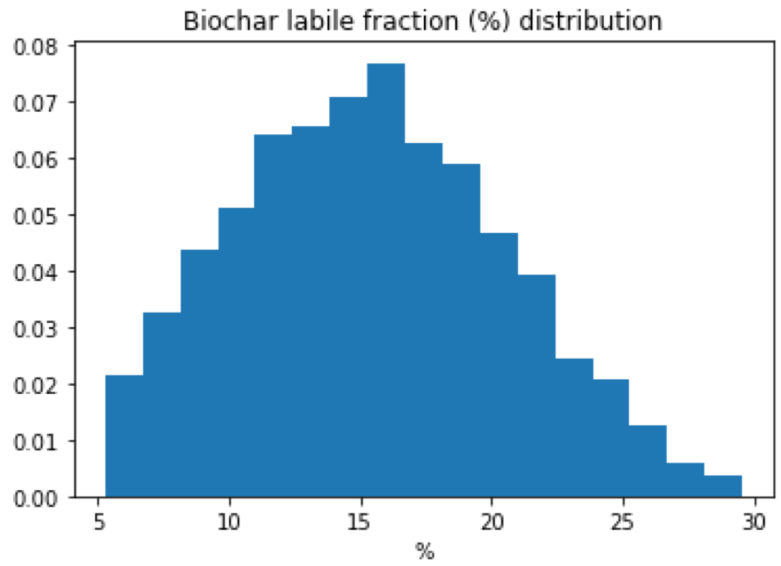
$$DR(t) = L\ exp\left(-\frac{\ln(2)}{t_{1/2L}}t\right) + R\ exp\left(-\frac{\ln(2)}{t_{1/2R}}t\right)$$

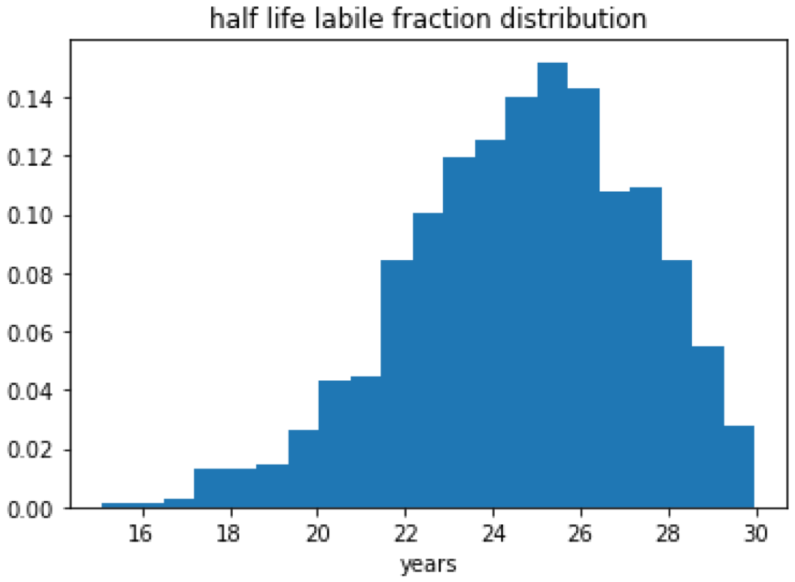
- where:
  - L is the labile fraction of biochar (mean: 15, range: [5–30]%),
  - R = 1-L is the recalcitrant fraction of biochar (mean: 85, range: [70–95]%),
  - t1/2L is the labile half-time (mean: 20, range: [1–30] years),
  - t1/2R is the recalcitrant half-time (mean: 300, range: [50–1,000] years),

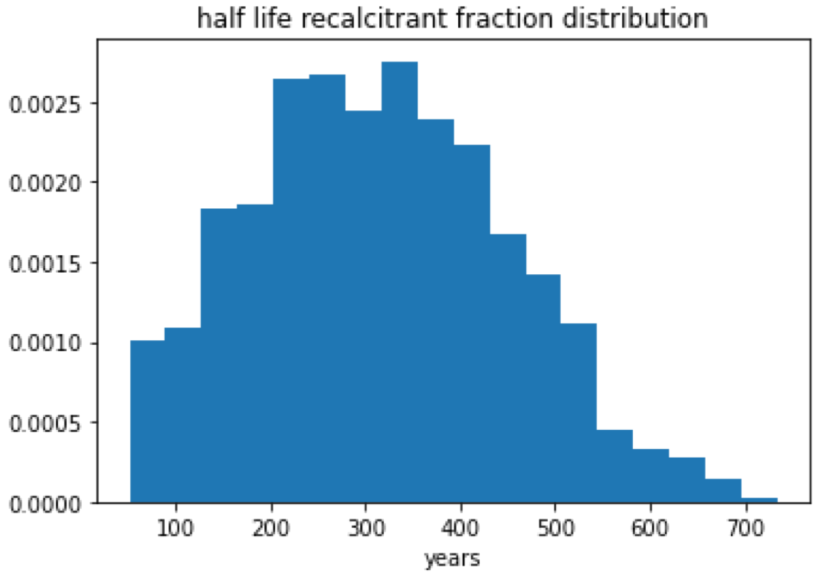
How long does biochar "last"..?

- This is a natural process – there is no "one answer"

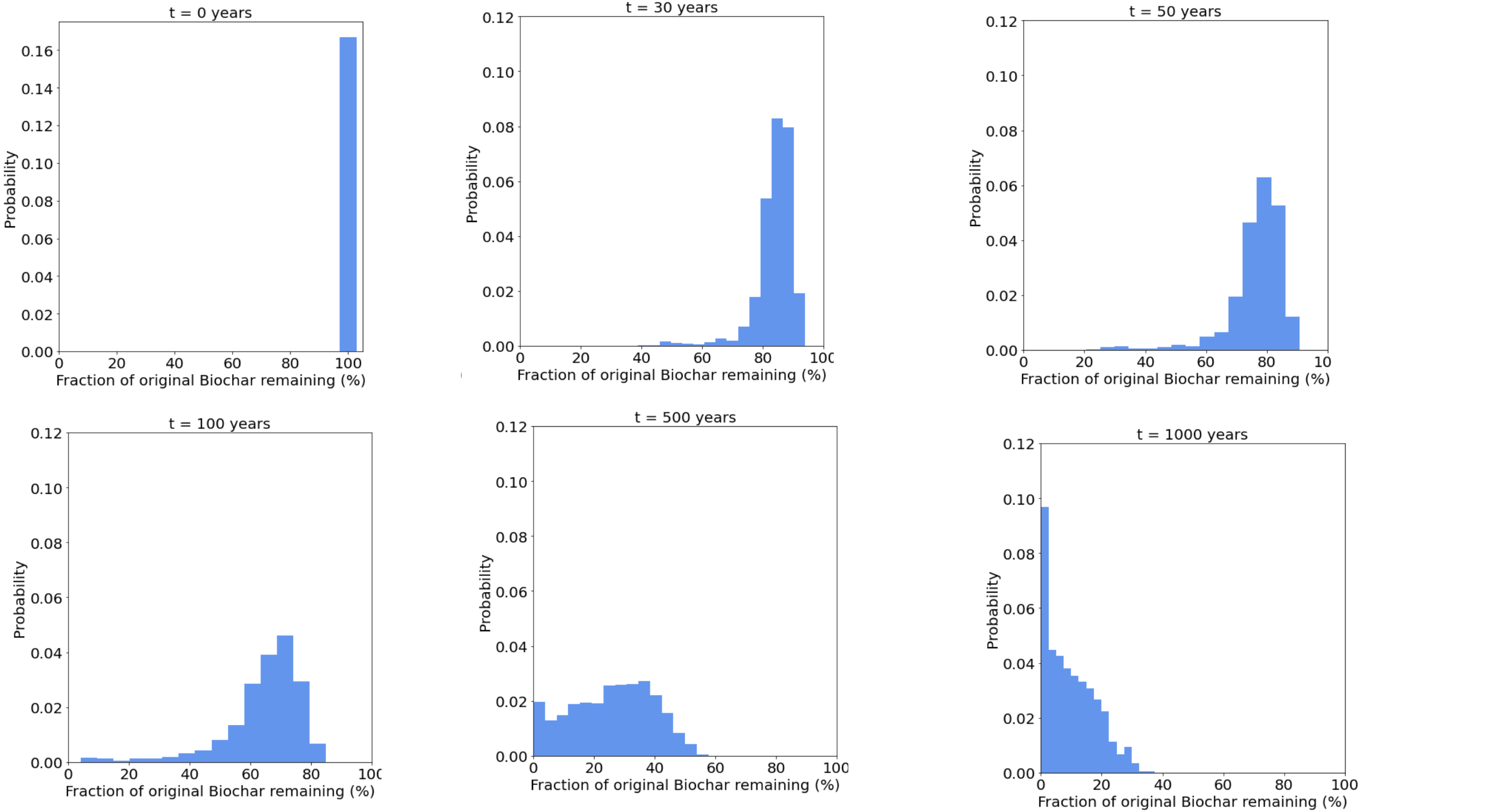
L ~ N(*15, 5.92*)	labile fraction of biochar
$t_{1/2L}$ ~ N(*20, 32*)	labile half-time
$t_{1/2R}$ ~ N(*300, 1522*)	recalcitrant half-time



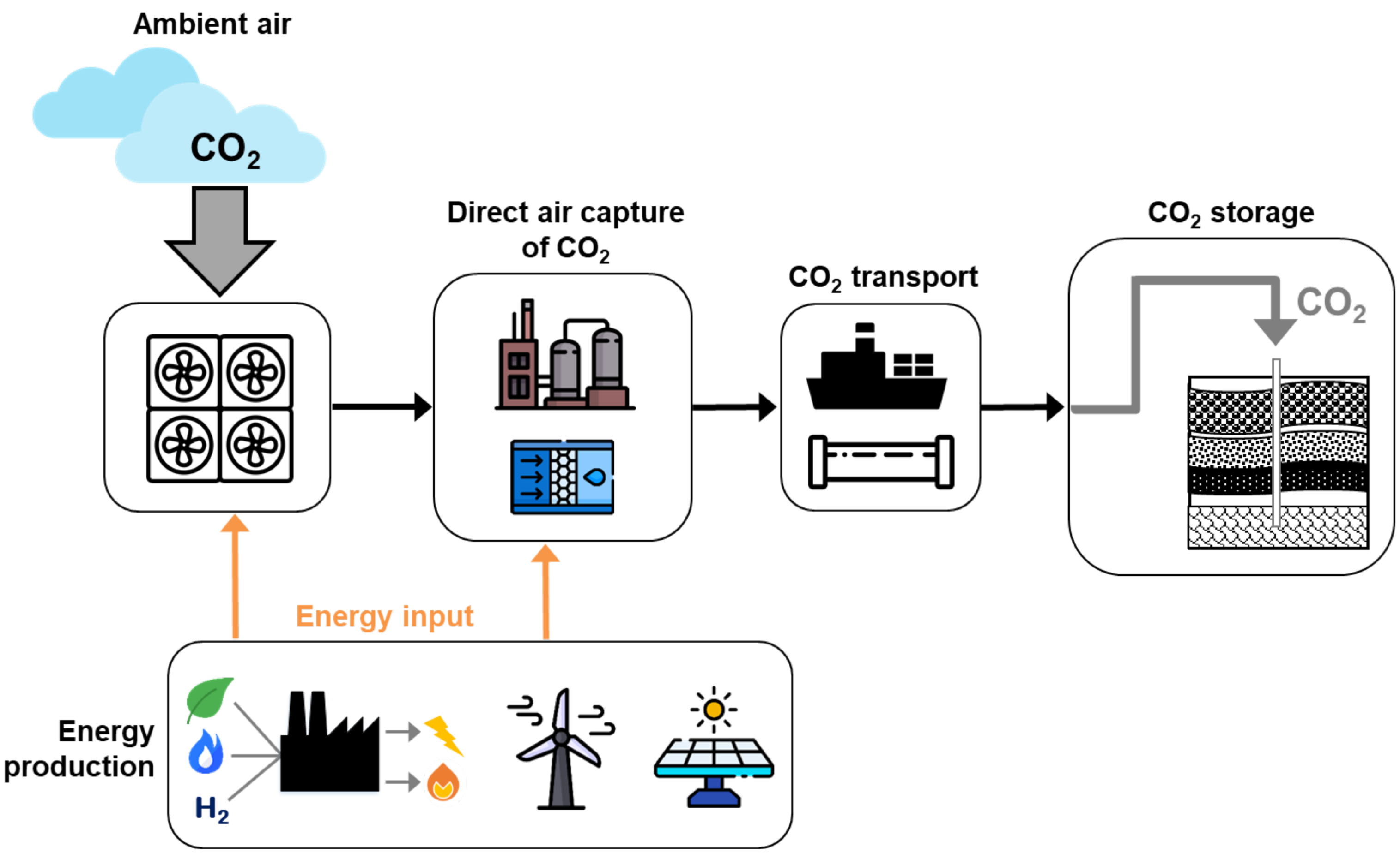




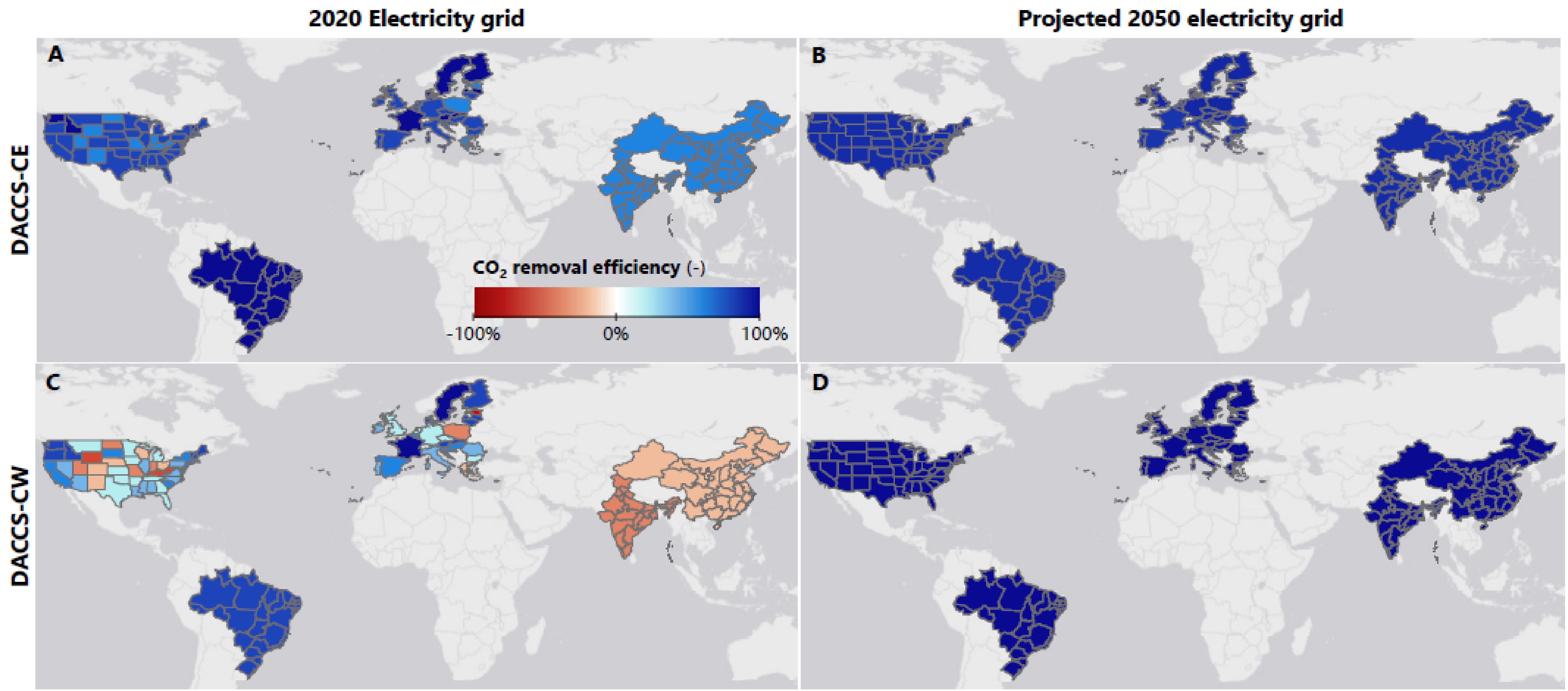
After 1,000 years, there may be very little char left!



Direct air CO_2 capture and storage (DACCS)

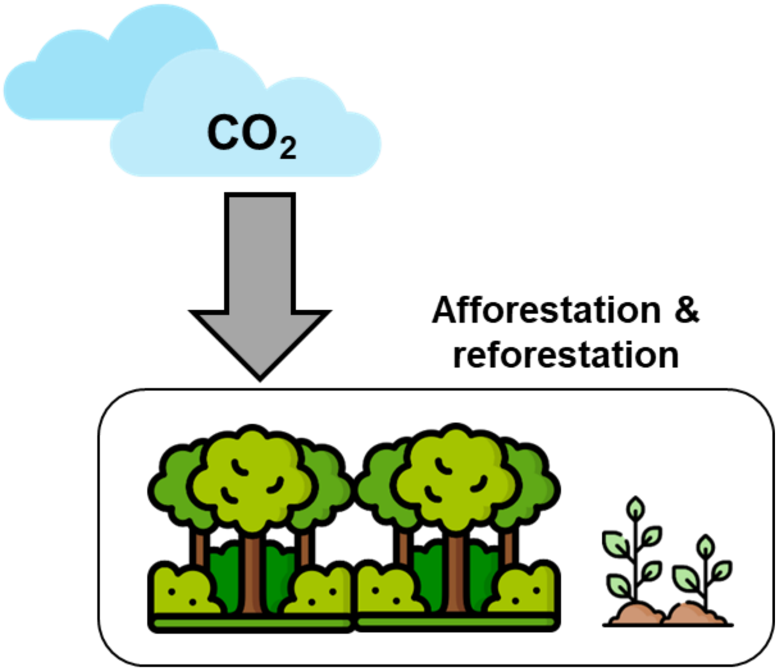


DACCS is not automatically carbon negative



Whilst the grid is not decarbonised, what is the best use of energy?

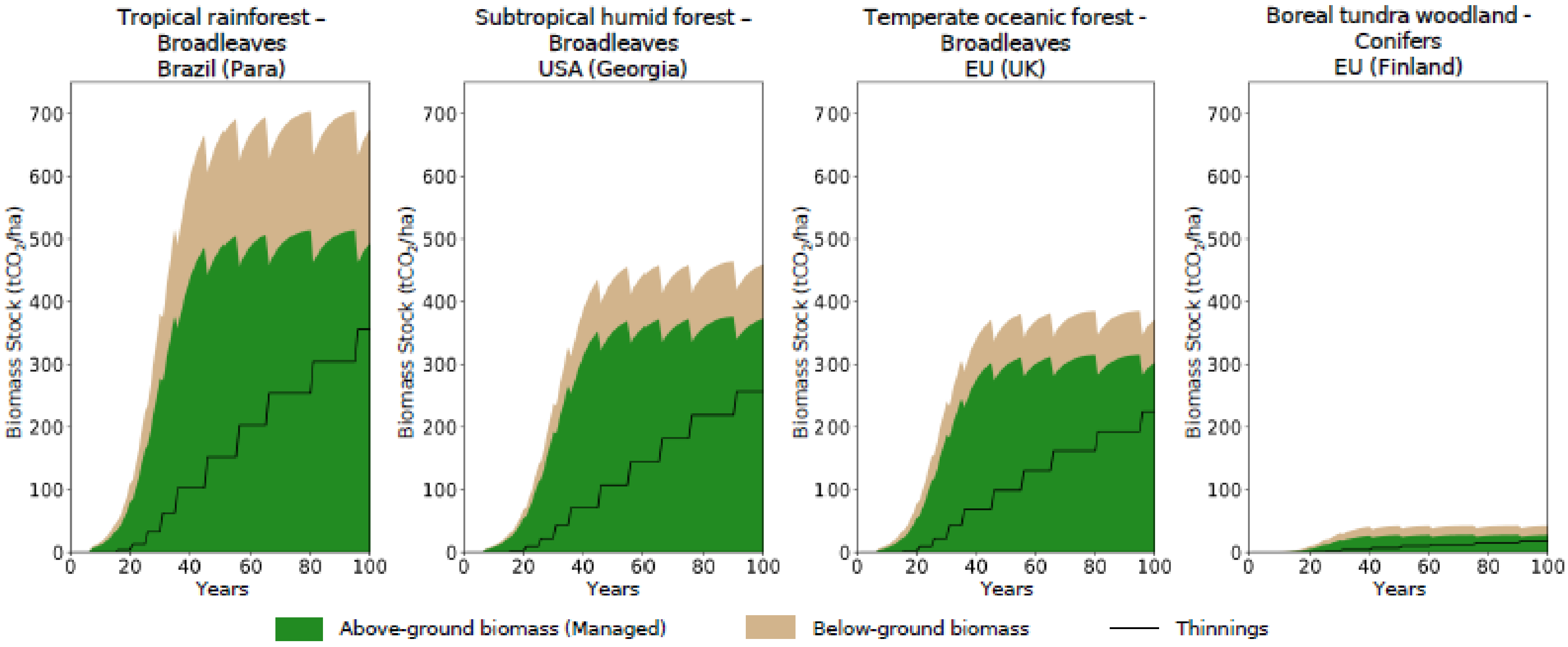
Afforestation and reforestation (AR)



Afforestation and reforestation

- Afforestation/reforestation is “easy” – you just plant trees…
- Uhm…
- Not remotely

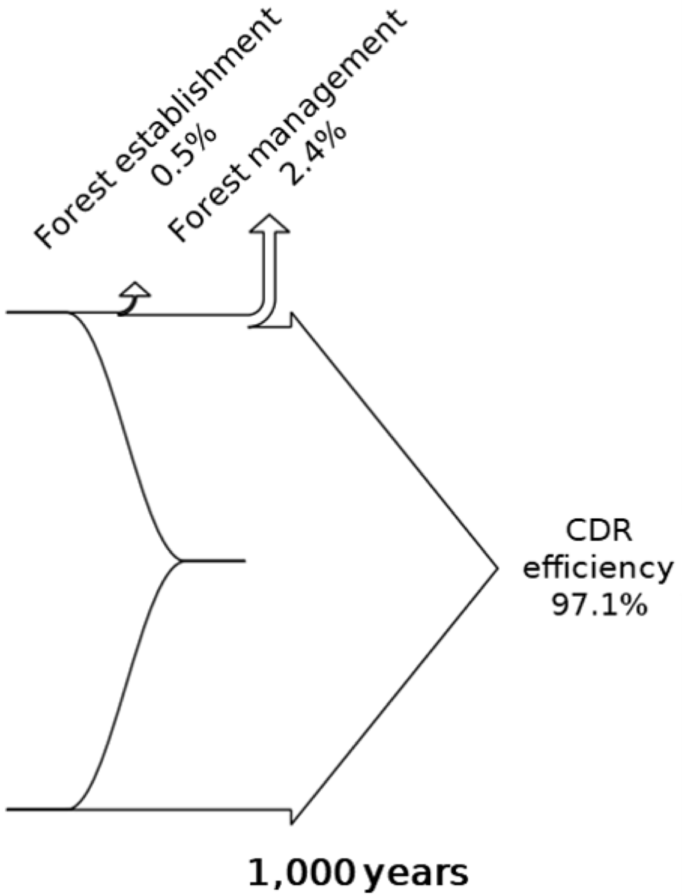
Forest growth curves



Regardless of location, a given area will "saturate" with carbon after ~ 30 – 50 years, but this carbon stock must be managed and maintained in perpetuity.

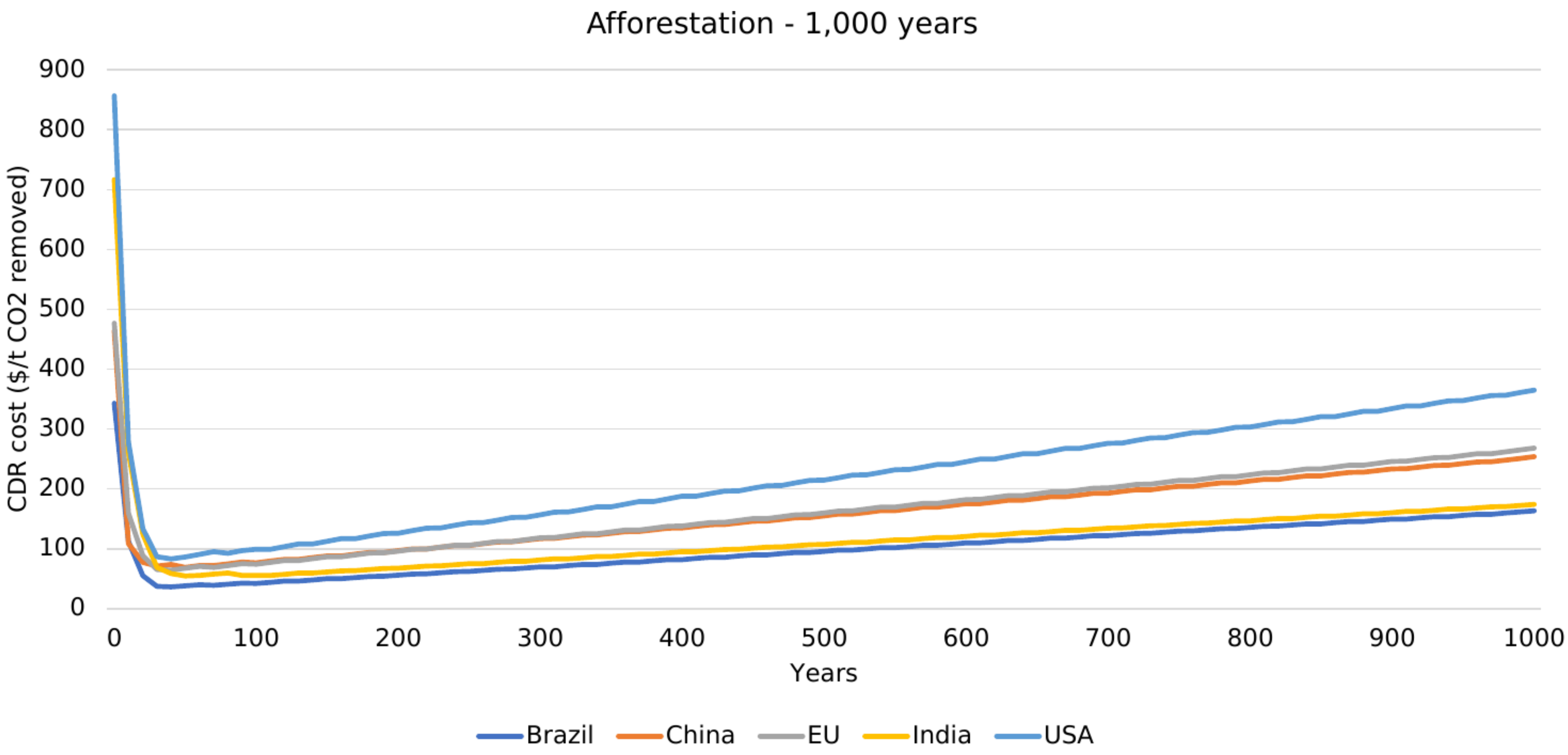
Chiquier, Fajardy, Mac Dowell, Energy and Environmental Science, 2021 (sub)

AR carbon removal efficiency



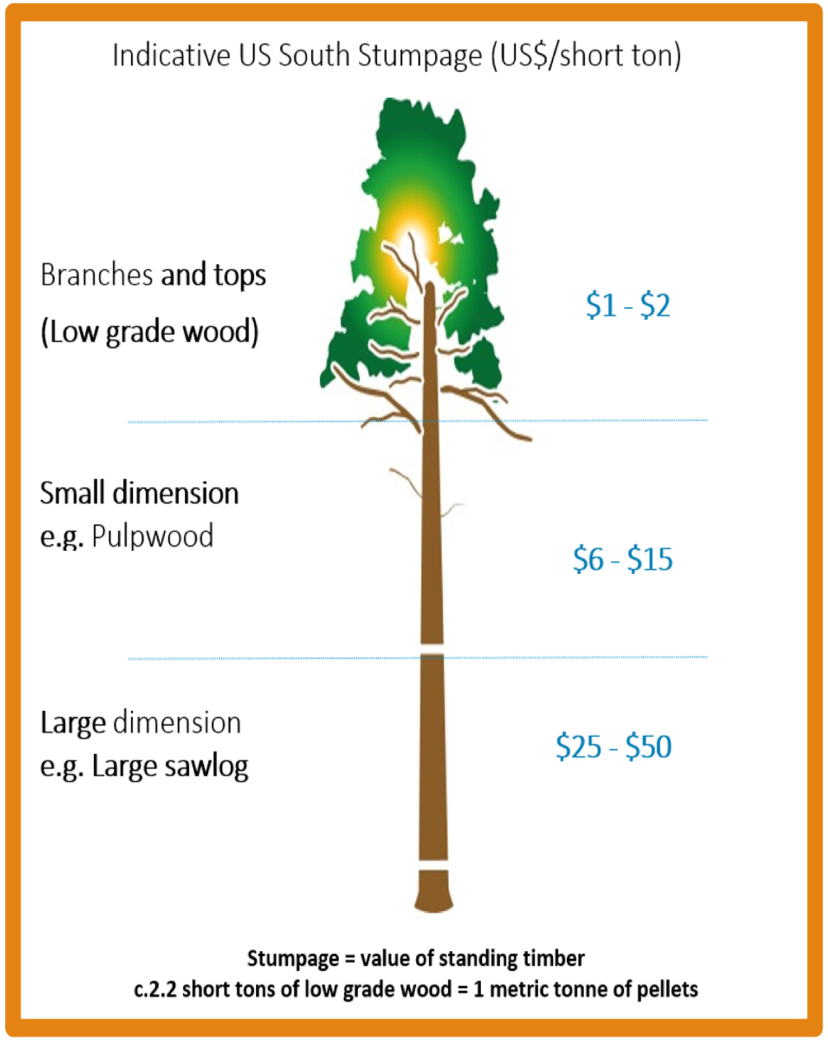
Illustrative carbon removal efficiency diagram for a UK AR project. Calculation performed with the MONET Framework.

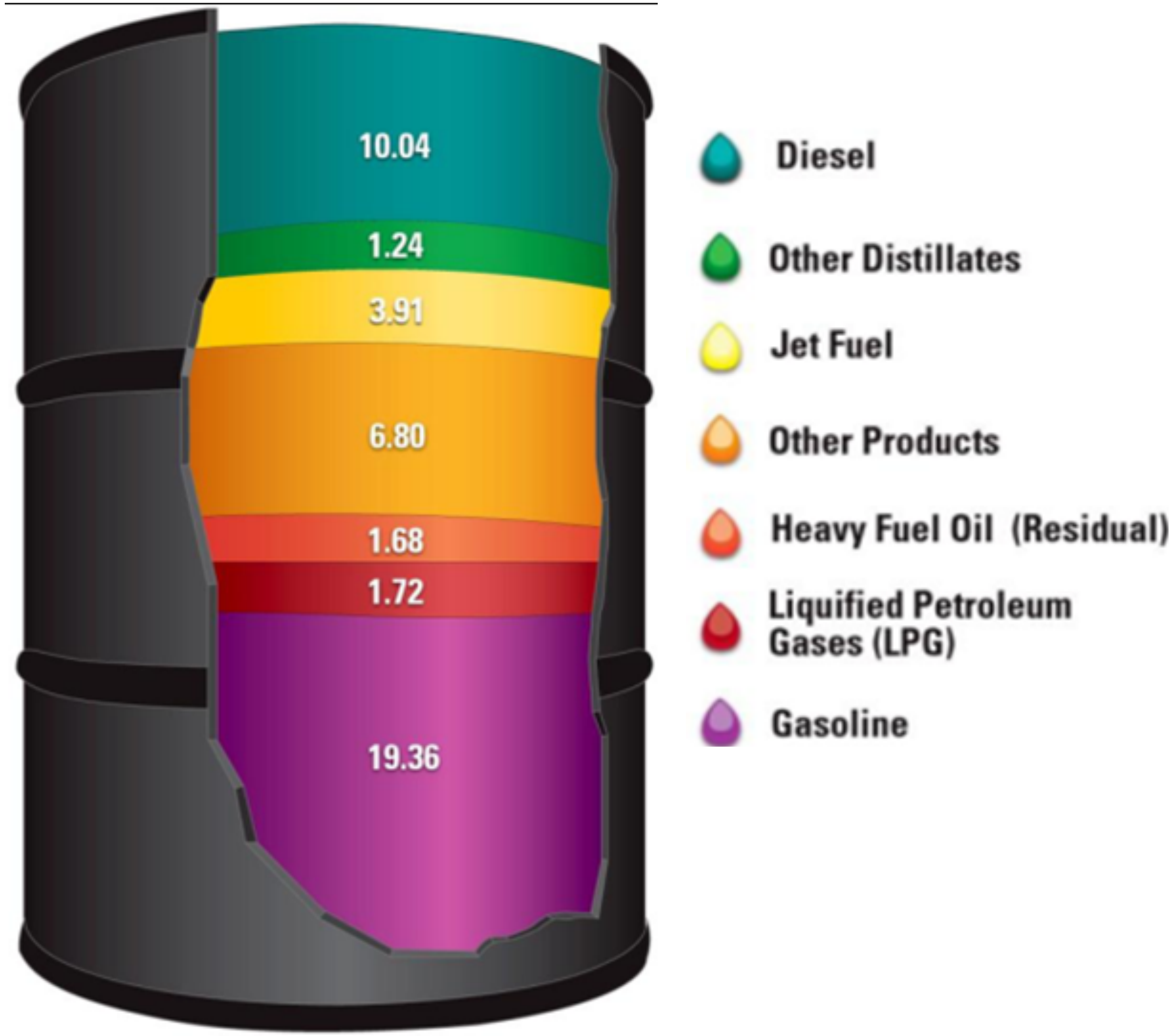
What is the cost of maintaining a carbon sink?



When is a tree like a barrel of oil?

When is a tree like a barrel of oil?





Tree data from Carly Whittaker, BEIS, oil data: https://www.energy.gov/articles/hows-and-whys-replacing-whole-barrel

Trees are “distilled” into various fractions…

Forest Products

Used in pellets

Sawlogs
Highest value, must be large and straight

n/a

Pulpwood
Lower value, can be random size and shape

21%

12%

25%

Sawmill Residues

Wood Chips
Highest value residues, often used in pulp industry

40%

Sawdust
Lower value, **often used on site in kilns or biomass boilers**

Slab-wood
Limited value as requires additional processing and contains bark- **often burnt**

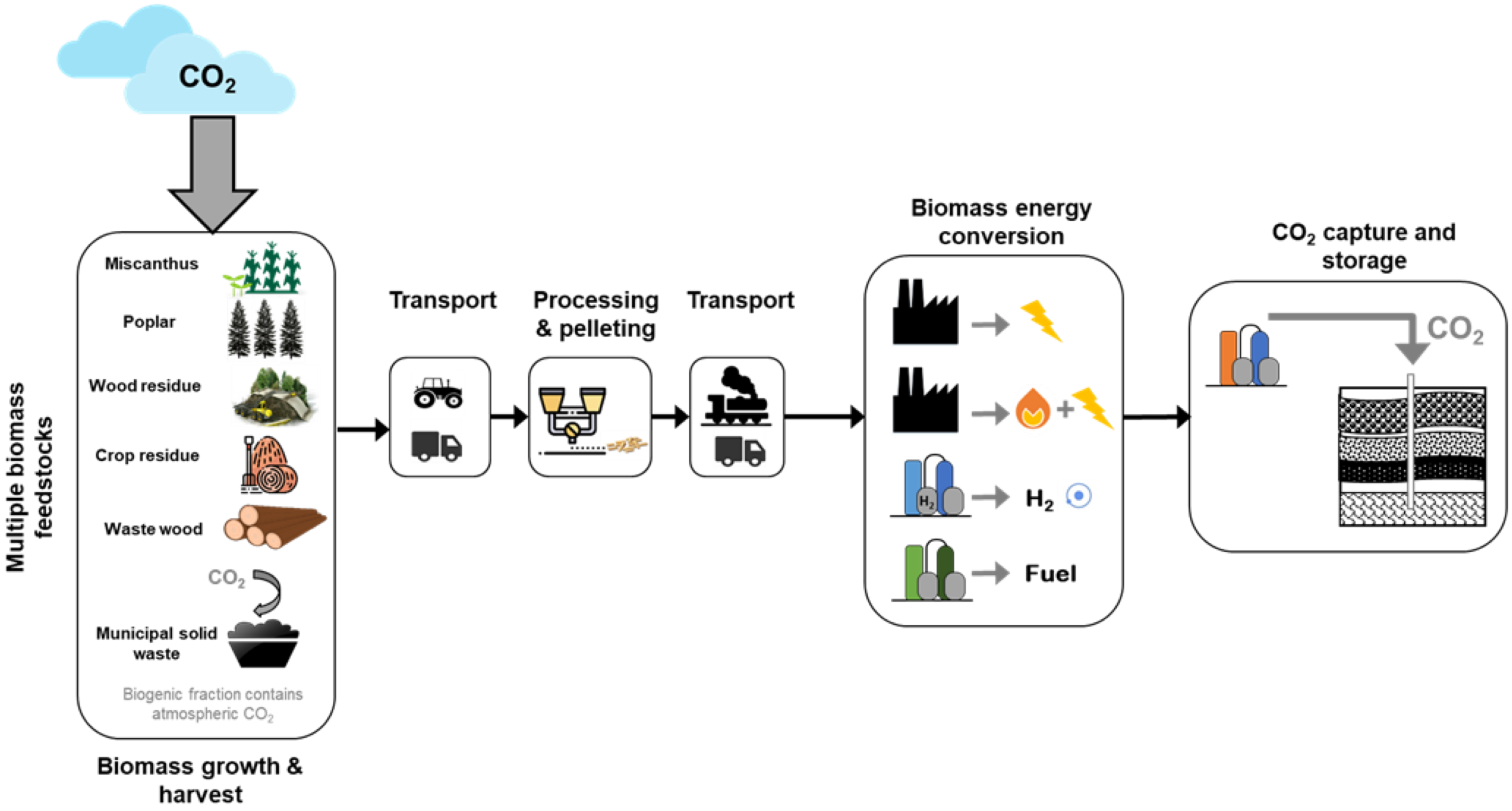
Slide from Carly Whittaker, BEIS

Sustainable biomass: seeing the wood for the trees

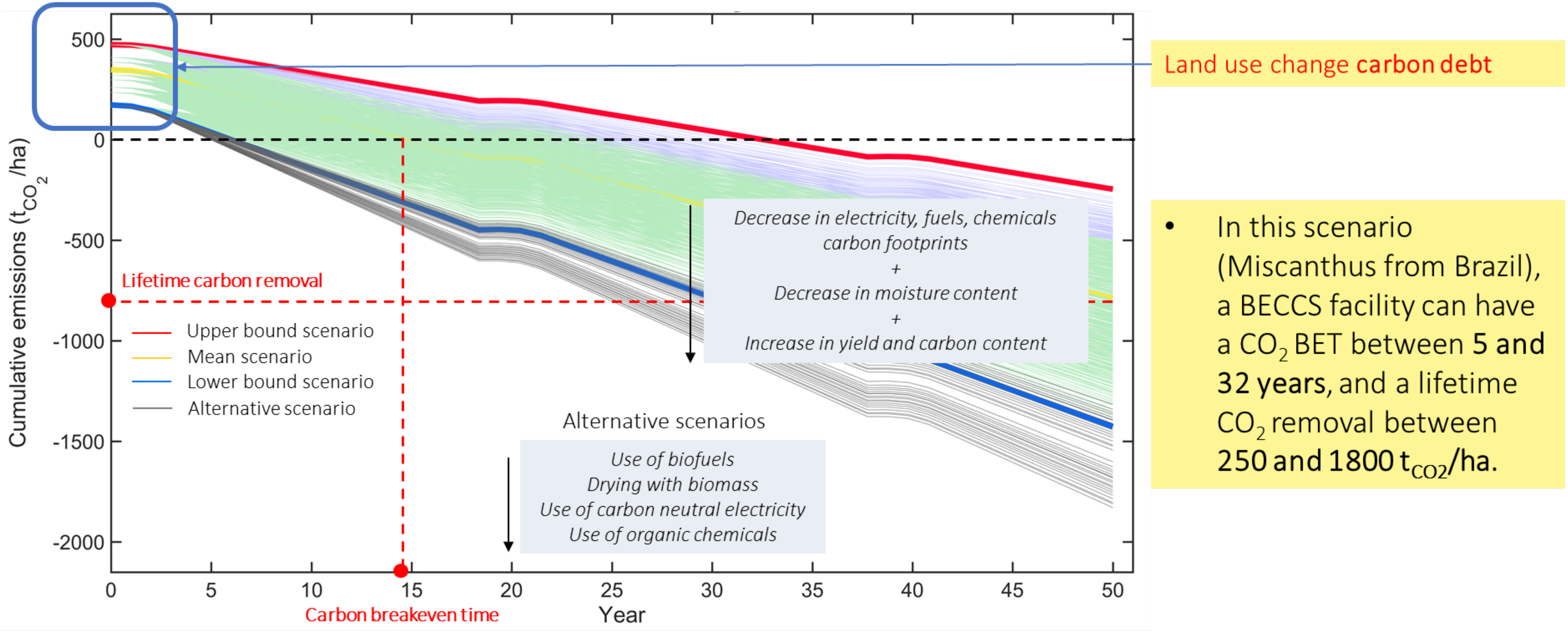
Production of sustainable biomass for BECCS, biochar, bio-H2-CCS, etc

- Managed afforestation will necessarily increase supplies of inherently sustainable biomass
- Cultivation of bioenergy crops, e.g., lignocellulosic, or short-rotation coppice, is also a key option
- Advanced options, e.g., algal biomass also highly promising, though currently low TRL

Bioenergy with CCS (BECCS)



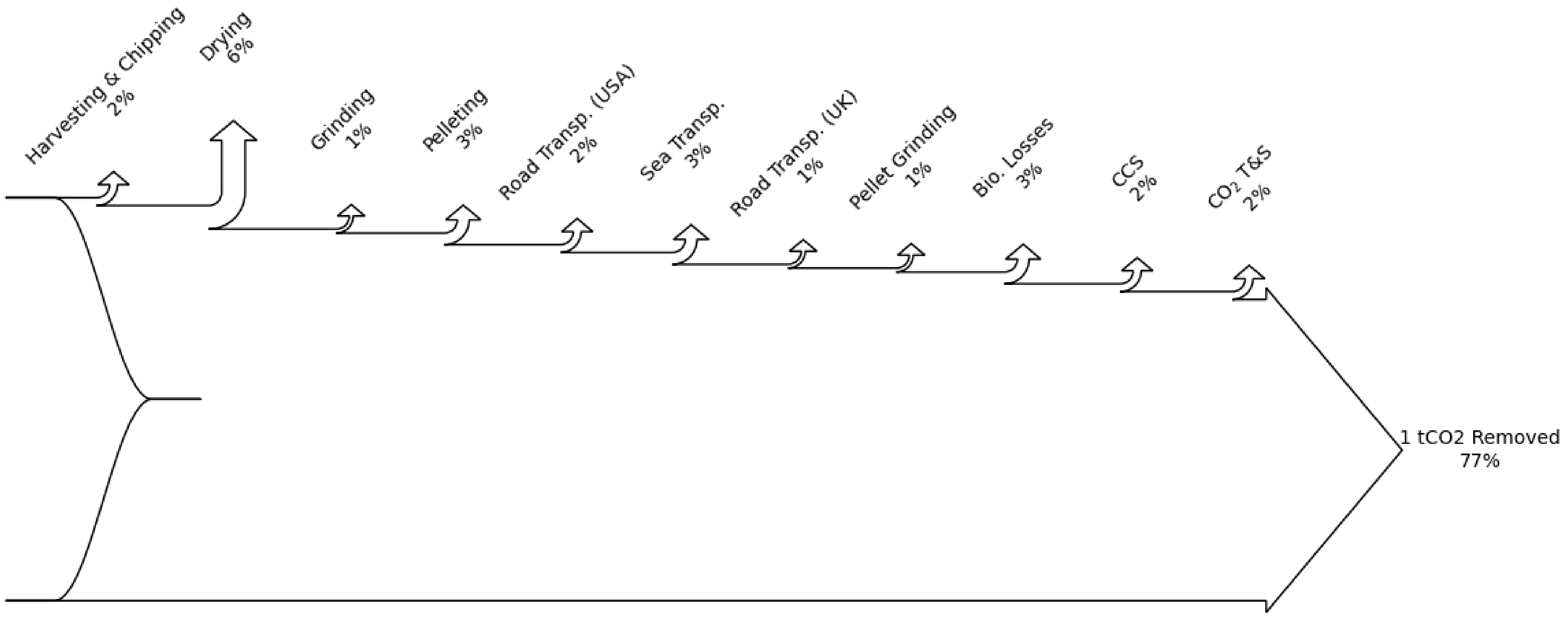
When, if at all, does BECCS become CO_2 negative?



- In this scenario (Miscanthus from Brazil), a BECCS facility can have a CO_2 BET between **5 and 32 years**, and a lifetime CO_2 removal between **250 and 1800 t_{CO2}/ha.**

Fajardy and Mac Dowell, Energy and Environmental Science, 2017

Carbon removal efficiency of BECCS



Illustrative carbon removal efficiency diagram for a UK BECCS project using biomass imported from the USA. This example assumes 98% CO_2 capture. At 90% capture rate, the carbon removal efficiency is reduced to approximately 70%. Calculation performed with the MONET Framework

Some conclusions

1. GGR is *not* an alternative to mitigation, it is an "and and".
2. How much we need is going to be a function of how late we properly start mitigating/reducing emissions at the global level.
3. There are a portfolio of options for GGR, each with their own unique characteristics.
4. No one GGR method is a "silver bullet" – we will likely need a portfolio.
5. In terms of climate repair, the permanent removal of CO_2 is key, and MRV is essential.
6. We need crystal clarity on taxonomy; removal ≠ use ≠ avoidance.

Some (more) conclusions

7. It is entirely possible to deliver sustainable biomass at scale.
8. It is entirely possible to very badly &*%$ this up.
9. Nobody wants to burn whole trees. This is just insane.
10. With BECCS, need to distinguish between value of dispatchable power generation (counterfactual: wind + sync comp + energy storage) and value of permanent and readily verifiable carbon removal (counterfactual: DACCS)
11. The cost of BECCS will vary as a function of location and biomass supply chain
12. The UK is in a good place for BECCS owing to existing biomass supply, the potential to increase domestic biomass supply, and excellent CO_2 storage potential in the North Sea (UK should develop this, and seek to provide it as a service internationally)

&*%$ = mess, obviously….

Too many conclusions…

13. Afforestation is *much* more complicated than “just” planting trees. MRV of the carbon stock is vital. And ultimately costly.
16. Biochar is an option, but is relatively wasteful of the biocarbon
17. Biochar decays in the soil, and can enhance soil microbial activity leading to methane production
18. Enhanced weathering can lead to permanent removal of CO_2
19. Major sources of carbon leakage are associated with crushing and grinding rock – this will likely reduce with time.

(finally) some recommendations

- We should
  1. Clarify liability value chain associated with carbon removal.
  2. Agree on a level of removal credit as a function of permanence.
  3. Establish and address gaps in the science in MRV capabilities for each GGR pathway.
  4. Develop detailed MRV protocols for each GGR approach, in parallel with initial commercial demonstration.
  5. Establish an independent regulatory body to sit between project developers and HMG and be responsible for an independent MRV regime to ensure that the amount and permanence of removals are quantified, robustly and transparently.
  6. Engage with relevant international stakeholders to share knowledge and understanding, and collaborate on addressing the governance and accounting challenges relevant to GGR.
  7. Consider developing a regulatory framework to enable the participation of GGR in an Emissions Trading Scheme.