Carbon Capture Methods

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2 Main carbon capture pathways

Physical

- carbon capture and storage (CCS)
- More efficient when applied where large amounts of CO2 are being produced
- Mostly pilot scale currently

Biological

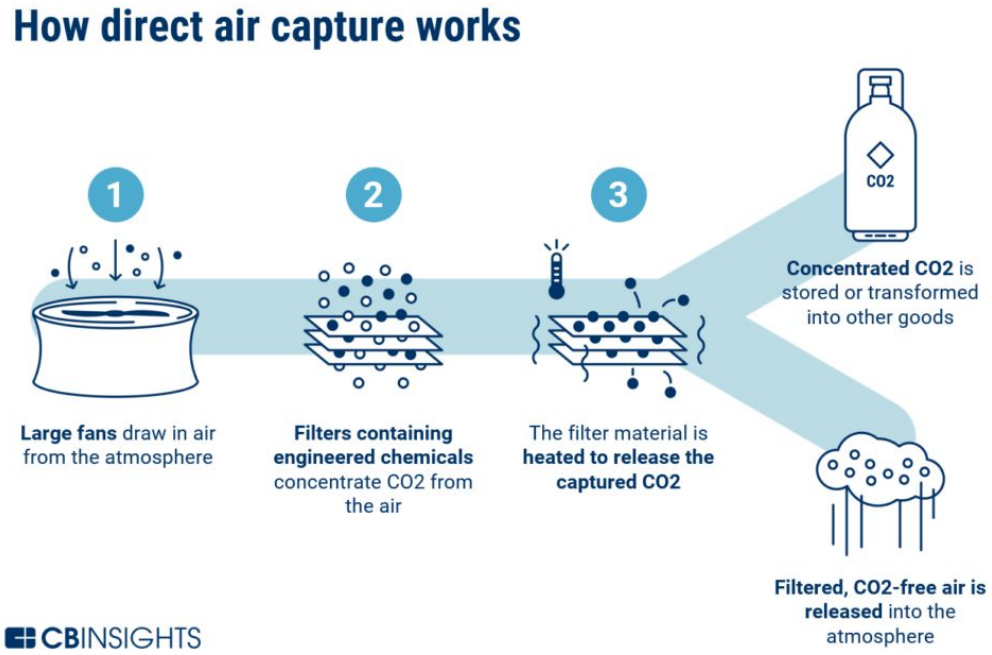
- Marine
  - Fertilization of the ocean to spur photosynthetic productivity
- Terrestrial
  - Large scale planting of trees
  - farming

Direct Air Capture

What It Is

- A process where chemical reactions capture CO_2 from ambient air to be stored permanently or used again.
- These chemicals are either:
  - **Solvents:** liquids that can capture CO_2
  - **Sorbents:** solids that can capture CO_2

How It Works


How direct air capture works
1
2
3
CO2
Concentrated CO2 is stored or transformed into other goods
Large fans draw in air from the atmosphere
Filters containing engineered chemicals concentrate CO2 from the air
The filter material is heated to release the captured CO2
Filtered, CO2-free air is released into the atmosphere
CBINSIGHTS

Solvent vs. Sorbent

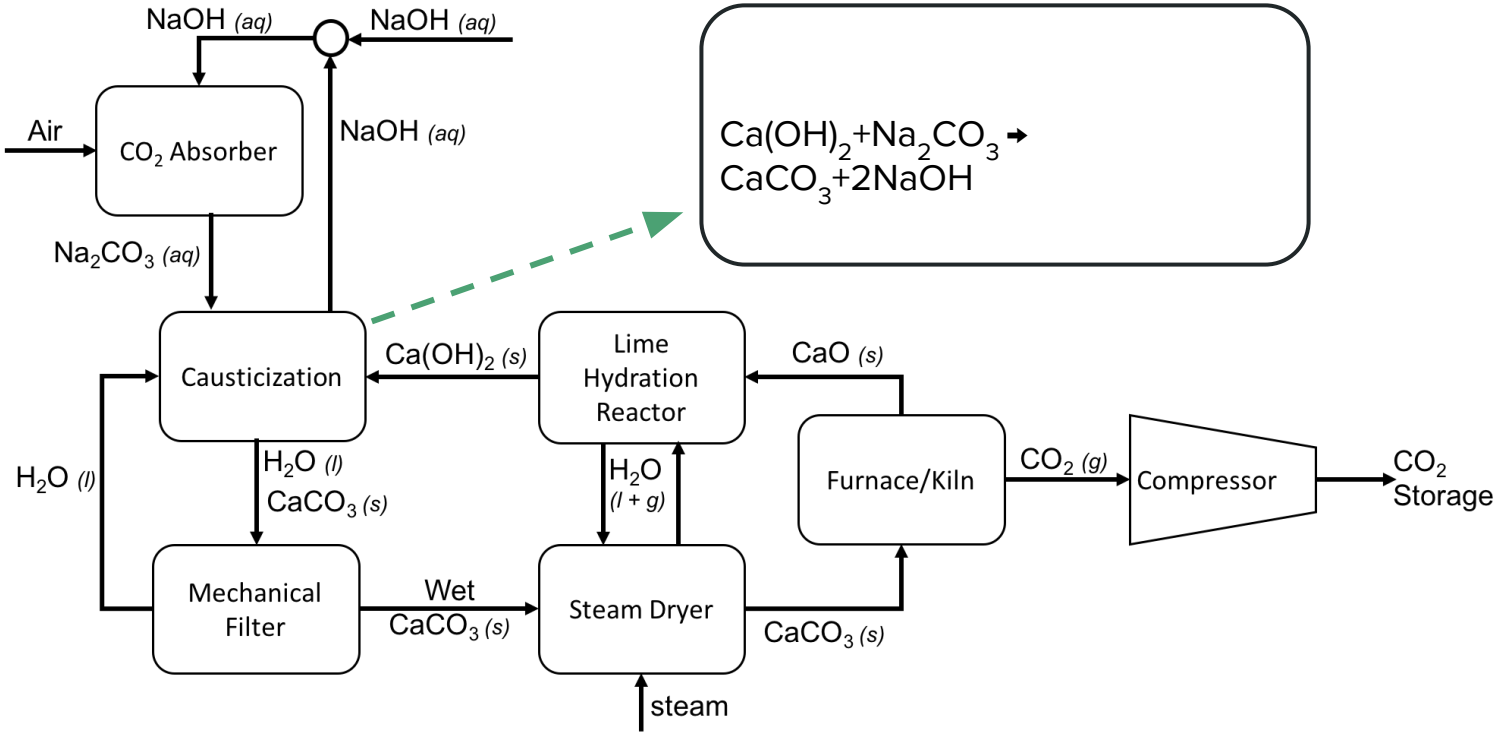
Solvent:

- Requires 900°C
- Most widely used
- Ex:
  - sodium hydroxide
  - potassium hydroxide
- Requires large amounts of energy
- Highly caustic (burns through skin)

Sorbent:

- Requires 80-120°C
- Still experimental, but shows promise
- Ex. - polymer resin
- Can use heat of existing power plants

How It Works



By JoseZZ - Own work, CC BY-SA 4.0, https://commons.wikimedia.org/w/index.php?curid=58335264

Uses for CO_2

- Enhanced oil recovery
  - Most popular - most money involved
  - Reduces oil's carbon footprint, but still a net increase in CO_2
- Concrete production
  - Might make concrete stronger
  - likely causes net increase in CO_2 due to transport using today's infrastructure
- Fuels
  - CO_2 converted to synthetic crude, can be used again as gas, diesel, jet fuel
- Permanent storage
  - Storing in bedrock deep underground
  - Market mostly companies trying to be carbon neutral (ex. - Microsoft)
  - IPCC: low risk and effective if done properly

Costs

- Currently, $200-1000 / ton
  - Costlier than most mitigation approaches / natural solutions
- Possible ways to drive down costs / increase use:
  - Decreasing energy use by DAC plants
  - Finding a strong, environmentally friendly market to sell captured CO_2
  - Govt. incentives to permanently store CO_2
- Expected to reach ~$50 / ton by 2050

Real World Use

- Right Now:
  - 0.01 Mt CO_2 / yr
  - 35 Gt CO_2 / yr in emissions
-
- 1 Mt CO_2 / yr US plant planned for 2024
  - Permanent burial and fuel
  - Eligible for US and California tax credits

Carbon Engineering

Summary

Pros

- Effective when done at large scale
- Could be profitable in future markets

Cons

- Needs lots of energy:
  - Energy from fossil fuels would have net negative impact
  - Much less efficient than capturing from source
- Current technology and market

Carbon Farming

Why agriculture?

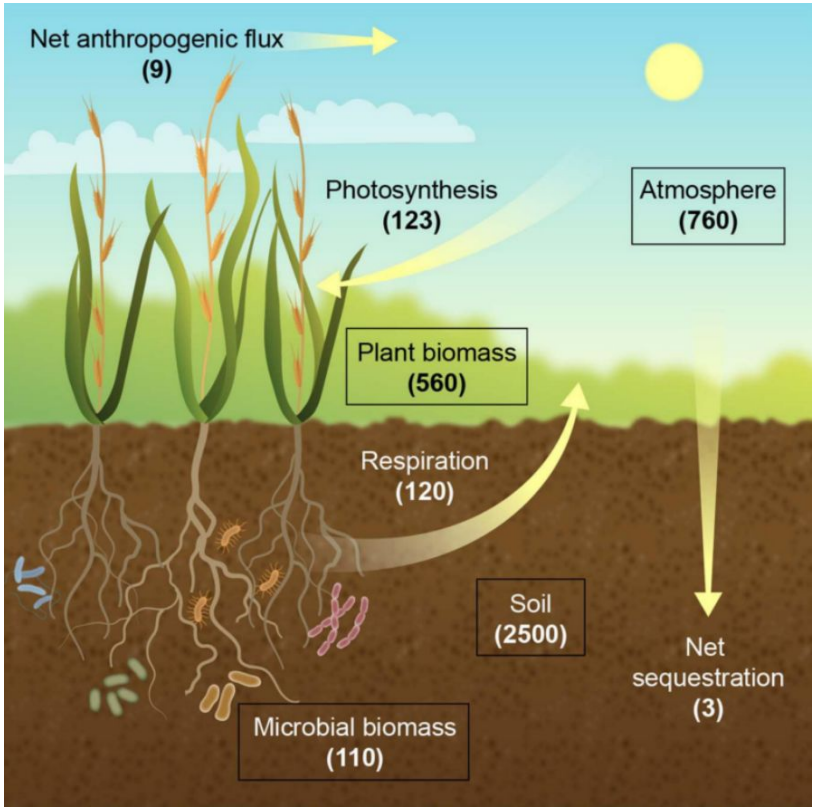
Agriculture is both a **carbon sink**...

- Vegetation / root systems
- Soils

...and a **carbon source**... (10-14% of global GHG emissions)

- Nitrogen-based fertilizers
- Livestock
- Poor soil management

Why agriculture?



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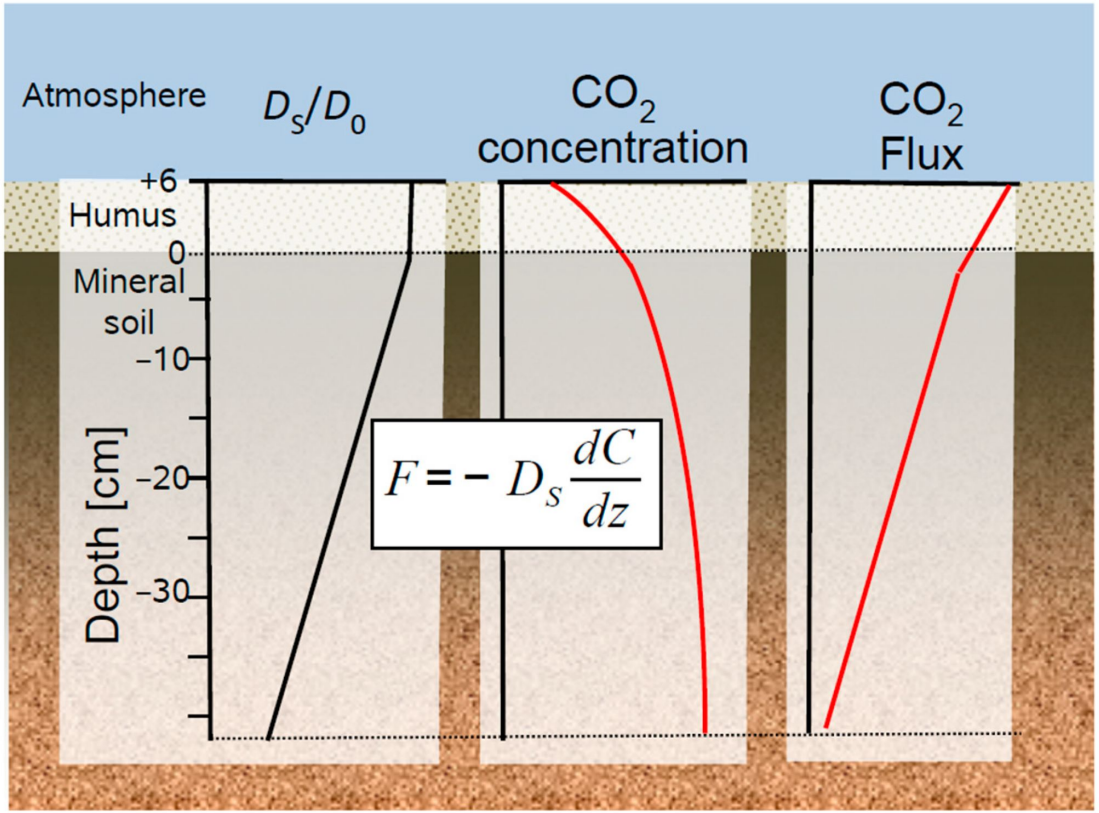

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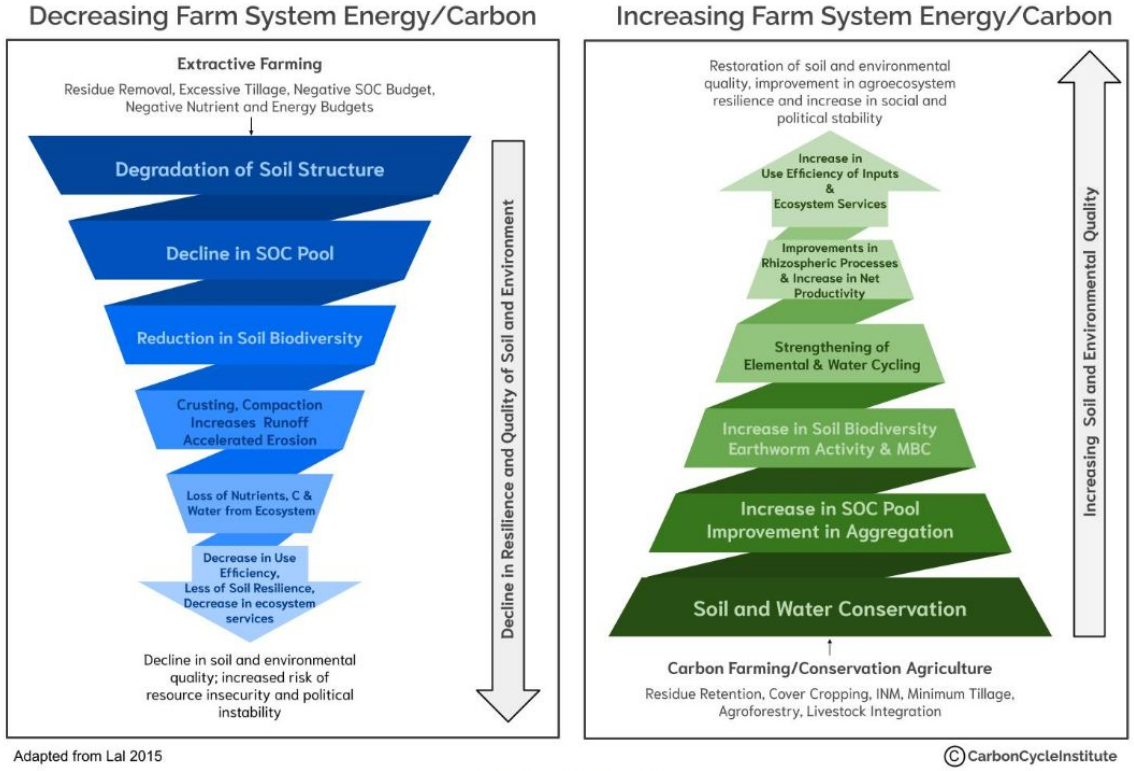
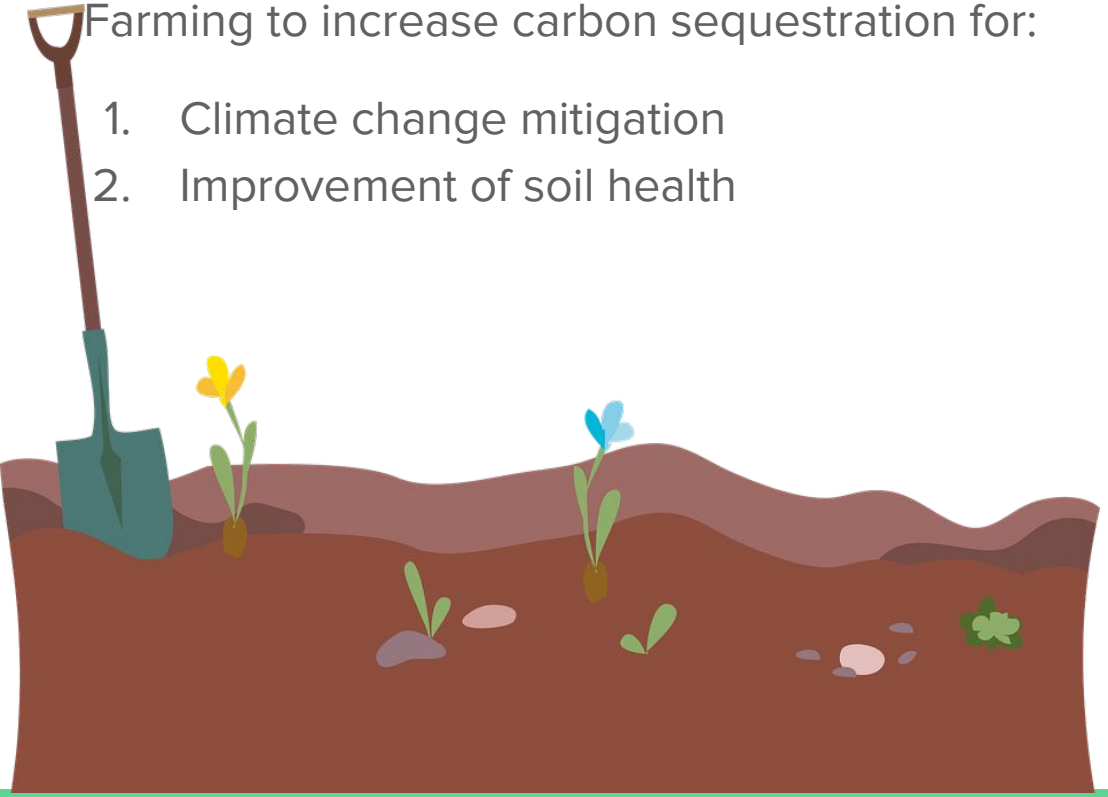


Adapted from Lal 2015.

What is carbon farming?

Farming to increase carbon sequestration for:

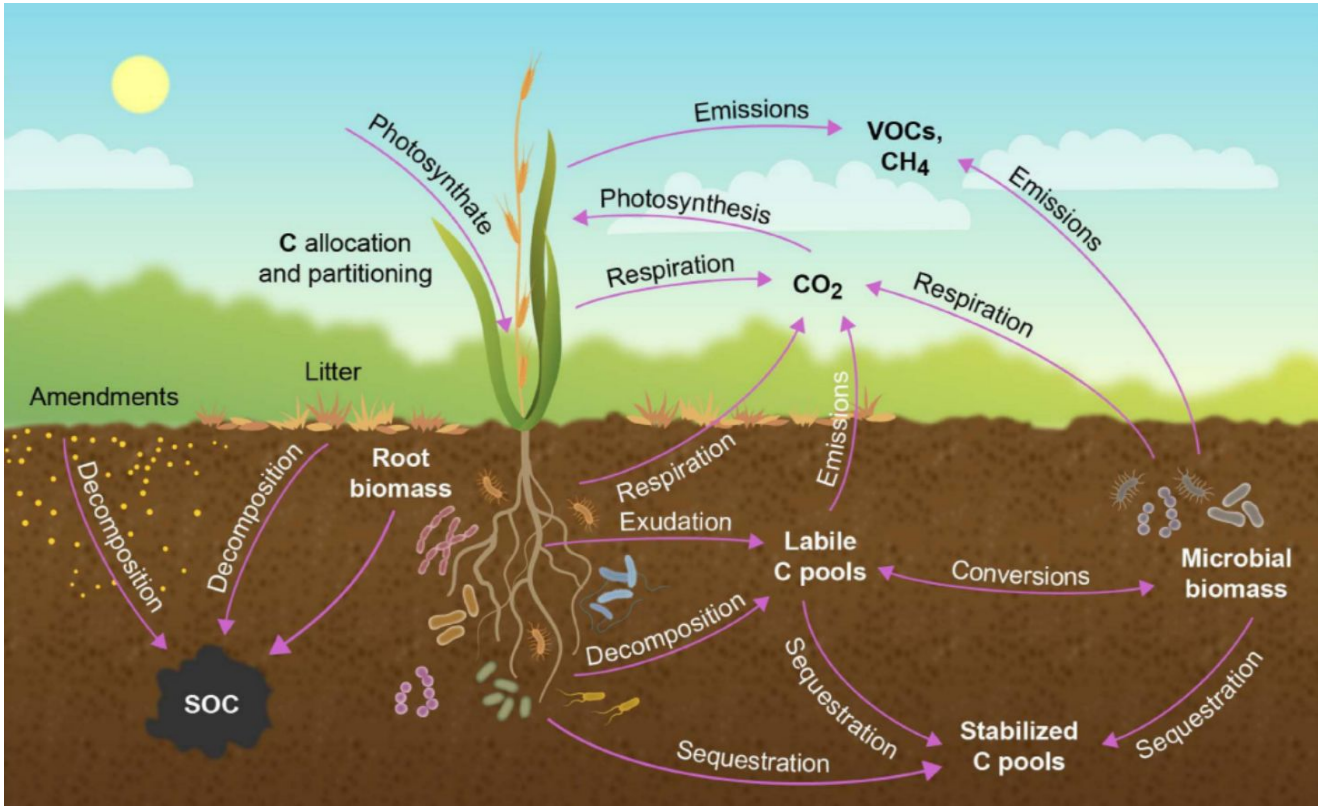
1. Climate change mitigation
2. Improvement of soil health



How does carbon farming work?

- Increase soil organic carbon (SOC)
  - Prompts “nutrient retention and water holding capacity”
  - Minimizes topsoil erosion
  - Supports microbiomes
- Conversion of SOC to sequestered forms of carbon

How does carbon farming work?



Examples of carbon farming:

- Return of leftover biomass
- Conservation tillage / no tillage
- Cover crops grown in off-season
- Crop rotation
- Integrated croplands (mimic natural ecosystems)

Carbon Mineralization

Weathering is a part of the carbon cycle

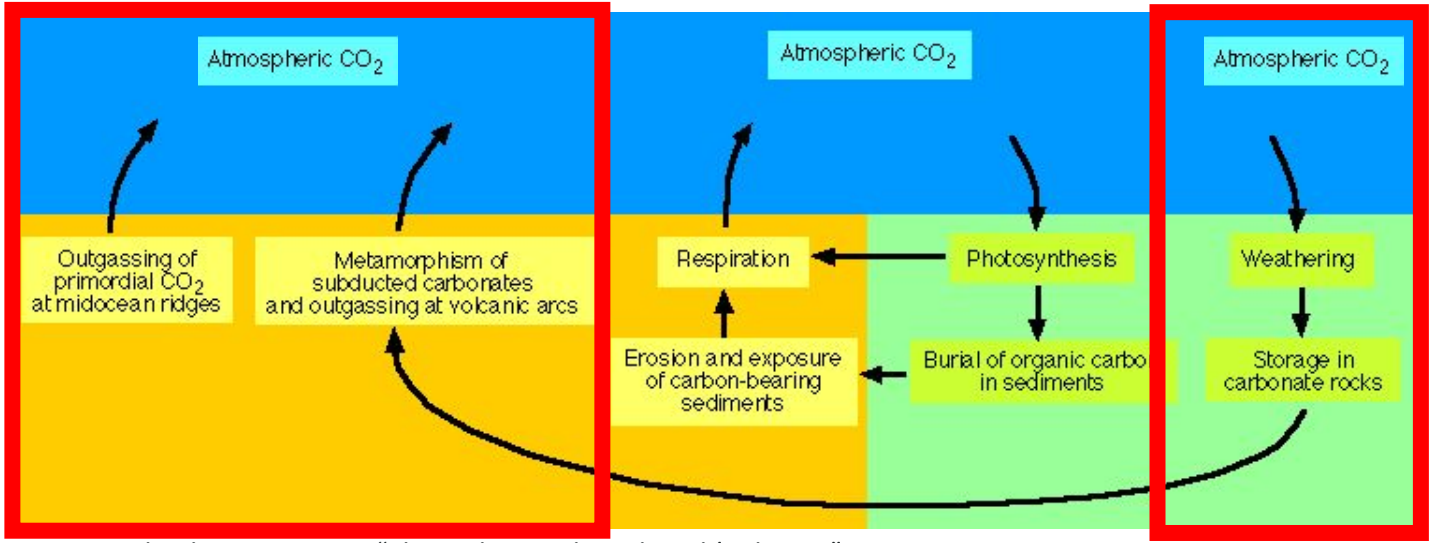
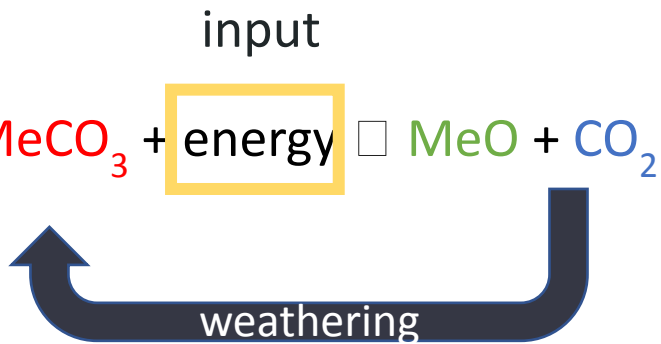


Image: Columbia University - “The Carbon Cycle and Earth’s Climate”

Pairing enhanced weathering with calcination can allow mineral feedstocks to repeatedly capture CO_2

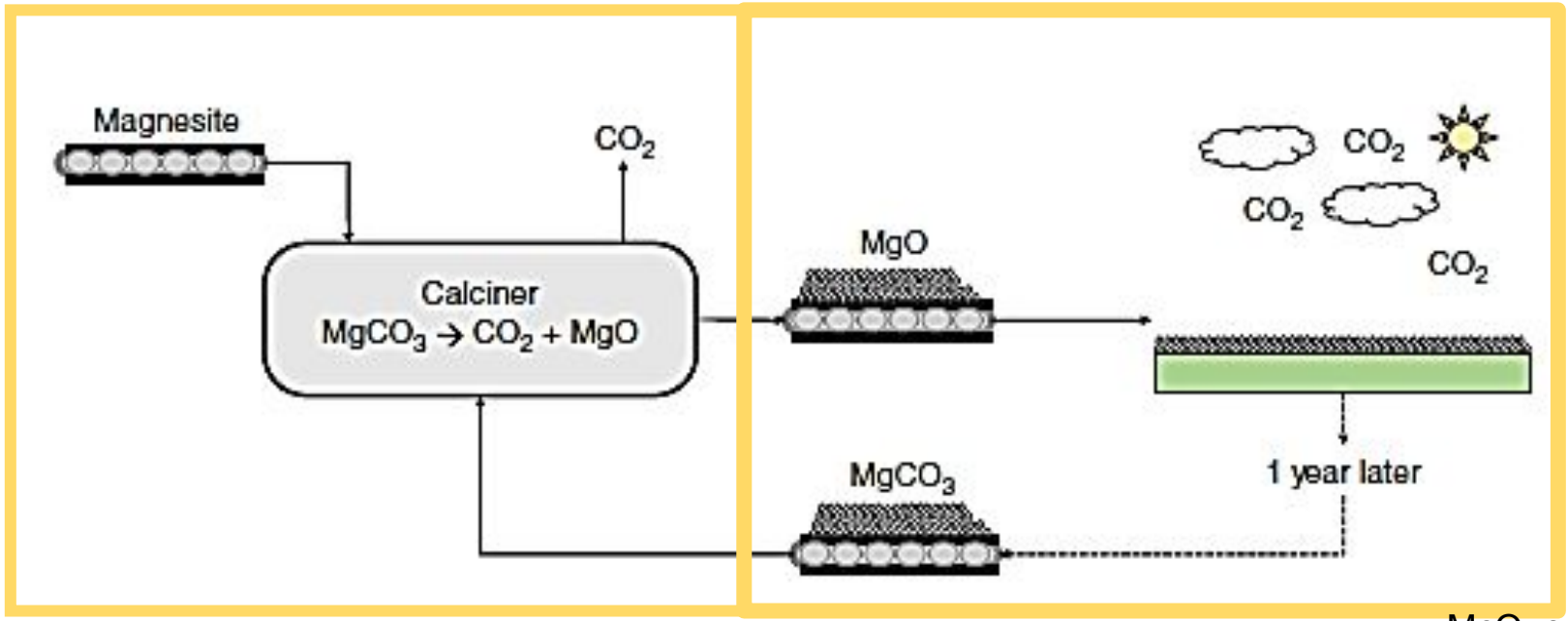
Natural weathering: $MeO(SiO_2) + CO_2 \rightarrow MeCO_3 + SiO_2$ + energy



McQueen et al., 2020

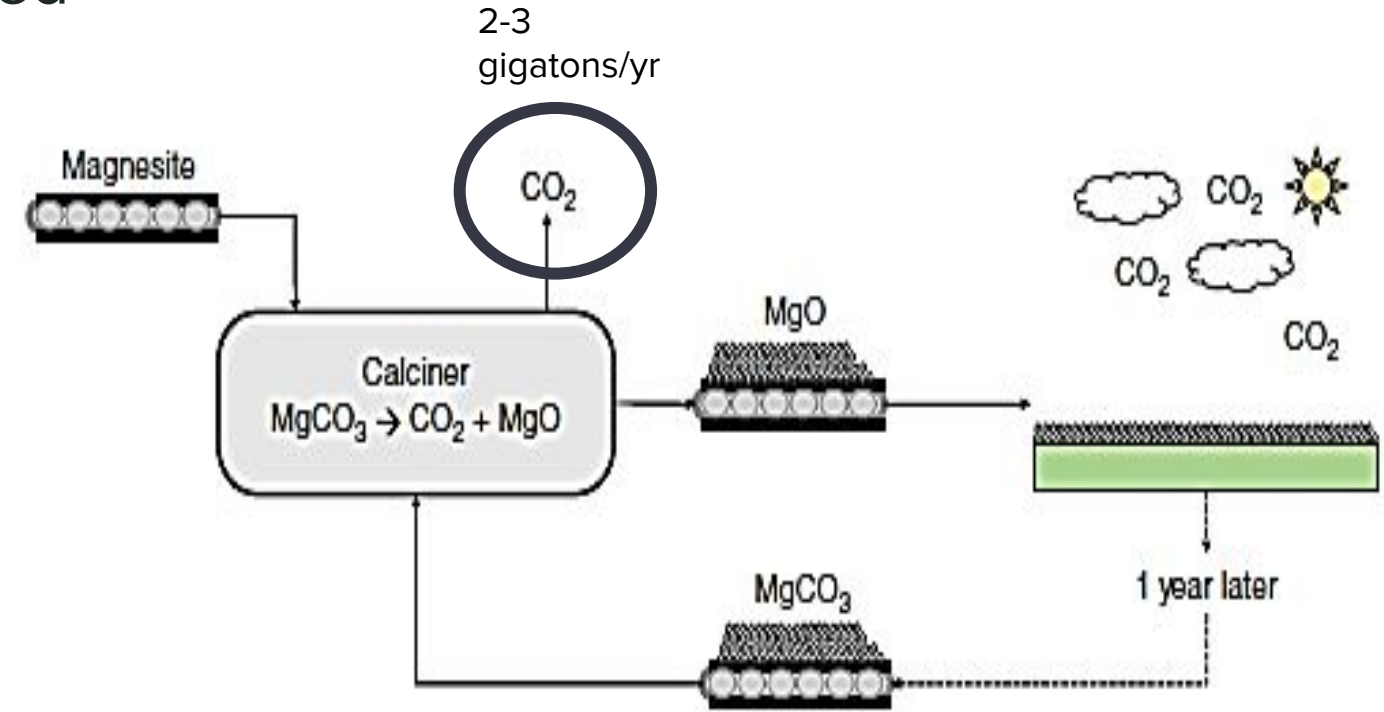
The cycle of calcination and weathering can be applied to magnesite to remove CO_2 from the atmosphere

Calcination: $MgCO_3$ + energy → $MgO + CO_2$ Weathering: $MgO + CO_2 \rightarrow MgCO_3$



McQueen et al., 2020

Pure CO_2 can be compressed and sold or permanently stored



McQueen et al., 2020

Further improvements in technology could make this process more cost effective and energy efficient

Energy intensive processes:

- Calciner
- Transporting materials
- Mixing the fields of MgO
- CO_2 condensation and storage

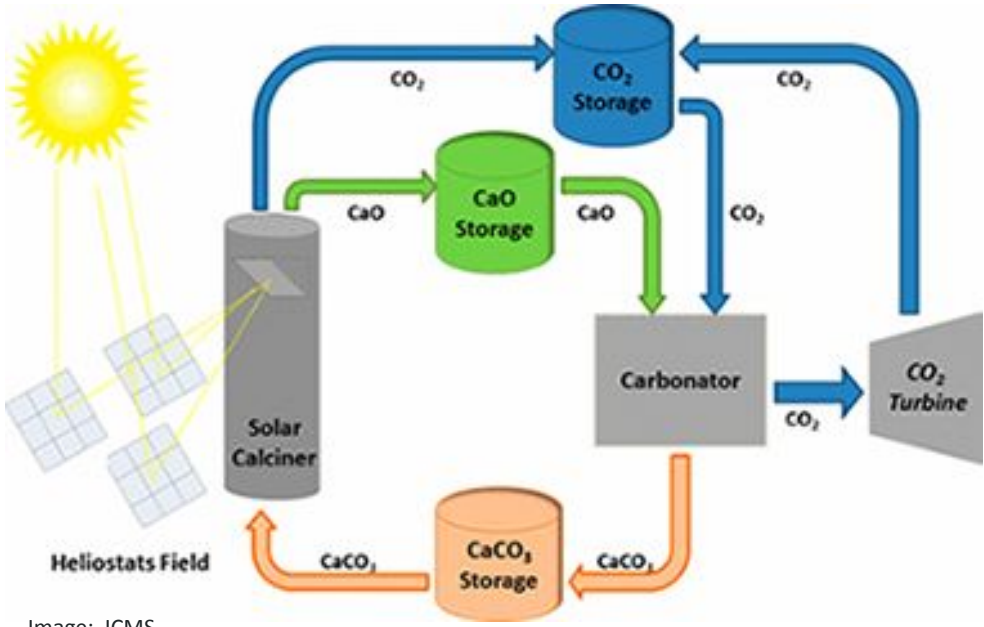


Image: ICMS

Conclusions

- Carbon can be removed directly from the air
- Technologies are new, still undergoing optimization, and costly
- Natural processes are slow–but may be accelerated

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