What is a holistic approach to climate intervention?

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1. Introduction to climate intervention

2. A holistic approach to climate response makes the research more **relevant, reliable, and responsible**

3. **Co-producing research** with communities could help guide a holistic approach

SOLAR GEOENGINEERING AS A TIME-LIMITED PROJECT

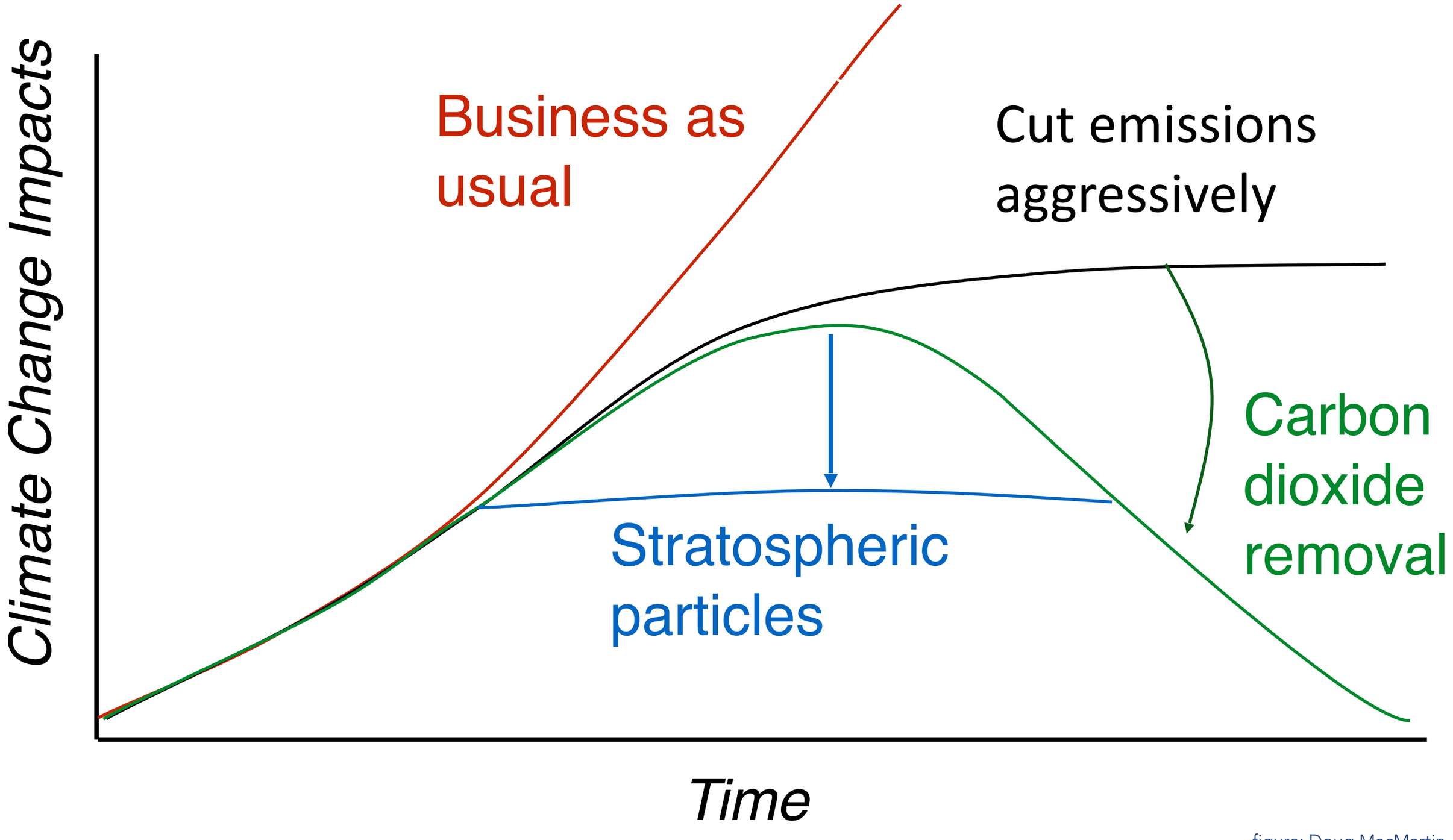


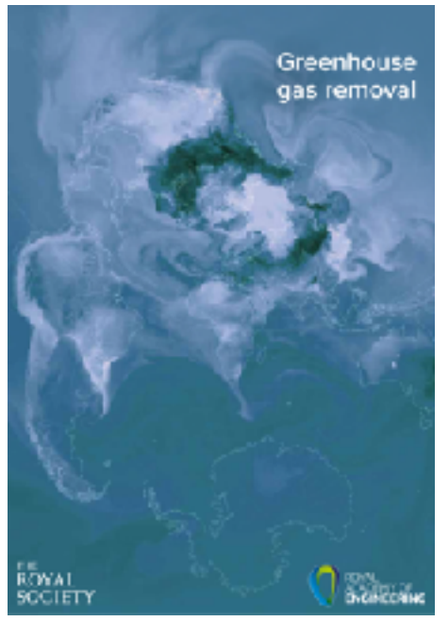
figure: Doug MacMartin

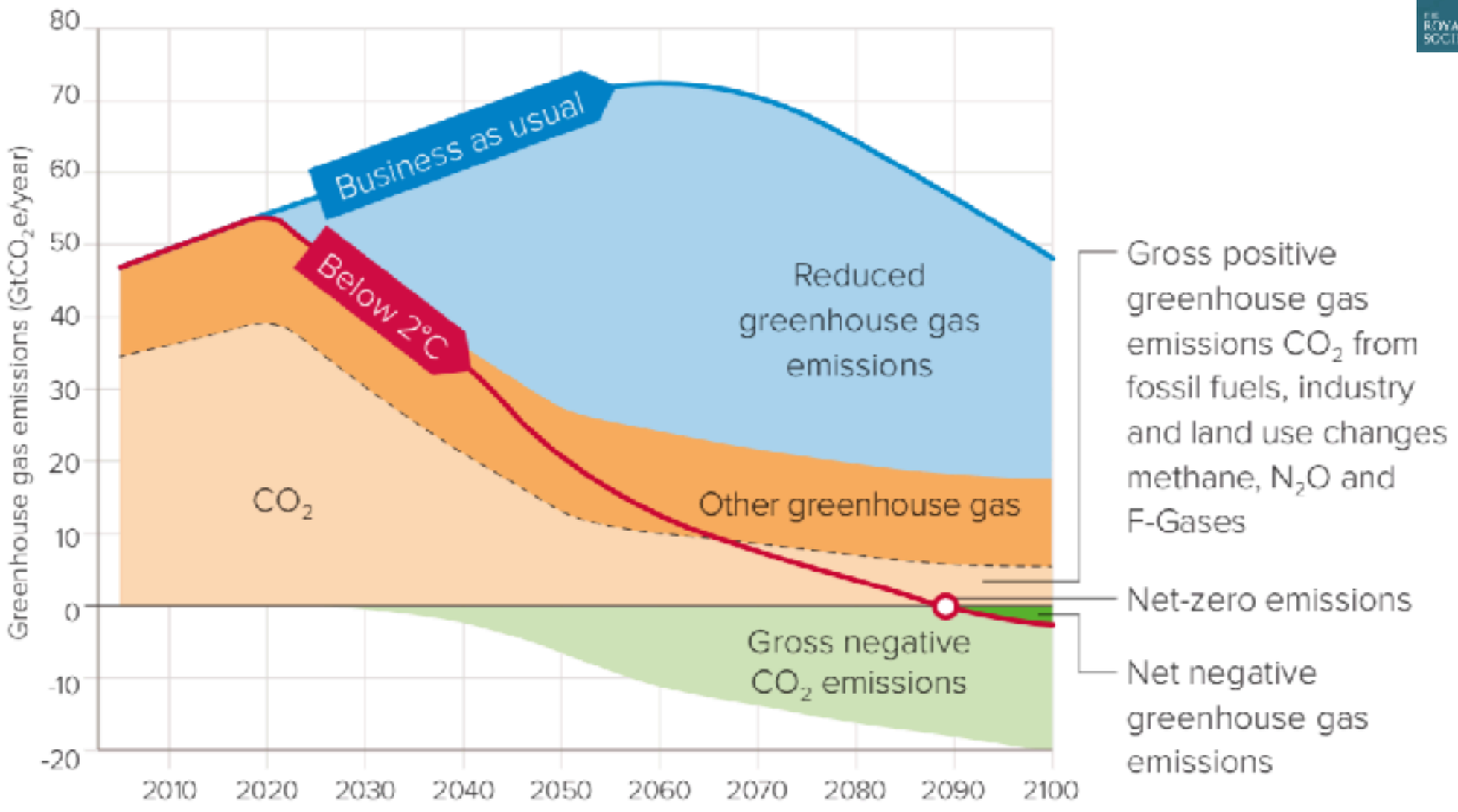
2020: Limiting warming to 1.5°C relies upon **removing carbon from the atmosphere**

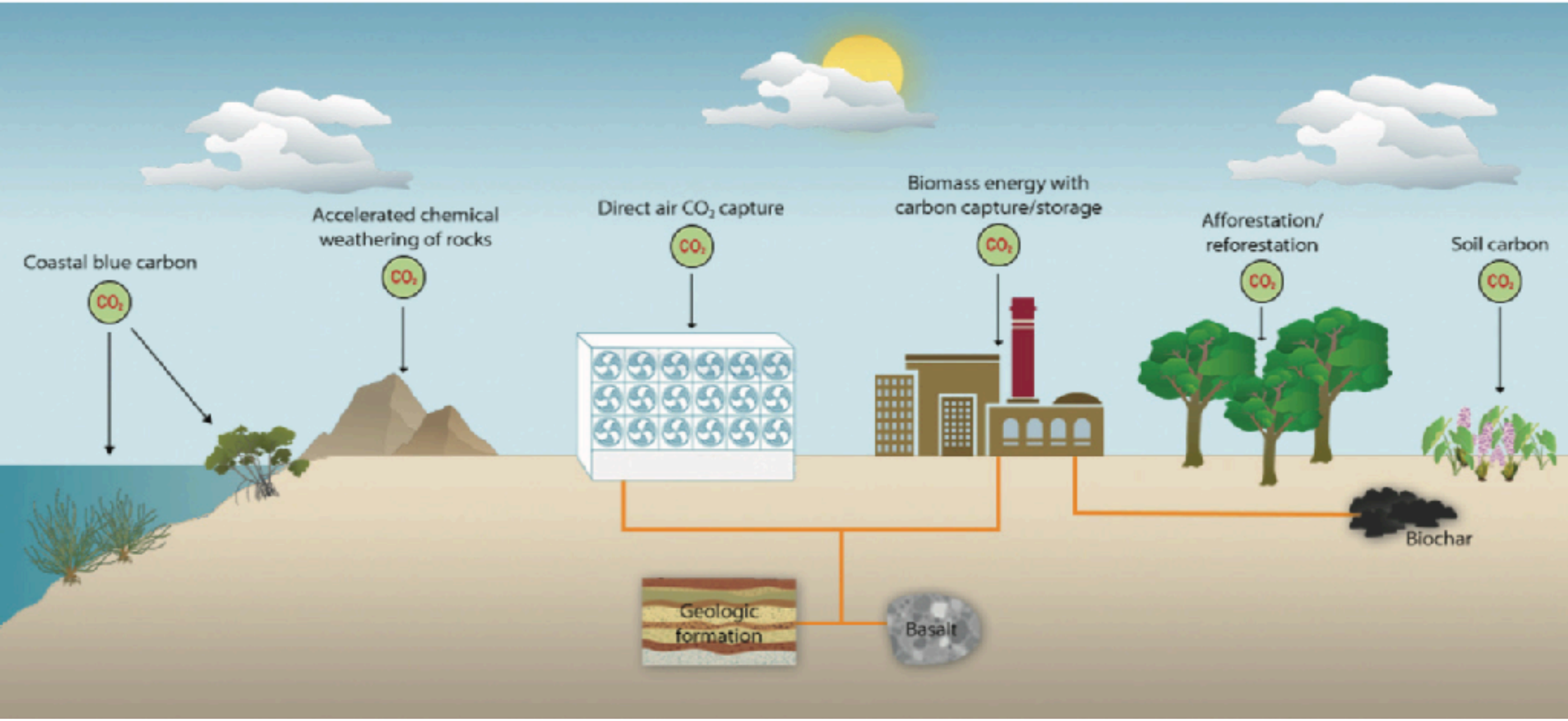
IPCC Special Report on 1.5° C

C3. All pathways that limit global warming to 1.5°C with limited or no overshoot project the use of carbon dioxide removal (CDR) on the order of 100–1000 $GtCO_2$ over the 21st century. CDR would be used to compensate for residual emissions and, in most cases, achieve net negative emissions to return global warming to 1.5°C following a peak (*high confidence*). CDR

Tight carbon budget is why people talk about **“overshooting”** temperature / emissions targets



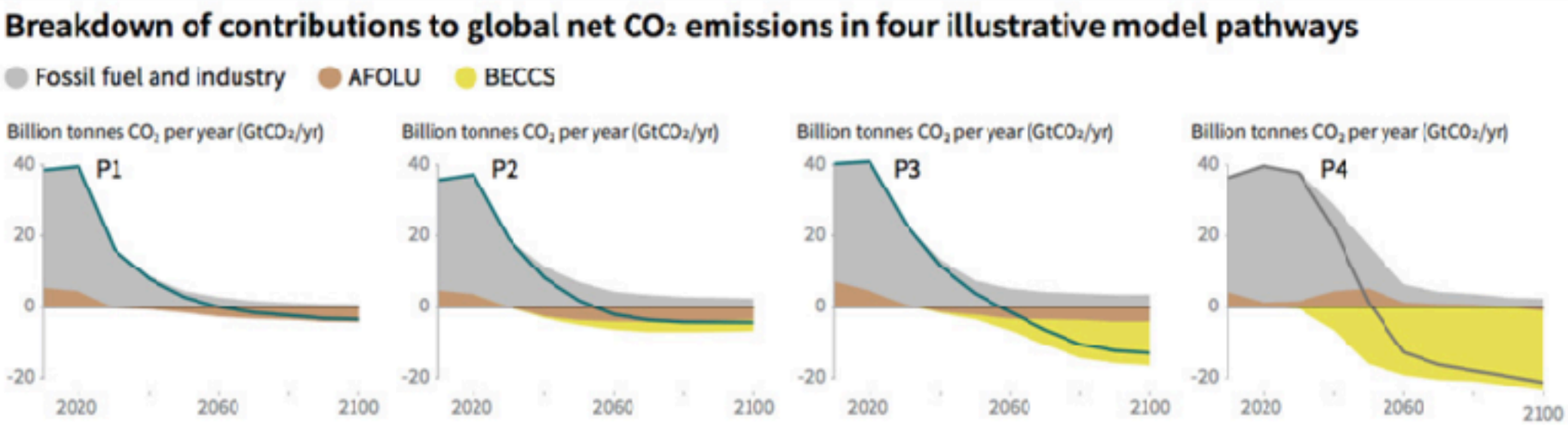




Carbon removal methods

National Academies (2018) *Negative Emissions Technologies & Reliable Sequestration*

What about relying on natural climate solutions?



Four illustrative scenarios for limiting temperature rise to 1.5C above pre-industrial levels. Grey shows fossil fuel emissions, while yellow and brown show the emissions reductions achieved by BECCS, and agriculture, forestry and other land use (AFOLU), respectively. Source: Summary for Policymakers, IPCC

- IPCC SR1.5 P1: +500m hectares to forestland; -500m hectares pasture (USA: 983m hectares)
  - nuclear grows 60% by 2030; renewables 430%

- *Everything* has to go exactly according to plan

SOME REMOVALS CAN ONLY BE DONE ONCE

	BIOENERGY WITH CCS	DIRECT AIR CAPTURE	PLANTING TREES	SOIL CARBON
YEARLY REMOVAL POTENTIAL GT CO2E/YR	3 - 5 (10 “Theoretical”)	UNKNOWN (15-18“Theoretical”)	2-5	3

National Academies (2018) *Negative Emissions Technologies & Reliable Sequestration*

Natural climate solutions like storing carbon in soils and planting trees can have biodiversity and farmer benefits

… but they can’t continue removing carbon indefinitely, because the “carbon sinks” become “saturated” after some decades

BIOENERGY WITH CARBON CAPTURE + STORAGE (BECCS)

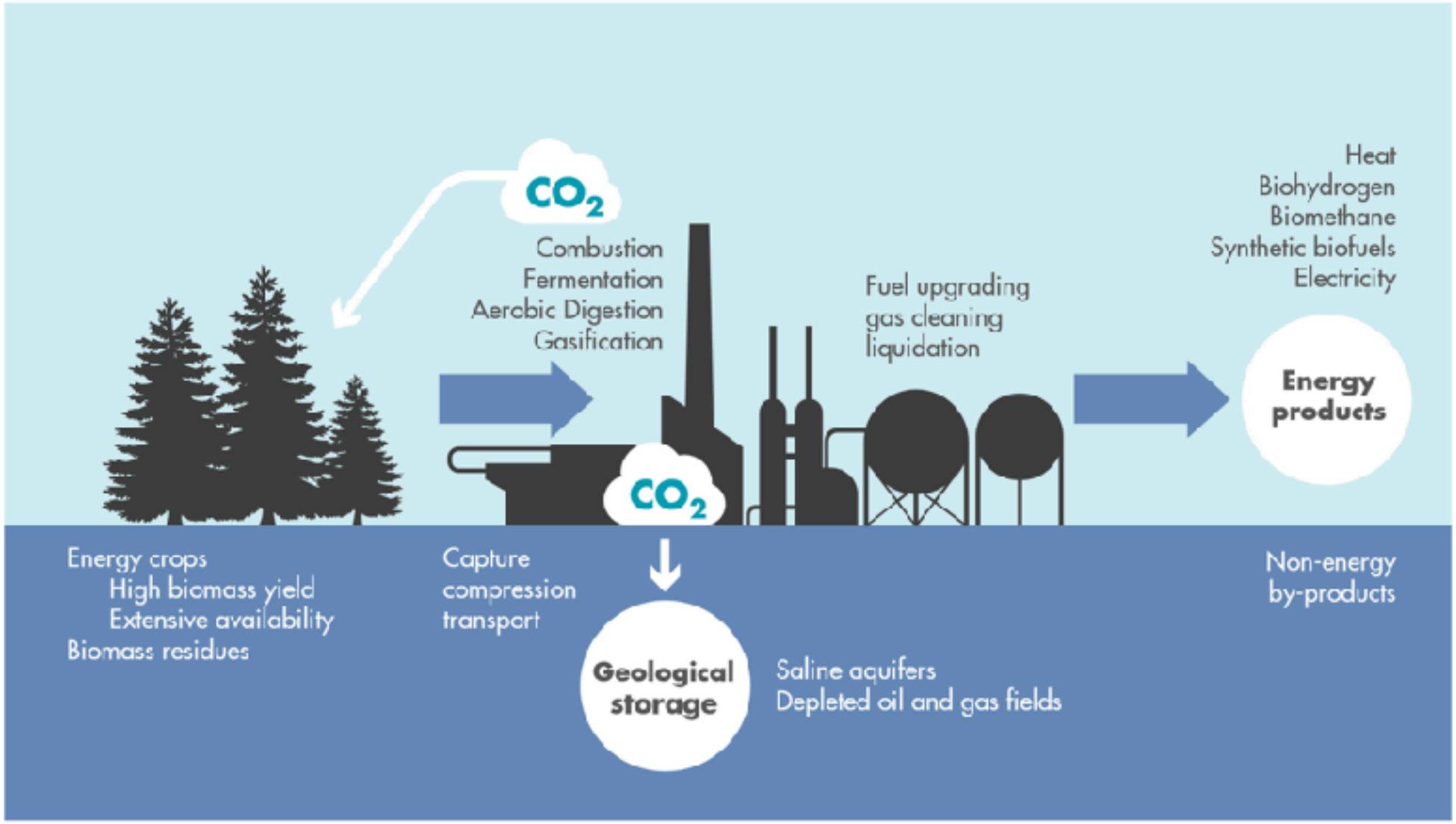


Image: https://blogs.shell.com/2018/04/11/achieving-the-balance/

This is what's already in the models

Land demands for bioenergy in 2100: **380-700 million hectares**, in a 2°C scenario (1-2 times the size of India) (see: IPCC SR on Climate Change and Land)

DIRECT AIR CAPTURE

- Extract CO2 from the air using chemicals that bind to CO2, but not to other atmospheric chemicals

- Very large energy cost at present. 1 Gt/year = 10% of today's total energy consumption in US (WRI, 2020, "Carbonshot").

- For range 850 million tons of DACS capacity — 219 GW nuclear, 494 GW wind, 658 GW solar PV (CA: ~26 GW solar right now) (Rhodium report, 2019 - Capturing Leadership)

Top: Climeworks; Bottom: Visualization by ASU Center for NCE

Carbon capture and storage (CCS) underpins these

- Roughly, need 1000 facilities per 1Gt CO2
- If you're going to draw down 10Gt CO2 by 2100…

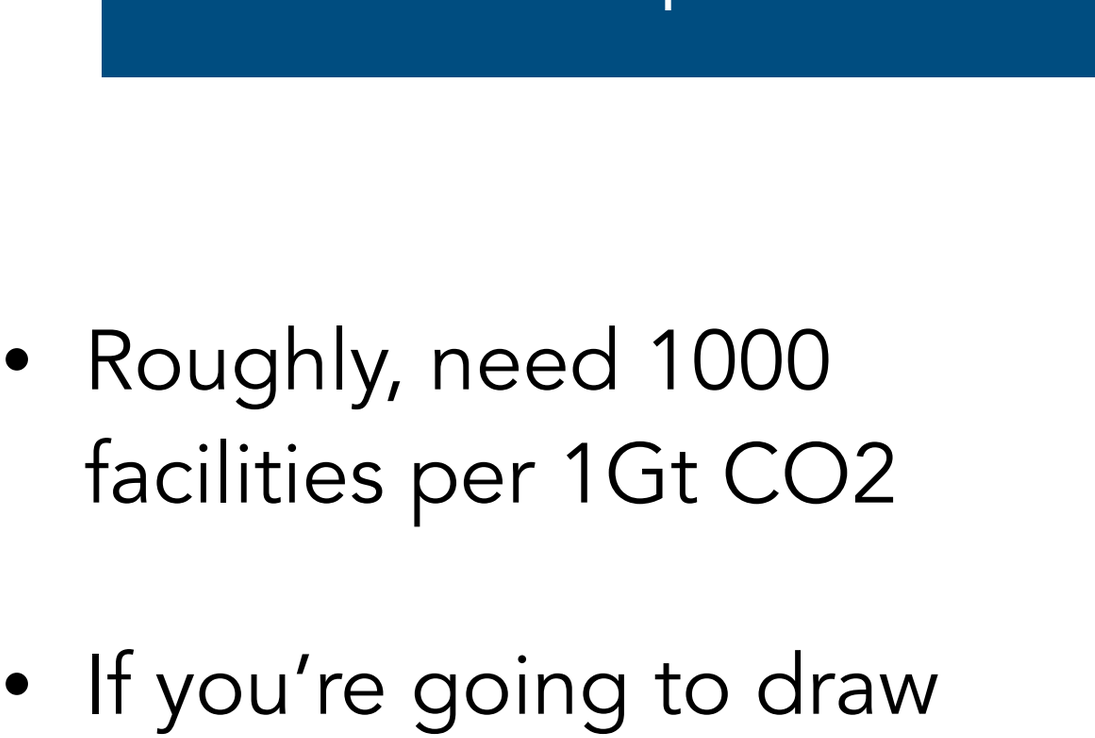


Image: Steven Vaughan

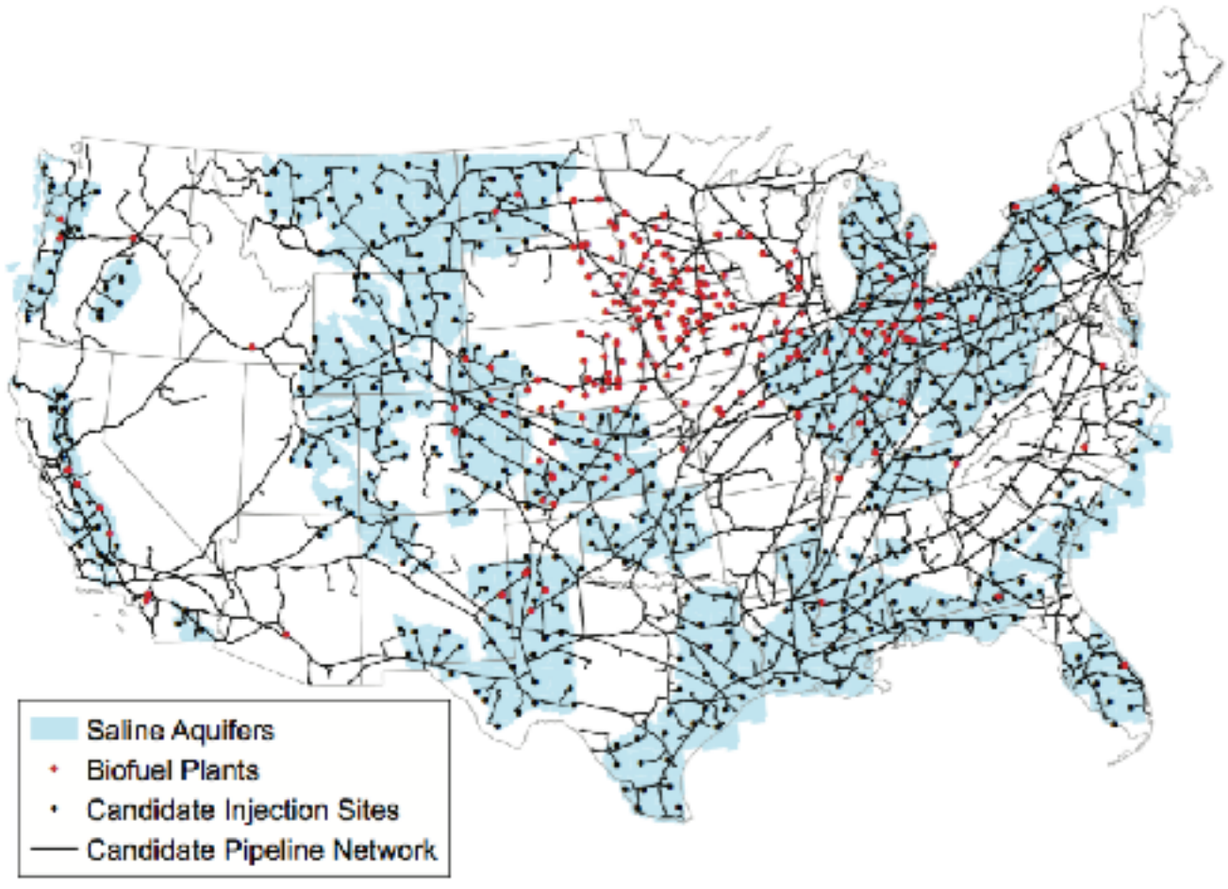


Illustration: Sanchez et al. 2018

Existing and planned ethanol biorefineries, saline aquifers for permanent storage of CO_2, candidate CO_2 pipelines, and candidate injection sites in the U.S.

Will large-scale carbon removal become a thing?

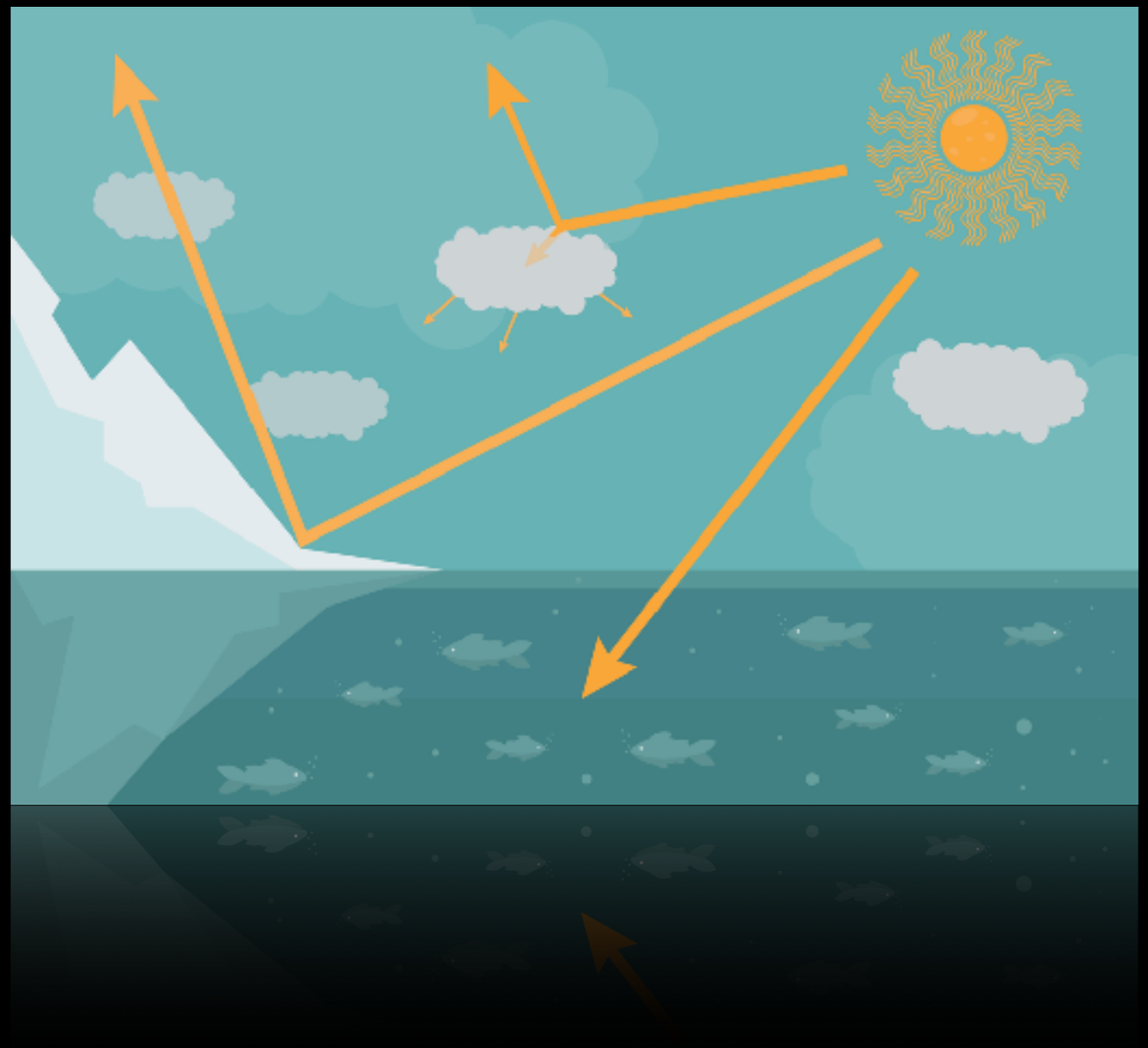
- California: Executive Order B-55-18: Carbon neutrality by 2045, “and achieve and maintain net negative emissions thereafter”
  - Low carbon fuel standard generates credits for direct air capture projects anywhere in the world (trading at ~$190/ ton)
- USA: 45Q tax credit for carbon stored ($50/ton)
- Other nations have net-zero or net-negative targets (e.g. Finland - Carbon negative after 2035)
- Recent corporate interest in carbon-negative goals

Microsoft’s quest to go ‘carbon negative’ inspires $1B fund

Heather Clancy
Thursday, January 16, 2020 - 5:01pm

Microsoft President Brad Smith, Chief Financial Officer Amy Hood and CEO Satya Nadella preparing to announce Microsoft’s plan to be carbon negative by 2030.

COOLING THE EARTH BY REFLECTING INCOMING SUNLIGHT BACK INTO SPACE?



- Increase the amount of clouds, and how reflective they are

- Put reflective particles (aerosols) in the atmosphere

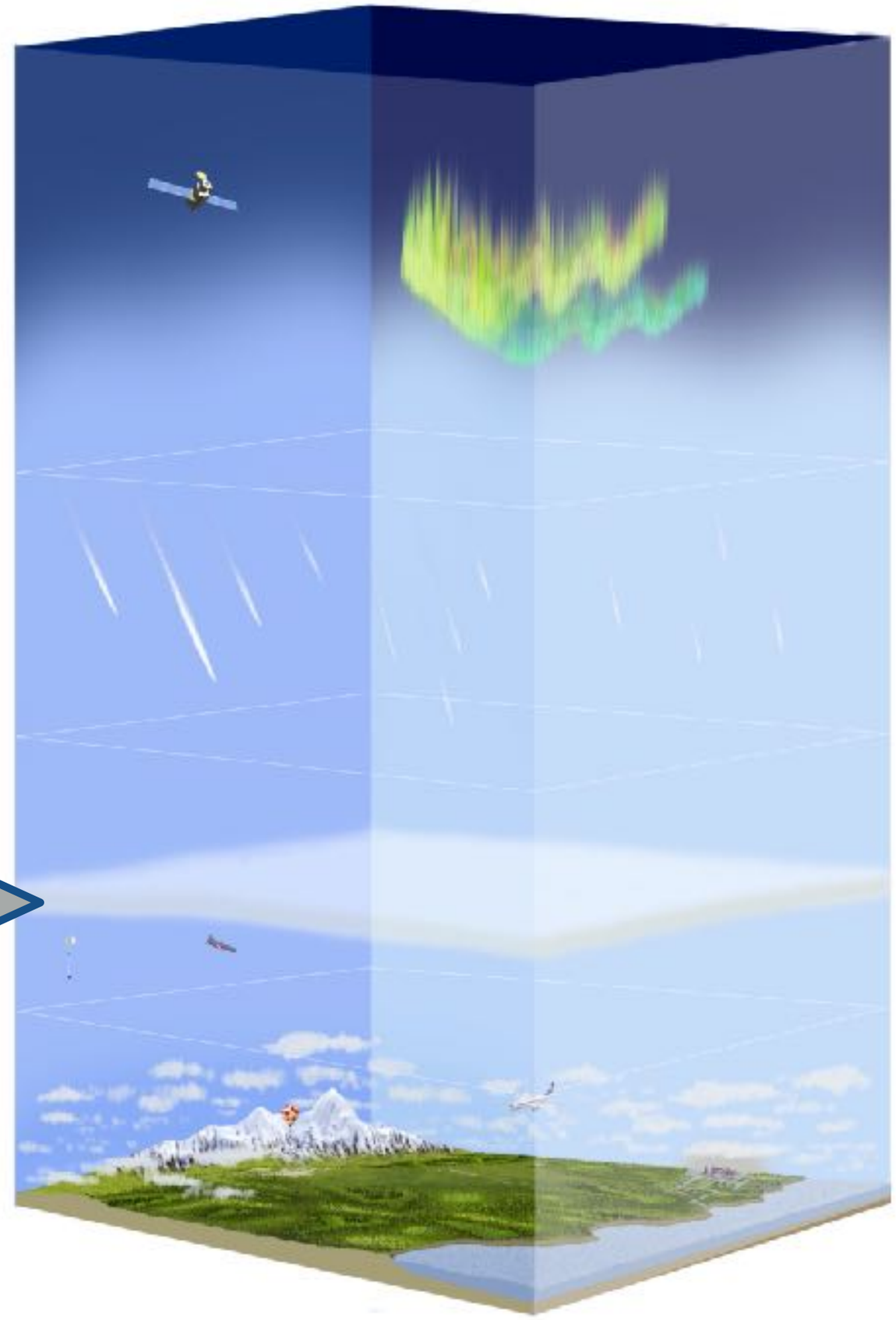
(Cleaning up sulfate aerosols may add half a degree of warming!)

Samset et al (2018) Climate Impacts From a Removal of AnthropogenicAerosol Emissions, in *GRL*

The stratosphere is a layer of the atmosphere above all clouds.

If using sulfates, particles would stay there for **1-2 years** and then fall to earth.

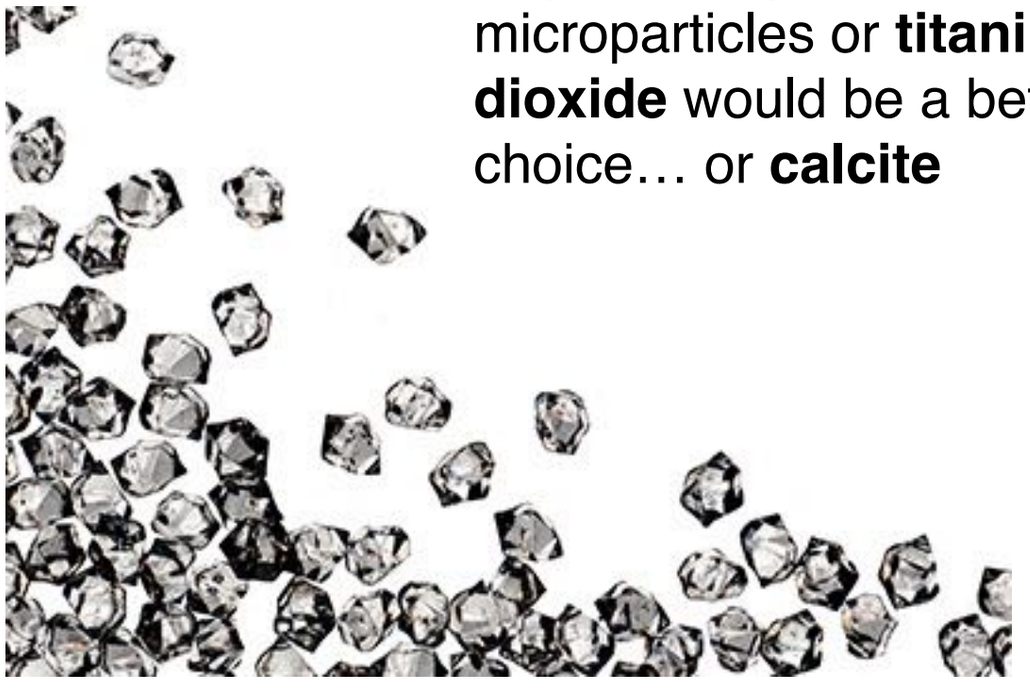
If the particles were placed in the tropics (30N-30S), they would **circulate over the whole globe.**



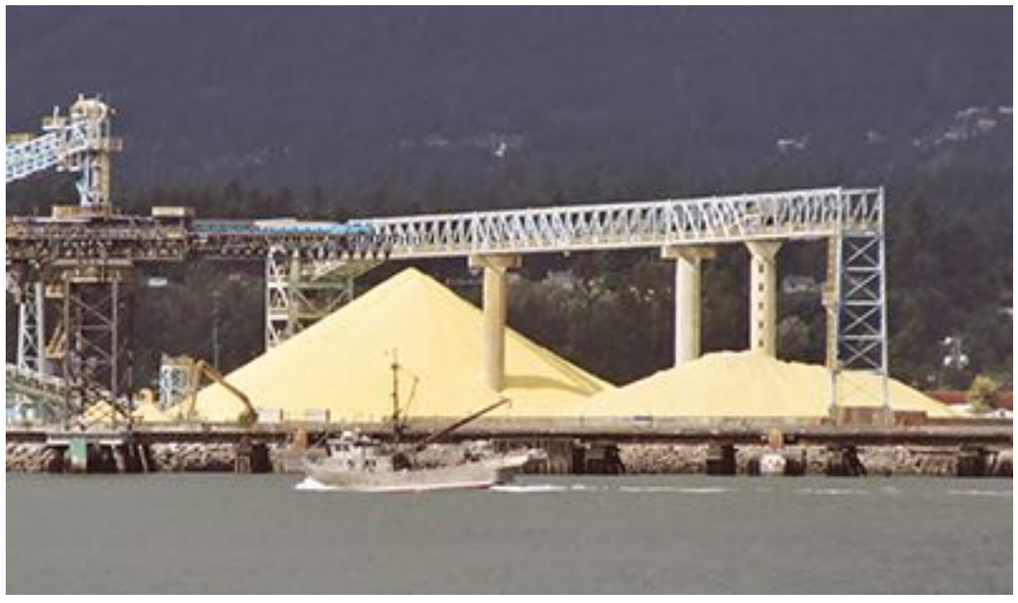
Stratospheric particles: **How** would they be placed?

Probably with a small fleet of **airplanes that are specially designed to fly in the stratosphere** and carry a load, continually flying

Stratospheric particles: **What** would be put up there?



Millions of tons of **sulfur dioxide** — potentially **diamond** microparticles or **titanium dioxide** would be a better choice… or **calcite**



…Or “nanoparticles”: microscopic reflecting composite particles that would be self-orienting and self-levitating, and thus might not have to be replaced very frequently.

Most studies have modeled sulfur.

THIS DOES NOT “RETURN” US TO A PRIOR CLIMATE…

BUT IN MODELS, IT CAN SEEM BETTER THAN THE WORST-CASE CLIMATE CHANGE SCENARIOS

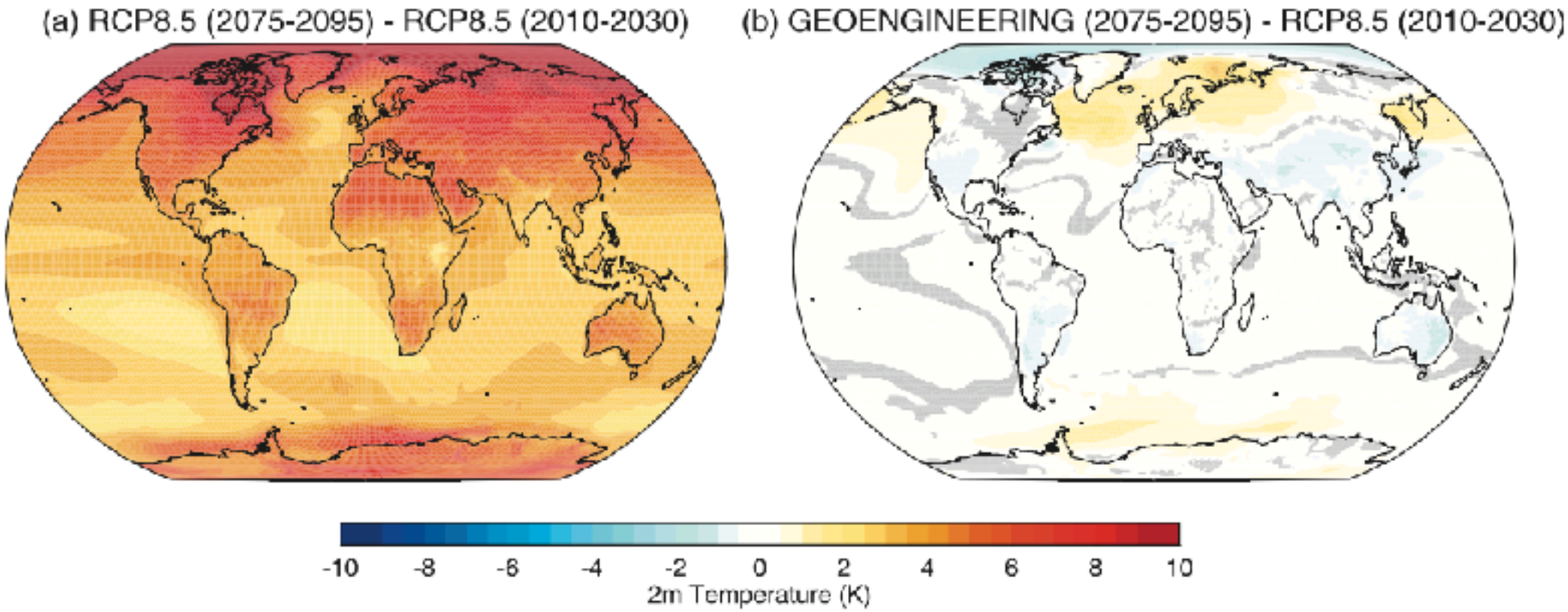


FIG. 6. Differences in the ensemble mean annual averaged 2-m temperature between (a) RCP8.5 in 2075–95 minus RCP8.5 in 2010–30 and (b) between geoengineering in 2075–95 minus RCP8.5 in 2010–30. Gray areas indicate regions where the differences are not significantly different from zero (p value < 0.05) using a two-sided t test.

Source: Tilmes et al (2018) CESMI (WACCM) Stratospheric aerosol geoengineering large ensemble project (AMS)

CLIMATE INTERVENTION DEMANDS UNDERSTANDING NOT JUST THE ATMOSPHERE, OR THE CARBON CYCLE - IT NEEDS AN EARTH SYSTEM APPROACH

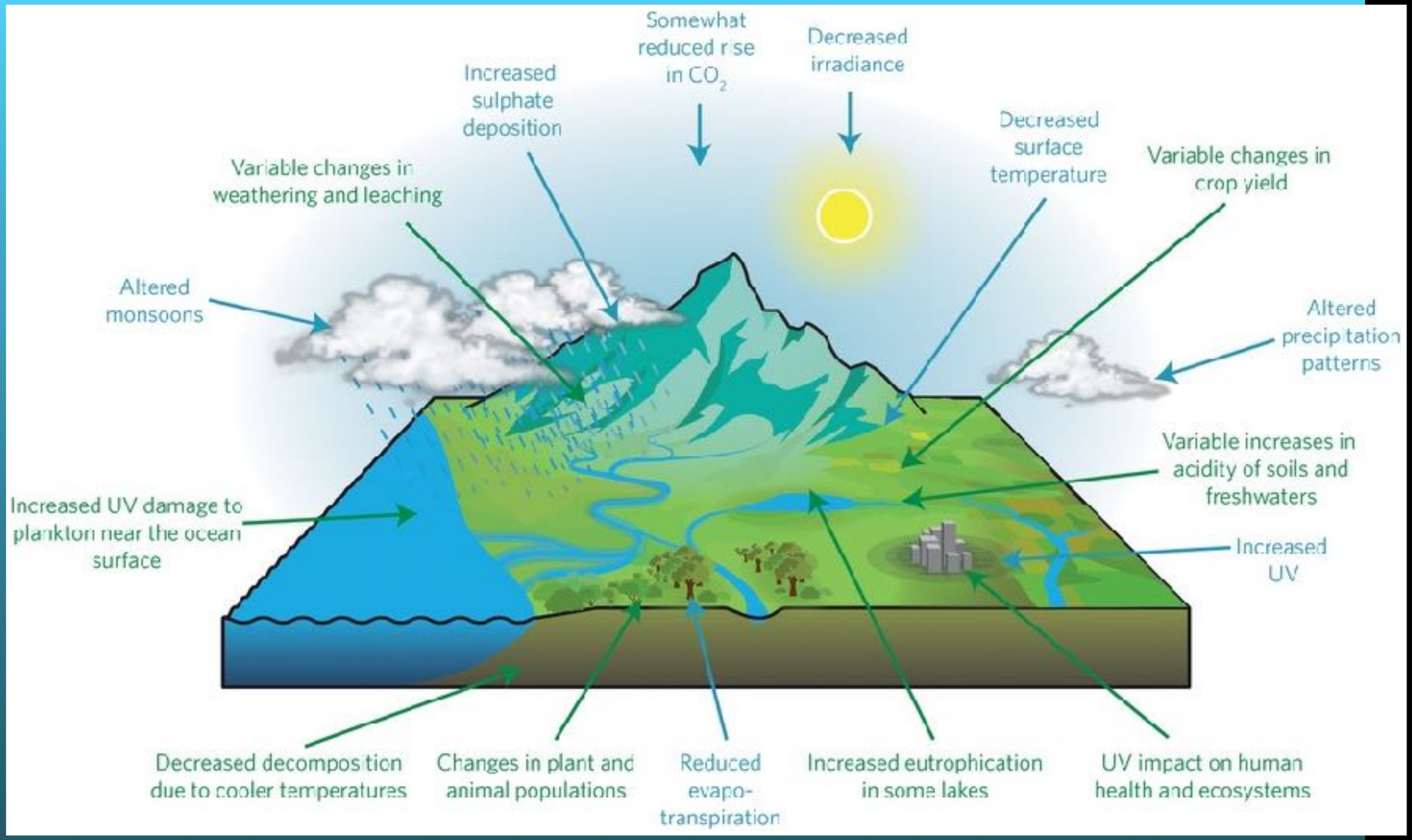


Figure: Barrett et al (2014) Nature Climate Change, doi:10.1038/nclimate2278

POTENTIAL NEGATIVE IMPACTS

1. Damage to the ozone layer
2. Interference with precipitation patterns
3. Ocean acidification continues
4. Whiter skies
5. Unknown ecosystem responses
6. **Termination shock**

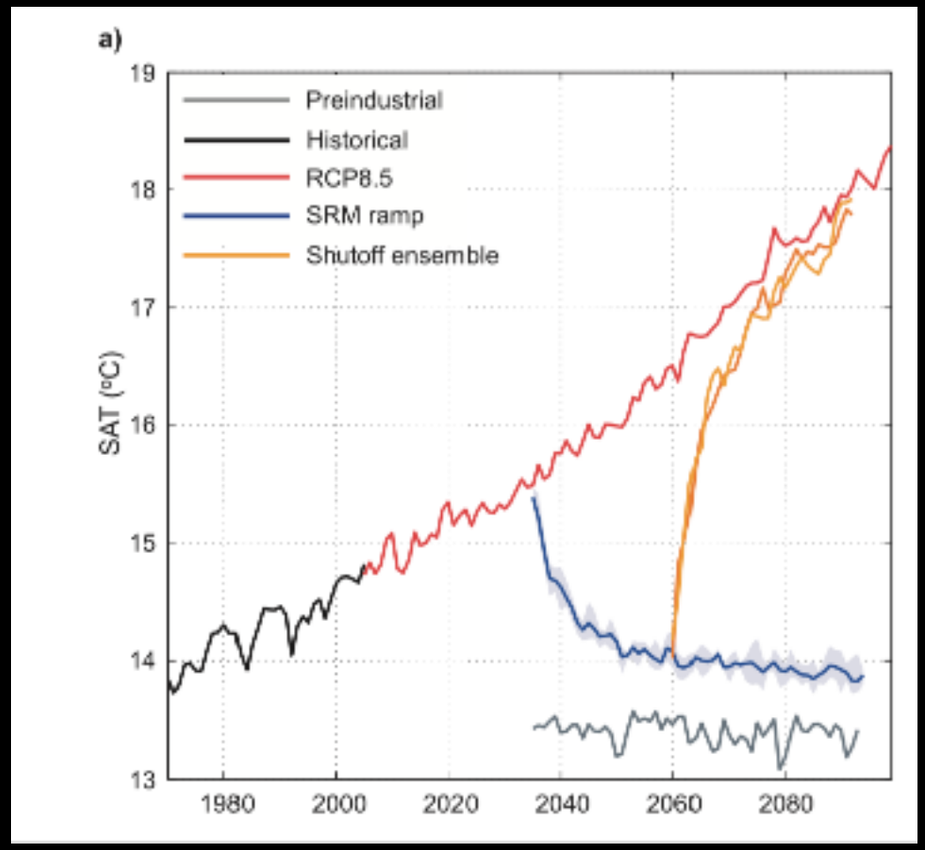


figure: McCusker et al (2014) Rapid and extensive warming following cessation of solar radiation management, in *ERL*

WHAT IF SOLAR GEOENGINEERING IS SUDDENLY STOPPED?

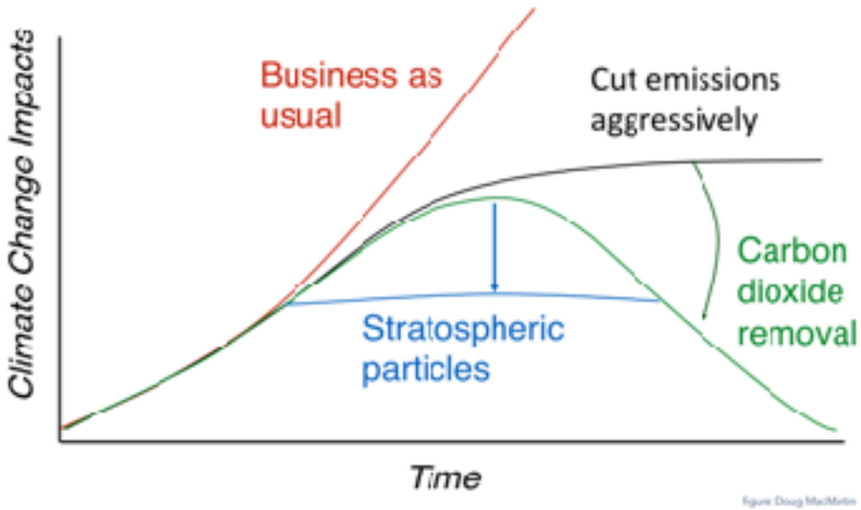
ALL THE WARMING THAT WAS BEING SUPPRESSED HITS US AT ONCE

Solar geoengineering as a stopgap measure

(band-aid, triage, hack, interim measure, bridge solution)

We define a stopgap measure as a measure that:

- 'buys time' to implement a more complex or long-term solution (even if that solution is not yet well defined, or agreed upon by all actors);
- is put in place to mitigate immediate harm under conditions of perceived exigency;
- is acknowledged by key actors to be interim or incomplete



nature sustainability
PERSPECTIVE
https://doi.org/10.1038/s41893-020-0497-6
Check for updates

Evaluating the efficacy and equity of environmental stopgap measures

Holly Jean Buck[1✉], Laura Jane Martin[2], Oliver Geden[3], Peter Kareiva[1], Liz Koslov[1,4], Will Krantz[1], Ben Kravitz[5,6], John Noël[7], Edward A. Parson[8], Christopher J. Preston[9], Daniel L. Sanchez[10], Lynn Scarlett[11] and Shuchi Talati[12]

Contemporary environmental policy is replete with measures that do not fully resolve a problem but are proposed instead to 'buy time' for the development of more-durable solutions. We define such measures as 'stopgap measures' and examine examples from wildfire risk management, hydrochlorofluorocarbon regulation and Colorado River water management. We introduce an analytical framework to assess stopgaps and apply this framework to solar geoengineering, a controversial stopgap for reducing emissions. Studying stopgaps as a distinct response to environmental crises can help us weigh their merits in comparison to alternative policy and management measures.

When is a stopgap really a stopgap?

When are stopgap measures sensible for buying time for complex solutions — and when are they just deterring real action?

Governance of CDR and SRM

Net-zero policies — governance of removals not well standardized

Solar geoengineering — no formal governance; various forms of "de facto" governance

"Oxford Principles"

1. Geoengineering to be regulated as a public good
2. Public participation in geoengineering decision-making
3. Disclosure of geoengineering research and open publication
4. Independent assessment of impacts
5. Governance before deployment

So what is a “holistic approach" to climate response?

Responding to climate change holistically

1. Holistic in terms of **understanding how carbon removal, adaptation, and mitigation interact,** and how solar geoengineering might impact those relationships - *both biophysically and socially*

    - Politically, will solar geoengineering act as stand-in for adaptation? What about mitigation deterrence?

    - How could solar geoengineering affect biological carbon sinks?

    - How does carbon removal at scale impact energy systems?

    - Will carbon removal projects have co-benefits, or will they create maladaptations?

    - *Need to identify these kinds of questions in a systematic way*

Responding to climate change holistically

2. Holistic in terms of **understanding** not just the climate context, but the **wider ecological crisis** — loss of species, water scarcity, pollution & more

- These things interact with climate change, but also exist beyond it

Responding to climate change holistically

3. Holistic in terms of understanding the **temporal dimensions** of climate responses

- Presumed sequencing of mitigation, biological CDR, geological CDR, solar geoengineering, adaptation — the temporalities and possibilities need to be better understood *both biophysically and socially*

Responding to climate change holistically

1. Holistic in terms of **understanding how carbon removal, adaptation, and mitigation interact**

2. Holistic in terms of **understanding** not just the climate context, but the **wider ecological crisis** — loss of life, water scarcity, pollution & more

3. Holistic in terms of understanding the **temporal dimensions** of climate responses

What might this look like in practice?

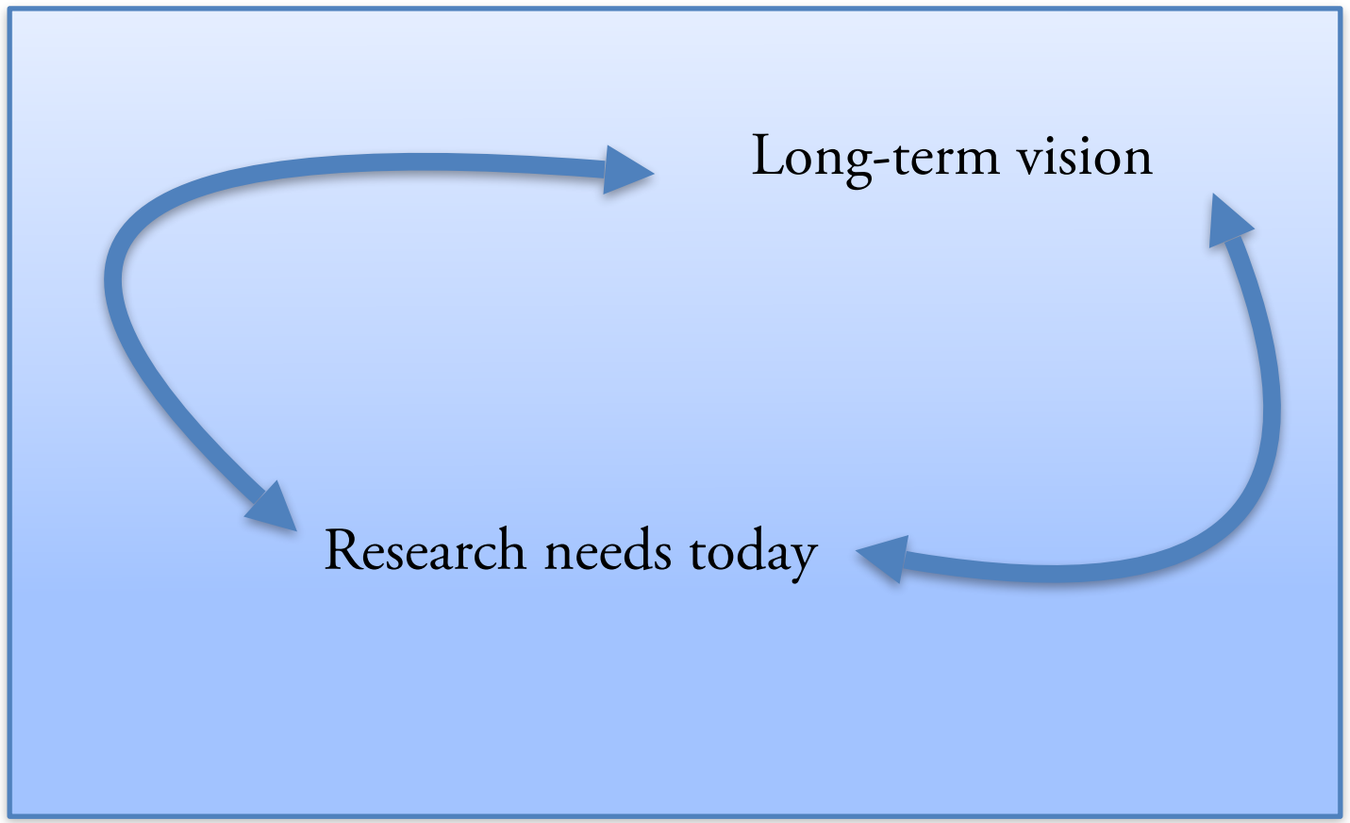
- Conferences that are not narrowly about CDR or SRM, but about climate response holistically
- Interdisciplinary journals; potentially peer review from other fields
- Funding opportunities that are explicitly for holistic research
- Developing better / transdisciplinary scenarios
- Generating “community”, in a social way (e.g. summer schools and mailing lists were important for this)
- Co-producing research agendas with communities on varying scales

Co-producing research can help guide a holistic response

People want to know not just about the science of SRM, but social context

A holistic approach isn't just about legitimacy or social license - coproducing research has a substantive rationale (it can make the research better)

Why would public engagement make for better science?



- Setting priorities / research agenda
- Generating new research questions
- Understanding the implications of research findings (e.g. what model outputs might mean for particular communities)

Example of research towards co-production: Pilot study — Finnish Lapland

Three-part design

1. Learn about community questions, ideas, concerns

2. Conduct modeling and scientific analysis based on this

3. Return to site, and co-interpret the results

22 semi-structured interviews;
Focus groups: Rovaniemi & Sodankylä

plant cultivation researcher

snow and ice building engineer

Arctic policy expert

environmental economist

tourism researcher

reindeer nutrition specialist

weather forecaster

gender studies professor

forest land use manager

exhibition designer

land use planner

cold weather auto testing worker

family-run tourism business CEO

reindeer herder official

game and wildlife expert

migration researcher

environmental artist

entrepreneur & Arctic developer

tourism security expert

local / national politician (National Coalition)

local / national politician (Social Democrats)

local politician (Center Party)

Ilmastonmuutos tuo tuholaisia Sodankylään

Hiilidioksidi siitos lämpiä ilmakehään

Ongelmia pohjoisille alueille

Takeaways for climate engineering governance

1. Climate preferences **not** obvious to outsiders or easily quantifiable

2. People care about more than what's local. Concern for others in far-flung locations, as well as other species

3. Concern not about climate engineering technology, but climate engineering within a world of Trump, Brexit, Duterte, Erdogan, terrorism, etc. — **people imagined the technology in a social context**

Going forward: Things to keep in mind

- **Local partners** are crucial
  - They need to be able to shape the inquiry towards their interests too

- Question of whether to adopt **wider framing** than just geoengineering as a discrete object - radical adaptation? climate solutions? energy transformation? reversing climate change?

- Certain participation technologies come from particular **cultural contexts** and may not be the right ones for other cultures

Going forward: What's scalable?

- Graphical user interfaces / digital deliberation

- **Institutions that scale engagement** - schools, professional organizations, NGOs with local chapters, scientific capacity-building research initiatives

- **Situated engagement / engagement in context** —schools, libraries, places of worship, etc., + **"engage the engagers"** approach

- How do publics **want to be engaged**? What's the role of the public in designing public engagement? We need a variety of experiments

- We need a holistic approach to climate intervention, not a siloed one

- Holistic and co-produced research can help make sure the right questions are asked (relevant), make sure there is transparency and oversight (reliable and responsible)

- This will require actively changing how science is practiced.

- From a social legitimacy standpoint, it may not be an option to do science-as-usual on this topic

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