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Background and research interests on marine carbon dioxide removal (mCDR)

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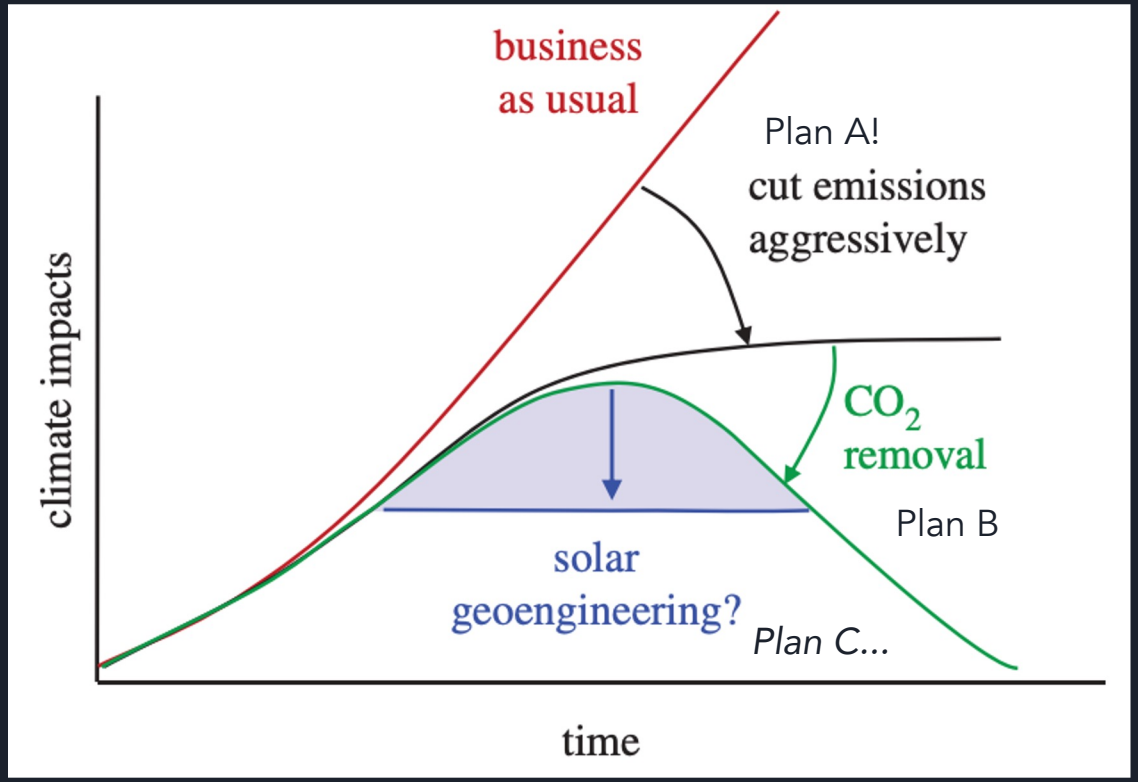
September 14, 2022

PNNL-SA-140781

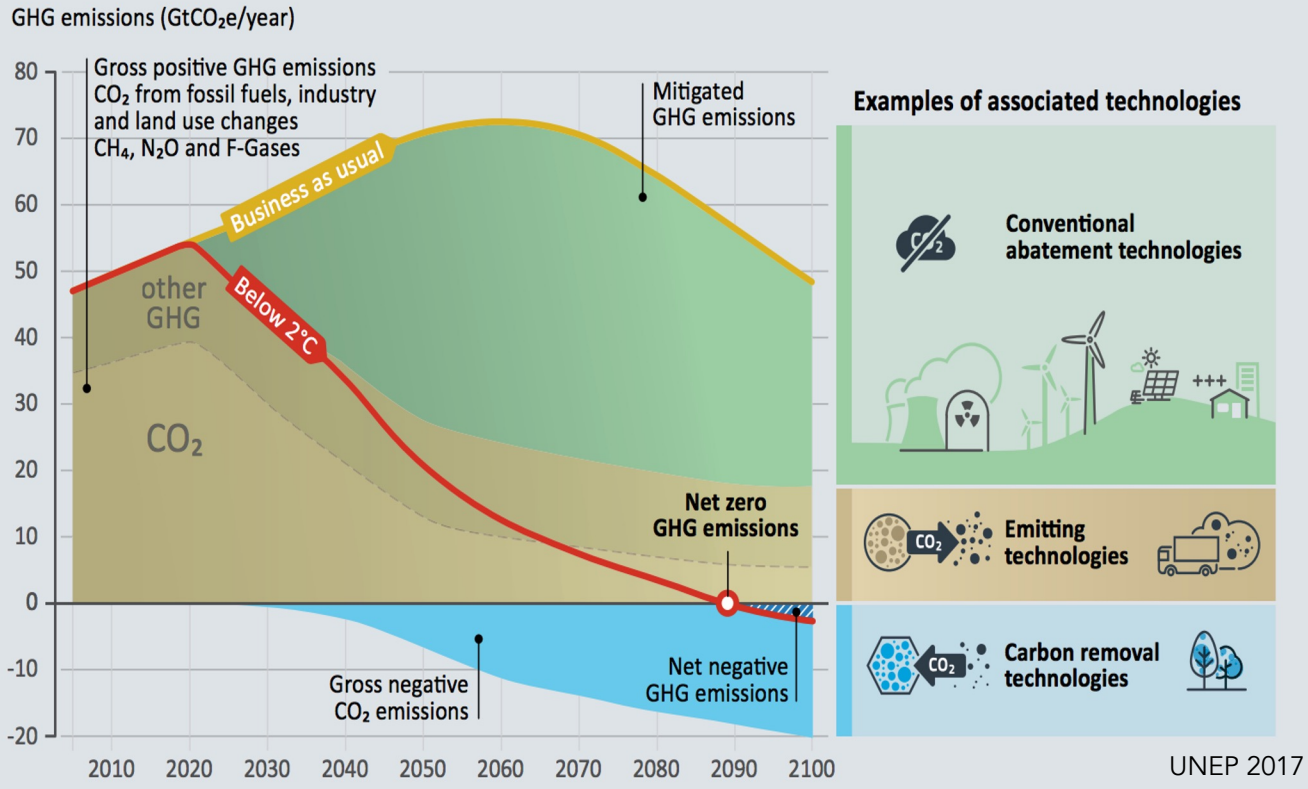
Solutions Summary: Plan A, Plan B, Plan C



Reducing greenhouse gas emissions, combined with future large-scale atmospheric CO_2 removal (CDR), may lead to long-term climate stabilization, but with some potentially significant overshoot of desired temperature targets.

MacMartin DG, Ricke KL, Keith DW. 2018 Phil. Trans. R. Soc. A 376: 20160454. http://dx.doi.org/10.1098/rsta.2016.0454

Plan B: Carbon Removal



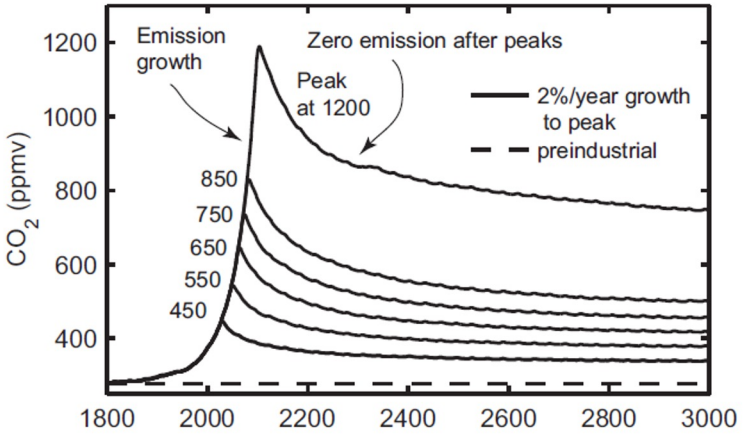
UNEP 2017

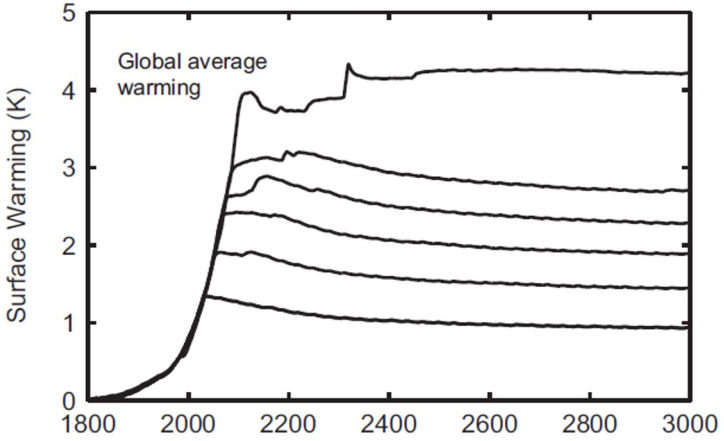
To make up for "stubborn" emissions, estimates suggest that we will need to extract 10 Gt CO_2 / yr out of the atmosphere by 2050, increasing to 20 Gt CO_2 / yr by 2100.

Why do we need to remove legacy carbon?

"...climate change that takes place due to increases in carbon dioxide concentration is largely irreversible for 1,000 years after emissions stop."

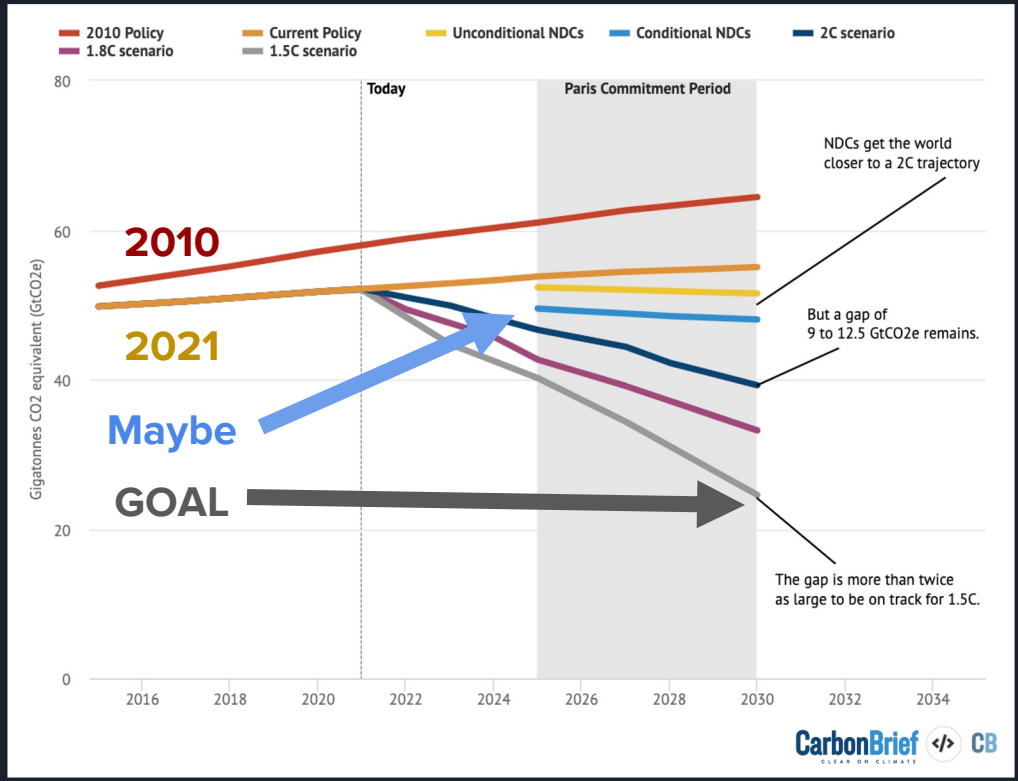
- Solomon et al., *Proceedings of the National Academy of Sciences*, 2009



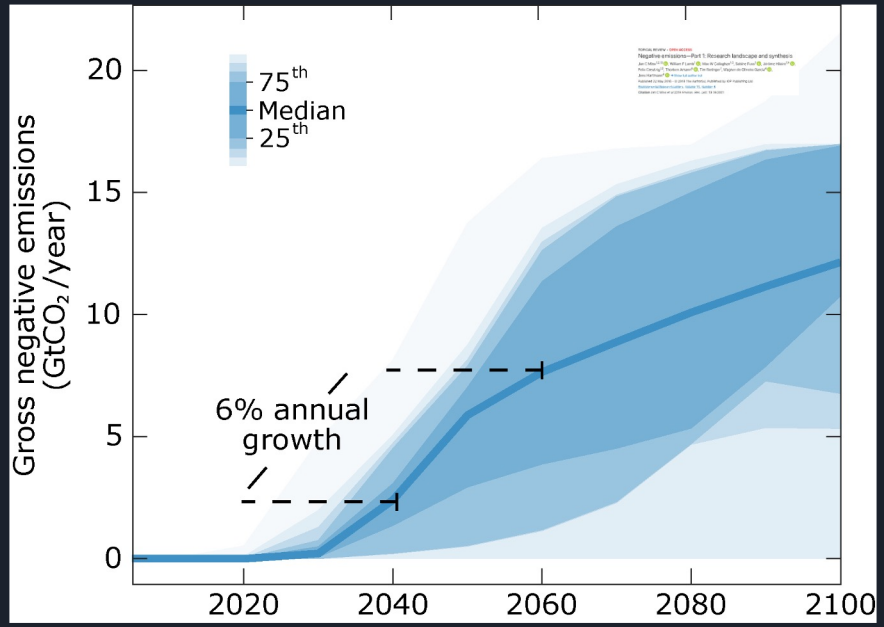


Are we on track for Plan A?

After COP26: Getting better, but not there yet

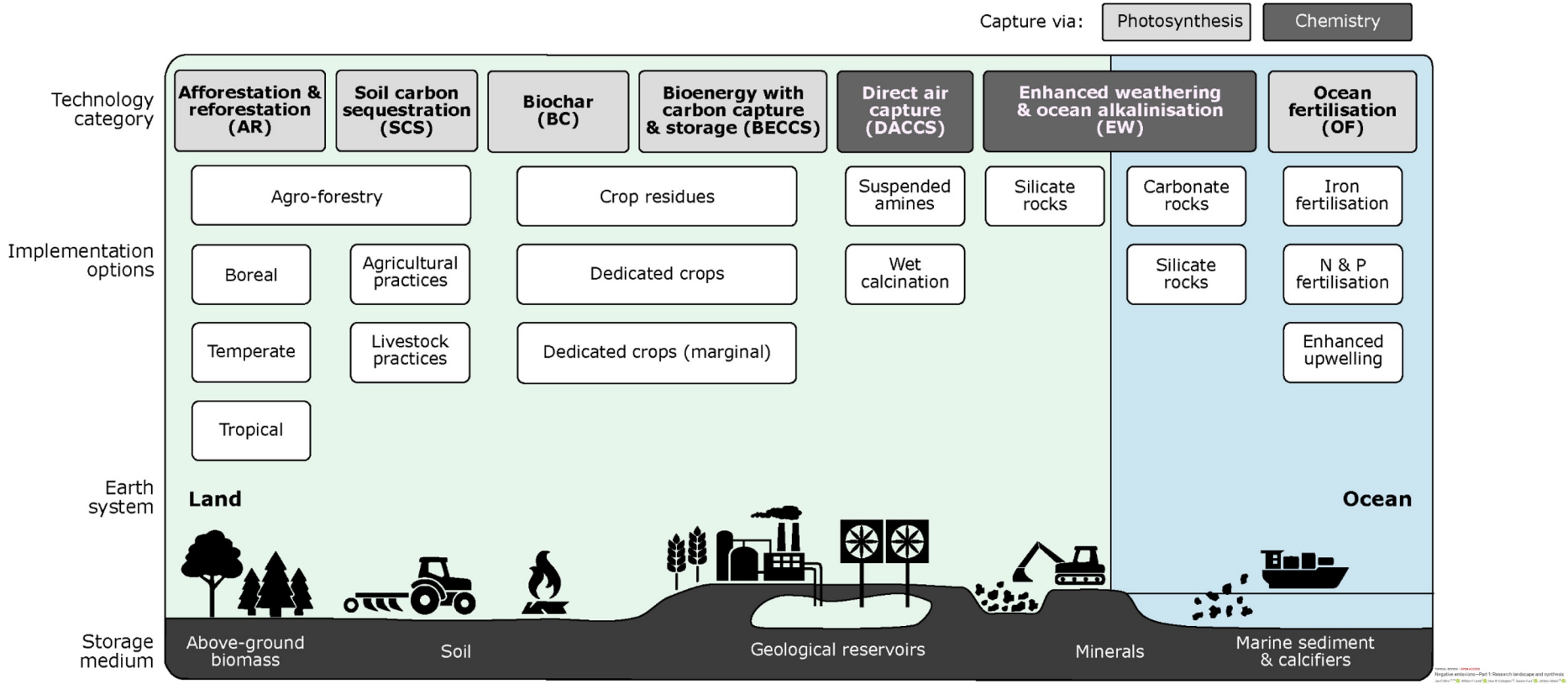


Are we on track for Plan A?



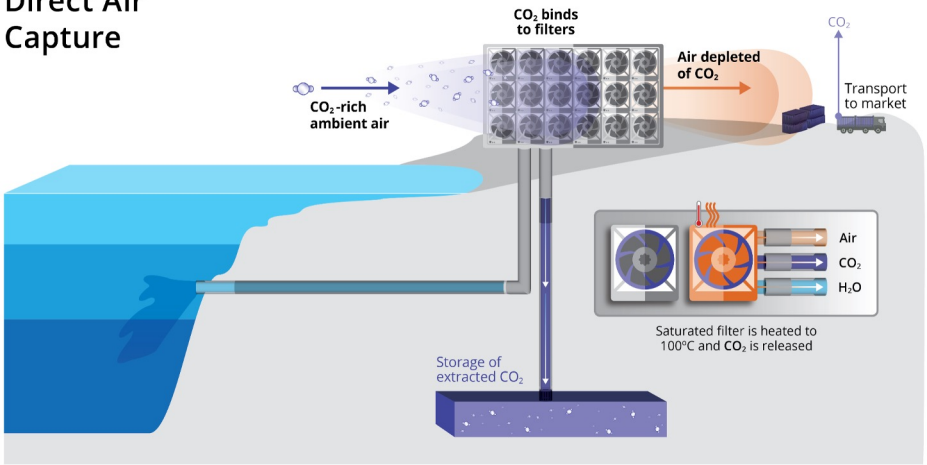
The longer we wait to implement Plan A, the more we need Plan B...

There are many carbon removal strategies

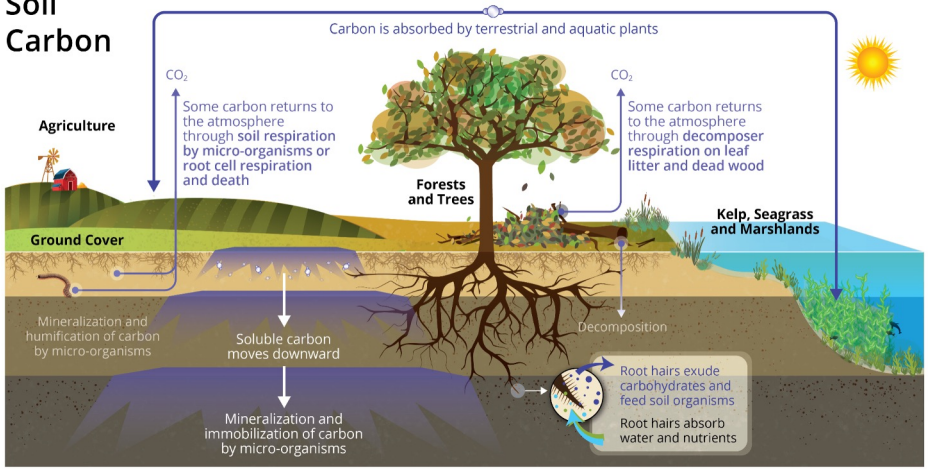


Land Approaches:

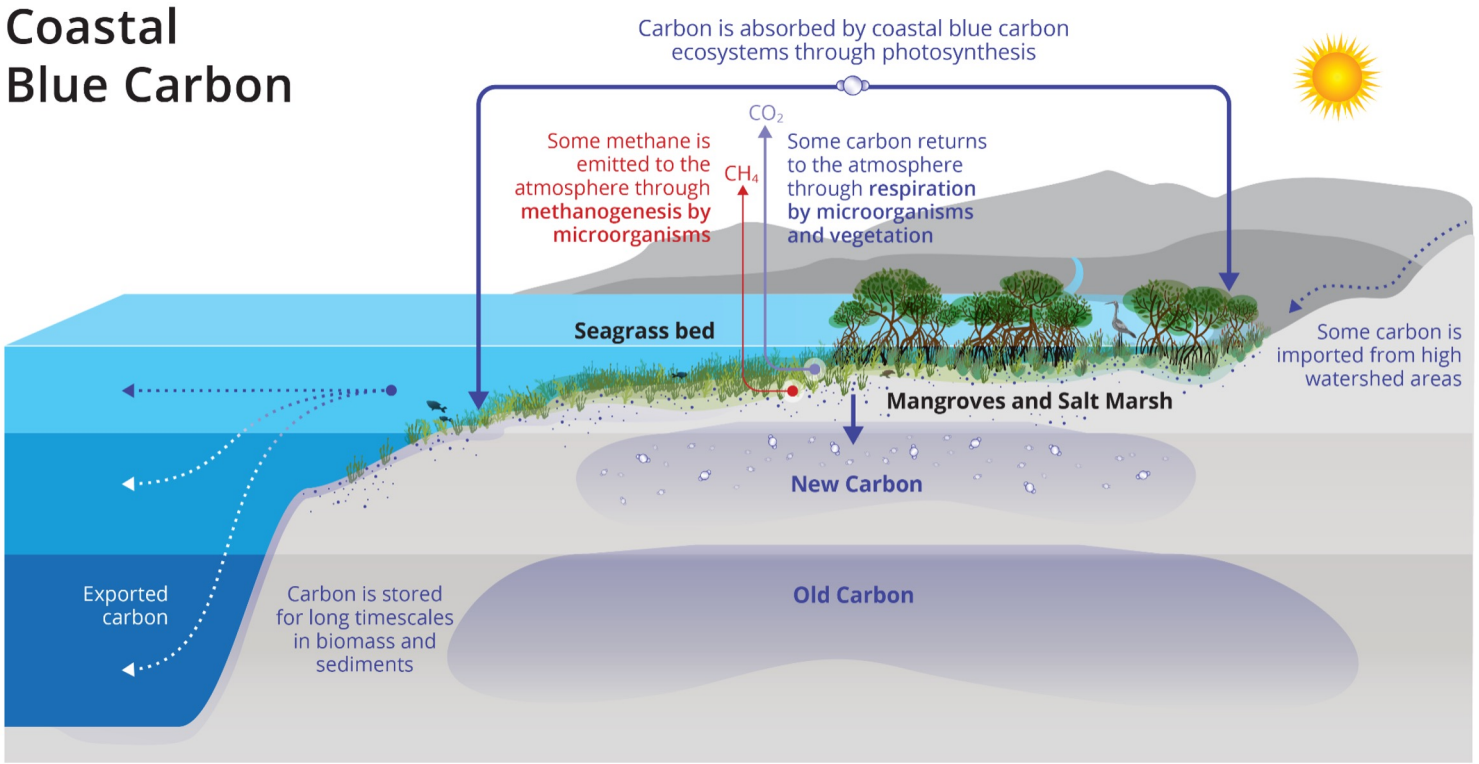
Direct Air Capture



Soil Carbon

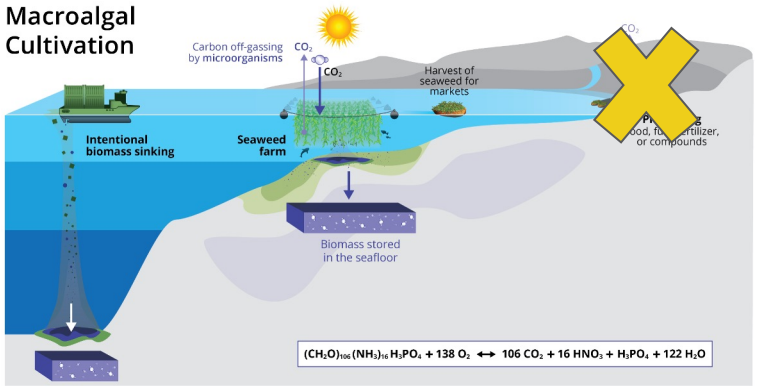


Coastal Approaches:

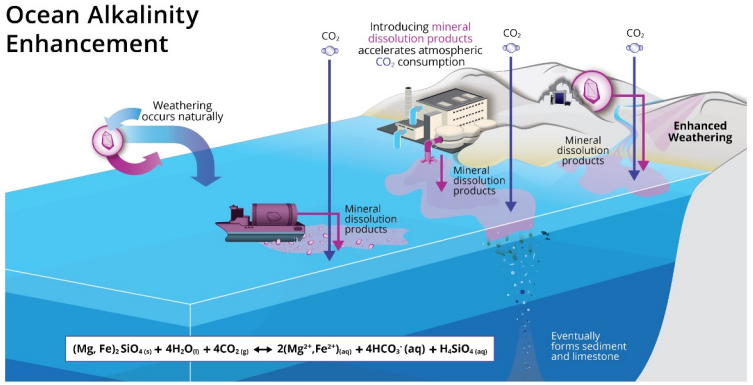


Marine Approaches:

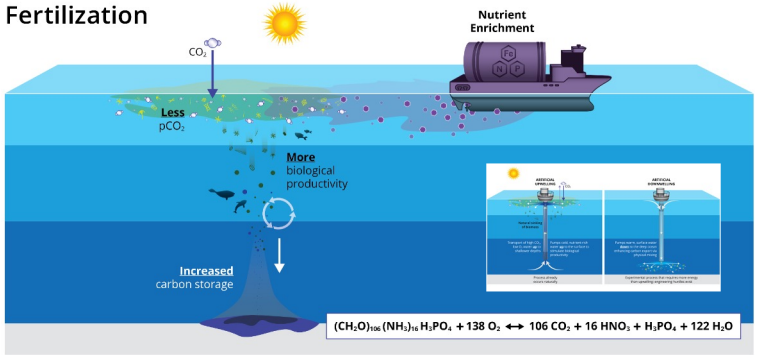
Macroalgal Cultivation



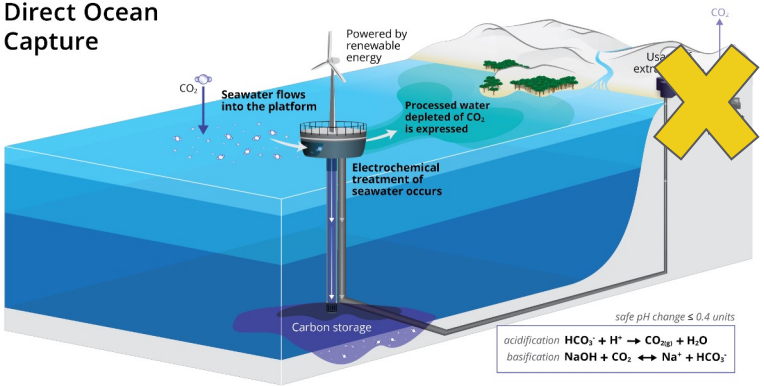
Ocean Alkalinity Enhancement



Ocean Fertilization



Direct Ocean Capture



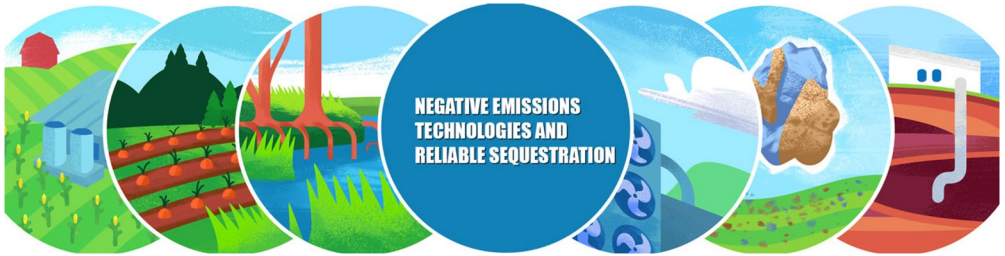
Are all CDR solutions created equal?

No Yes

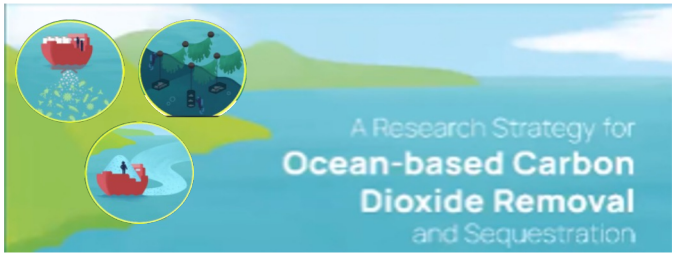
Evaluating CDR methods

- **Do they remove carbon from the atmosphere?**
  - How fast? (Rate)
  - For how long? (Permanence)
  - Do they exist yet? (Readiness)
- **How much do / will they cost?**
  - Scale-up: Infrastructure costs
  - Operation: Energy costs
  - Sustainability: Storage costs
- **Side Effects:**
  - Environmental hazards
  - Competing use cases
  - Justice

& many open questions!



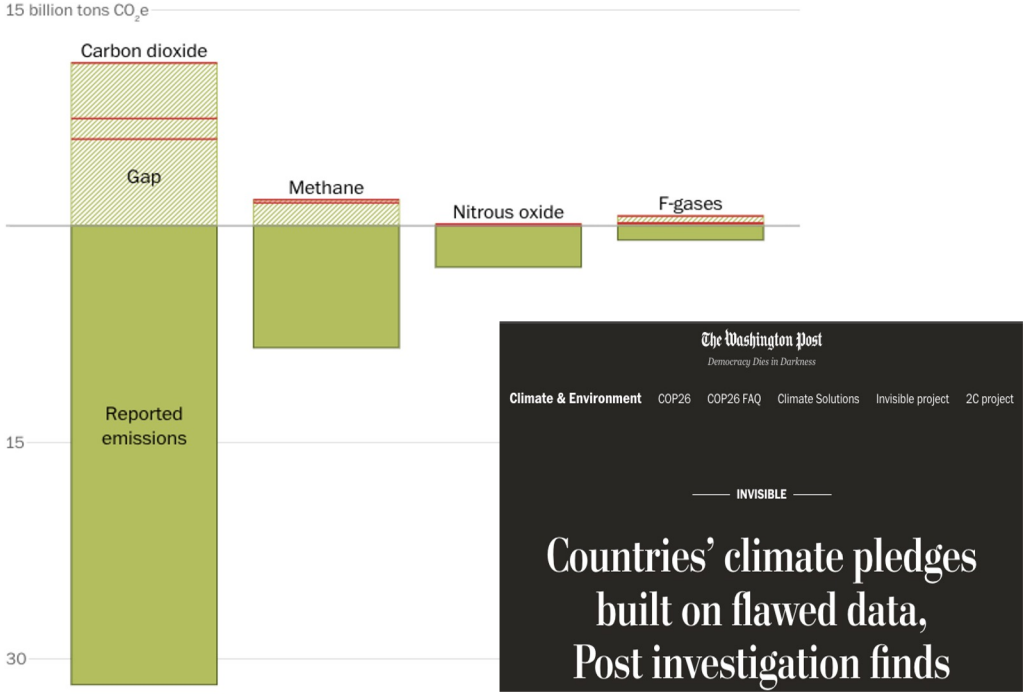
NASEM 2019 CDR success will rely on "silver buckshot:" no one technique is a panacea. Some CDR strategies are ready for deployment now (e.g., soil carbon, BECCS, geologic storage). Some high potential methods need more study (e.g., DAC, oceans).



NASEM 2021 3 top ocean CDR research priorities: Ocean fertilization, afforestation, and alkalinity enhancement

Better data could help stabilize a CDR / offset market

What kind of data would be more helpful?



Note: Independent global emissions measurements come from the Global Carbon Project, Minx et al., the U.N.'s Food and Agriculture Organization and the World Meteorological Organization.

- **Test, Track, Trade: MRV**
- **Environmental monitoring**
- **Risk assessment**
- **Lifecycle analysis (LCAs)**

Jobs and Carbon Management

Carbon management is already a $Bn industry. There are and will be many, many jobs in this field.

- Engineering
  - *R&D, design, construction, operations*
- Economics
- Policy
- Federal Science
  - *12 agencies… led by DOE*
- *Ethics / NGOs*

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For Discussion

- ***Status and magnitude of the problem***
- ***Carbon removal strategies***
- ***Evaluations questions & MVR***

CDR Resources

- NASEM 2019 (General NETs)
- NASEM 2021 (Ocean CDR)
- CDR Primer from DOE's J. Wilcox

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For Discussion

How do we think beyond on our own 'silos of excellence' to advance emerging ocean-based climate solutions?

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