

Geoengineering 2: Air-Capture of CO₂

EES 2110

Introduction to Climate Change

Jonathan Gilligan

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Albedo Control as Technological Fix

Albedo Control as Technological Fix

1. Cause-Effect Relationship?

- Mismatched changes: incoming shortwave vs. outgoing longwave
- Feedbacks
- Temperature vs. precipitation
- Geographic distribution
- Ocean acidification

2. Assessable Effects?

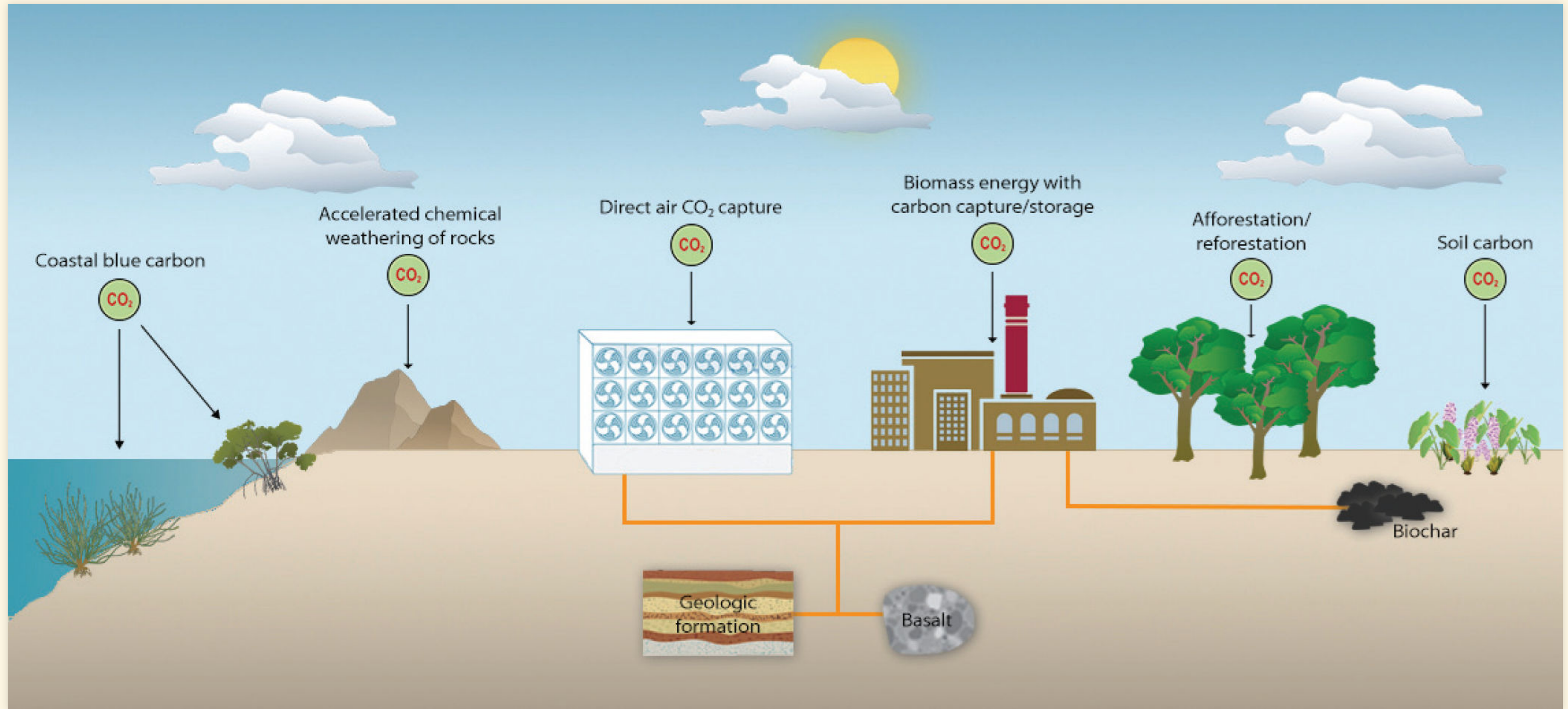
- No way to test it on small scale
- No way to assess unintended consequences

3. Established Technological Base?

- No “practice earth” for testing
- Can’t build it incrementally

Air-capture of CO₂

Technologies



Trees

- Trees capture around 920 metric tons of CO₂ per sq. mile per year, for 20–50 years
- US emissions: 6.5 billion metric tons per year
 - Plant 7.1 million square miles every 35 years
 - 200,000 square miles per year (a circle 250 miles across)
 - Tennessee = 109,000 square miles
 - Texas = 270,000 square miles
 - Lower 48 = 3 million square miles

Forests and Soil

Potential capture/storage rates (GT CO₂ per year)

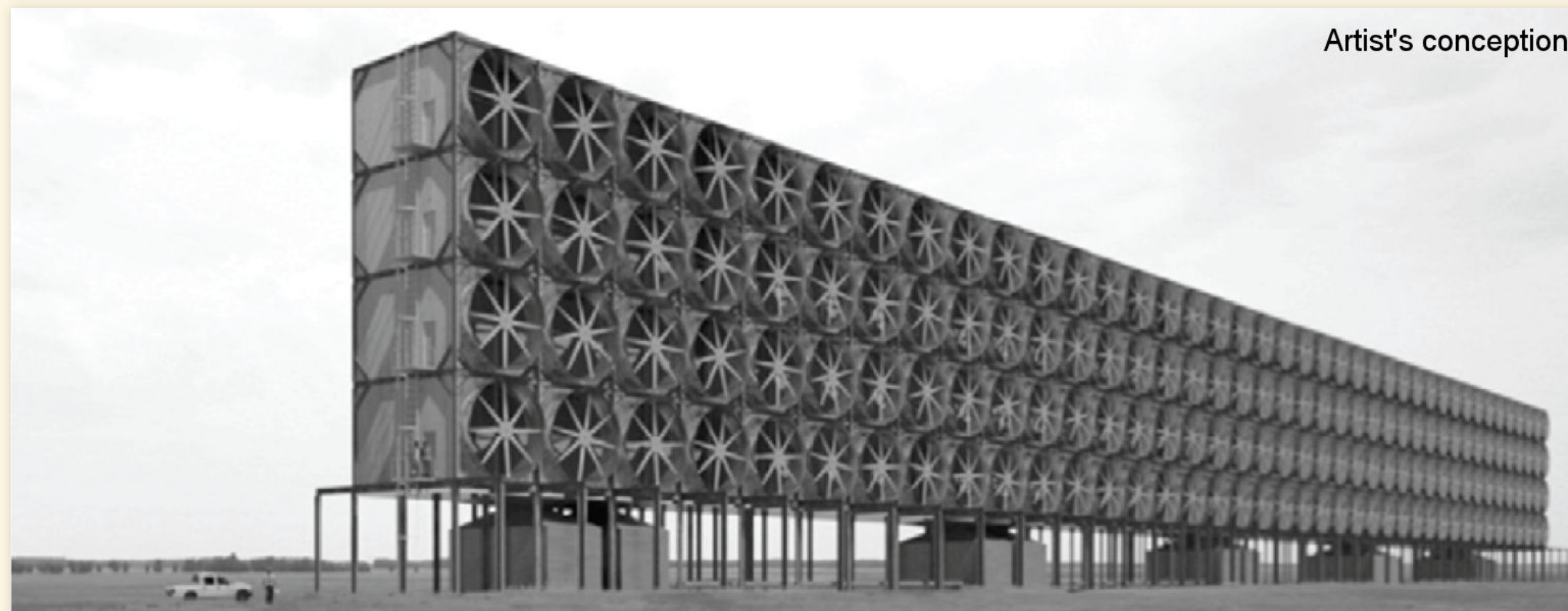
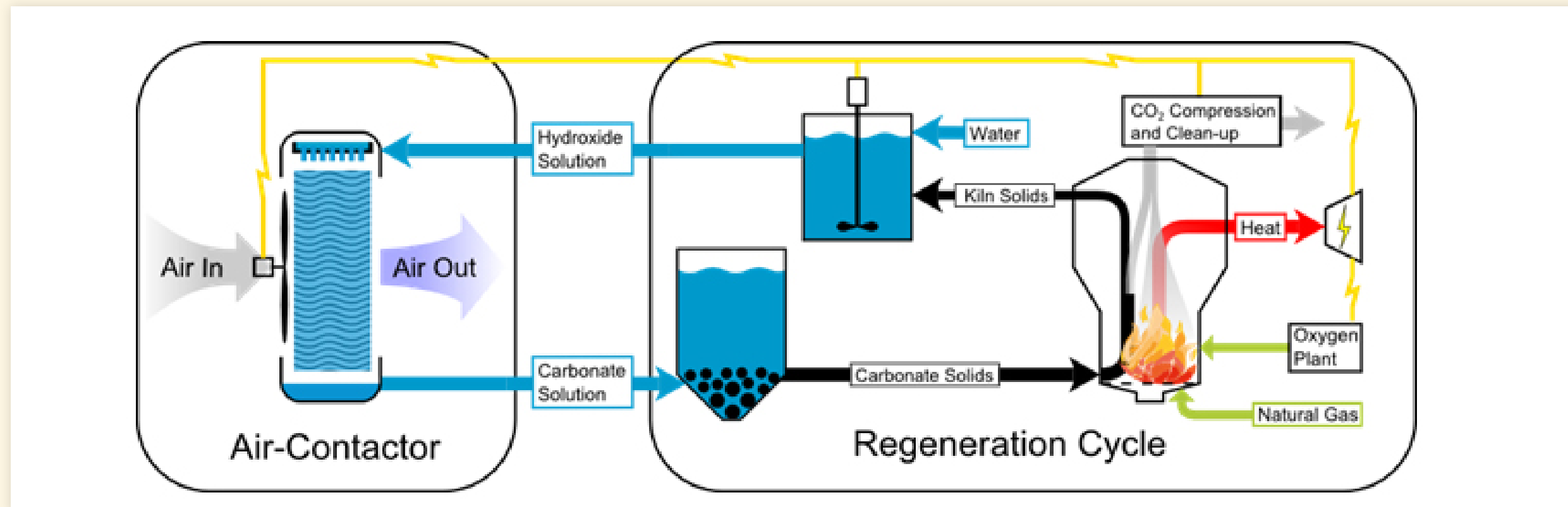
Technology	Cost	US	Global
Forest Growth	Low	0.15	1.0
Forest Management	Low	0.10	1.5
Agriculture/Soils	Low to Med	0.25	3.0
Total		0.50	5.5

National Research Council, *Negative Emissions Technologies and Reliable Sequestration*, (2019)

- For comparison, global emissions in 2022 were 37 billion tons, so forests and soil can capture around 27% of global emissions.

Direct Air-Capture ("Artificial Trees")

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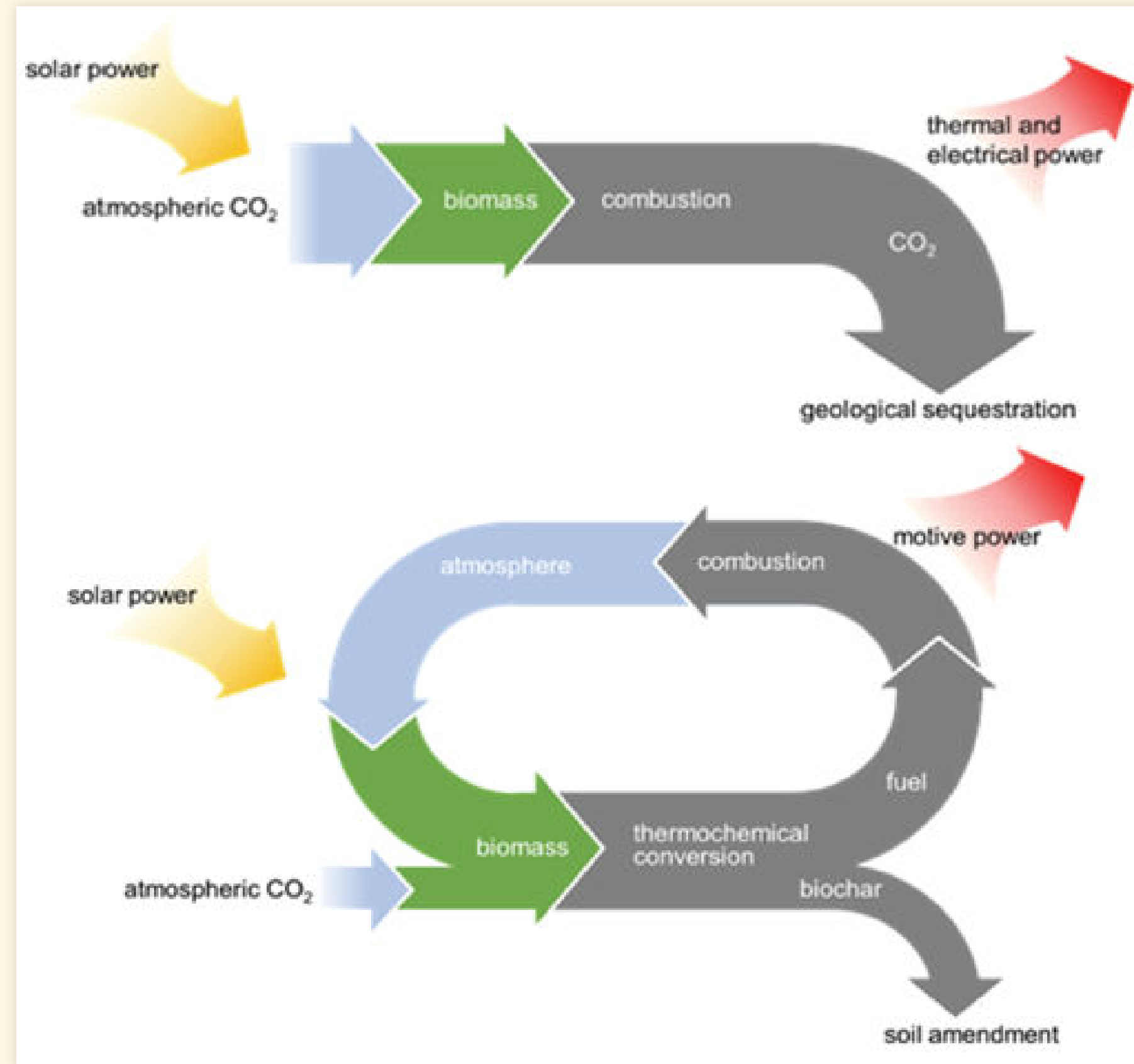


Feasibility of Direct Air-Capture

- Possible in principle
- Hasn't been tried on large scale
- Very expensive
- Why it's not hopeless:
 - National Academy Estimates: \$90–600/ton
 - Capture from smokestack uses 30% of energy from power plant
 - CO₂ in air is 300 times more dilute
 - Doesn't take 300 times more energy
 - Takes 1.5–3.4 times as much

Bioenergy with Carbon Capture and Storage (BECCS)

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Bioenergy with Carbon Capture and Storage (BECCS)

- Biomass production for fuel is already in wide use
- Carbon capture is not currently used, but would be three times as energy-efficient as direct air capture.
- Estimated costs:
 - For power plants: \$70/ton
 - For vehicles: \$40–130/ton
- Concerns about impact of converting so much land to energy production.

Feasibility of Air Capture

Cost & Capacity of Air Capture

Technology	US	Global	Cost per Ton CO ₂
Coastal	0.02	0.13	\$0
Forest Growth	0.15	1.00	\$70–90
Forest Management	0.10	1.50	\$250–500
Agriculture/Soils	0.25	3.00	\$0–50
BECCS	0.50	4.35	\$30–130
Direct Air Capture	NA	NA	\$90–600
Total Storage Capacity	1.00	9.98	

Cost of Air Capture

- Cost to capture all human emission:
 - At \$140/metric ton CO₂:
 - \$6–8 trillion: 10–15% of world GDP
 - At \$27/metric ton CO₂:
 - \$1.2–1.5 trillion: 2–3% of world GDP
- Is it worth it?
 - Stern: “If mitigation costs 1% of world GDP by 2100 ... this is equivalent to growth rate dropping from 2.50% to 2.49%”
 - GDP in 2100 would still be 950% greater than today.

Air-Capture as Technological Fix

1. Cause-Effect Relationship?

- Yes: Removing CO₂ would cancel adding CO₂

2. Assessable Effects?

- Yes: We can measure CO₂ concentrations
(almost 70 years experience)

3. Established technological base?

- Laboratory projects to build on
- Challenge is scaling up

4. What's missing?

- Where to store CO₂ after we capture it?

Scaling Up

An apparatus the size of a semi trailer could remove a ton of carbon dioxide per day, or 365 tons a year.

The world's cars, planes, refineries, and power plants now produce about thirty six billion tons of CO₂ annually, so ...

... if you built a hundred million trailer-size units you could actually keep up with current emissions.

— Elizabeth Kolbert, The New Yorker, 20 Nov. 2017

Should Geoengineering
Be on the Table?

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- Playing God argument
- Moral hazard argument
- Illusion of safety argument

Recent Scholarship

Negative-emission technologies are not an insurance policy, but rather an unjust and high-stakes gamble. There is a real risk they will be unable to deliver on the scale of their promise.

The promise of ... negative-emission technologies is more politically appealing than ... rapid and deep mitigation now.

If we rely on [negative-emission technologies] and they are ... unsuccessful at removing CO₂ from the atmosphere at the levels assumed, society will be locked into a high-temperature pathway.

— K. Anderson & G. Peters, *Science* **354**, 182 (14 Oct., 2016)

Context

The IPCC considered more than 1000 possible [emissions] scenarios.

Of these, only 116 limit warming to below [2°C], and of these 108 involve negative emissions.

In many below-two-degree scenarios, the quantity of negative emissions ... reaches the same order of magnitude as the “positive” emissions being produced today.

— E. Kolbert, The New Yorker, 20 Nov. 2017

*You might say it's against my self-interest to say it,
but I think that, in the near-term, talking about carbon removal is silly,
because it almost certainly is cheaper to cut emissions now
than to do large-scale carbon removal.*

*— David Keith,
Founder, Carbon Engineering
(carbon capture company)*

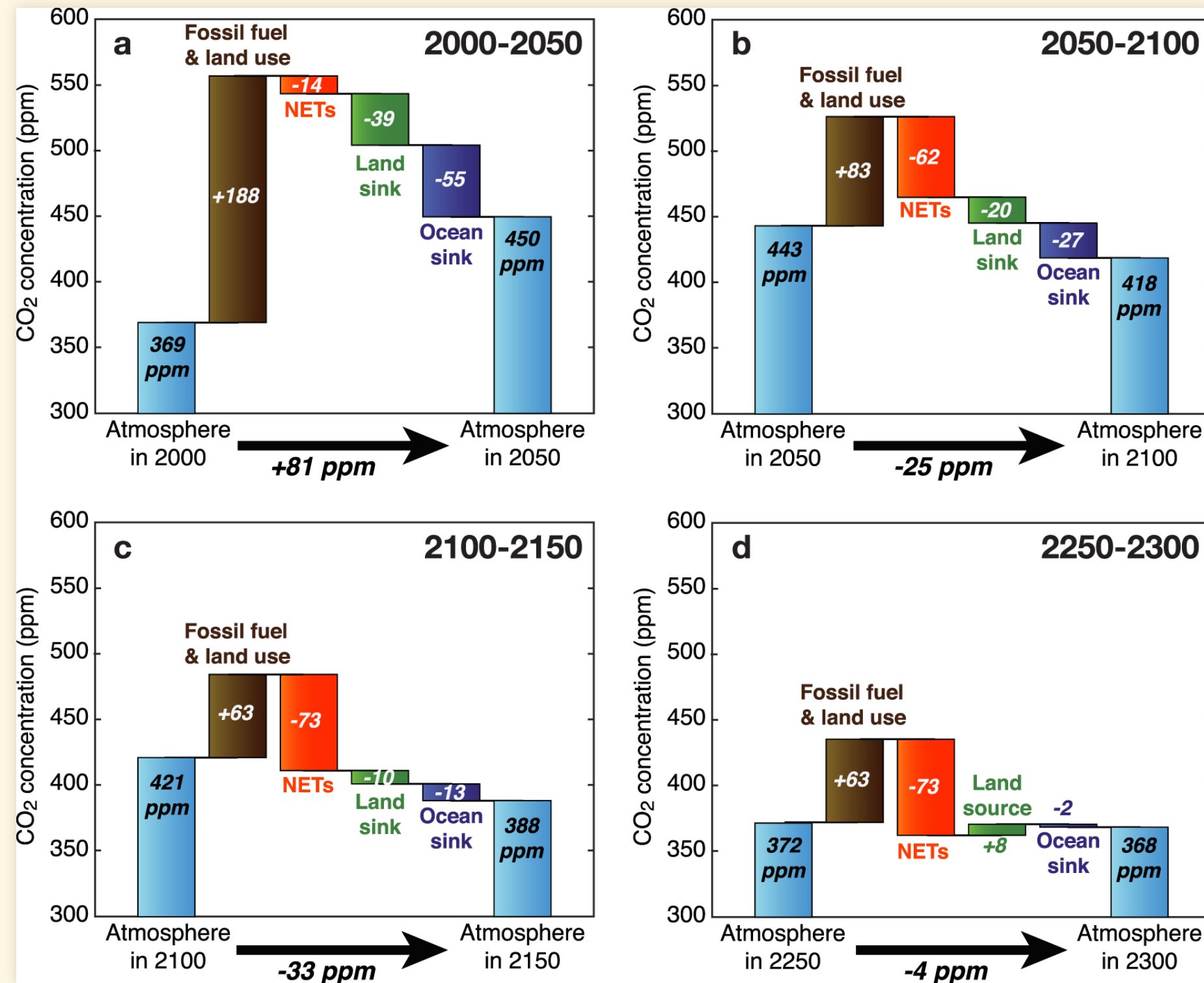
*The punch line is, it doesn't matter. We actually need to do direct air capture,
so we need to create technologies to do that. Whether it's smart or not,
whether it's optimized or not, whether it's the lowest-cost pathway or not,
we know we need to do it.*

*— Julio Friedmann
former Principal Deputy Assistant Secretary (2013–2016),
Office of Fossil Energy,
U.S. Department of Energy*

National Research Council Report (2019)

Negative emissions technologies are best viewed as a component of the mitigation portfolio, rather than a way to decrease atmospheric concentrations of carbon dioxide only after anthropogenic emissions have been eliminated.

National Research Council Report (2019)



Comparing Imperfect Solutions

- Mitigation
 - Cut emissions
 - Geoengineering
- Adaptation
- Do nothing

*“We have three options:
mitigation, adaptation, and suffering”
— Prof. Lonnie Thompson*

