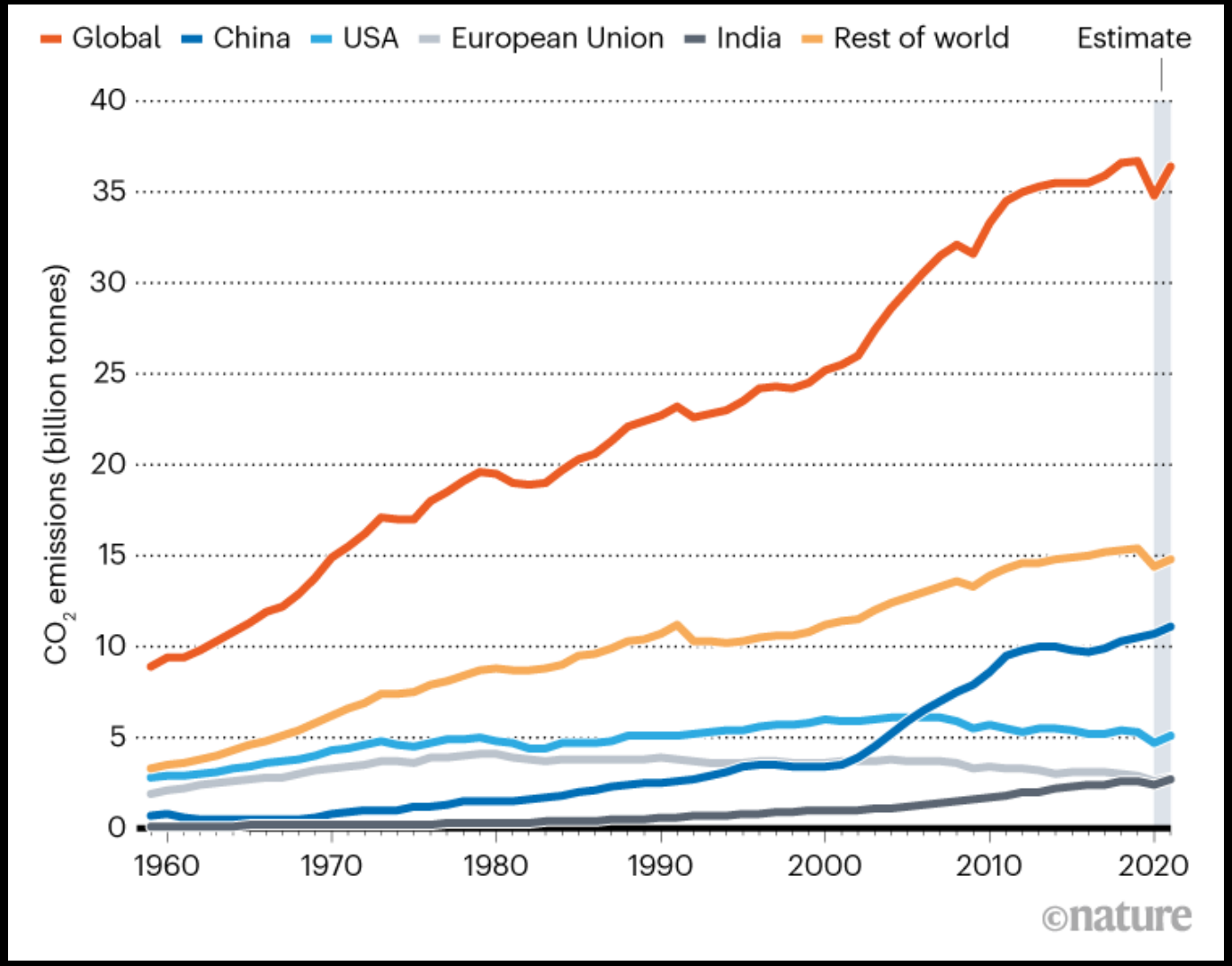
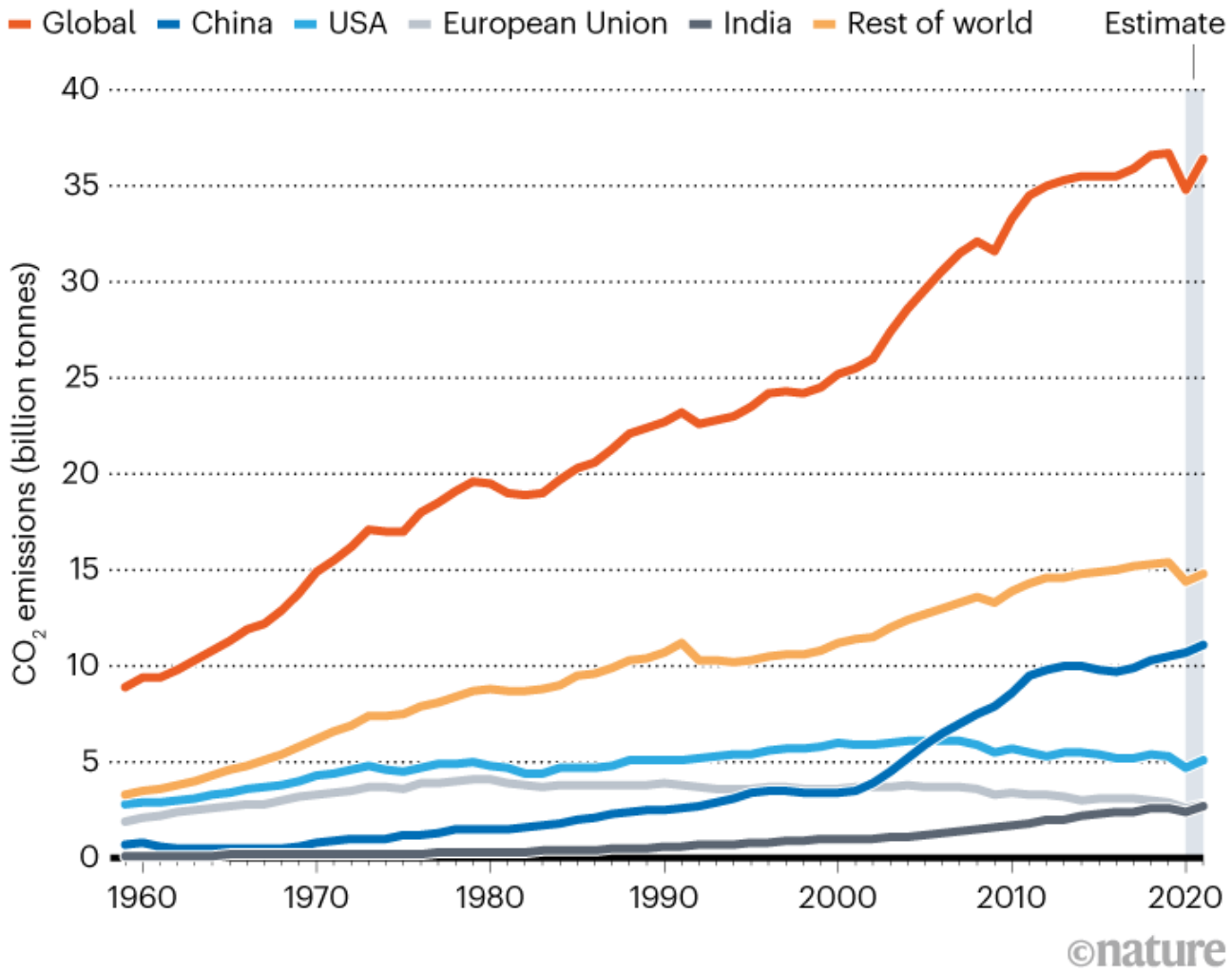


Source: Global Carbon Project



Source: Global Carbon Project + umpteen climate-econ model runs

Many options available now in all sectors are estimated to offer substantial potential to reduce net emissions by 2030. Relative potentials and costs will vary across countries and in the longer term compared to 2030.

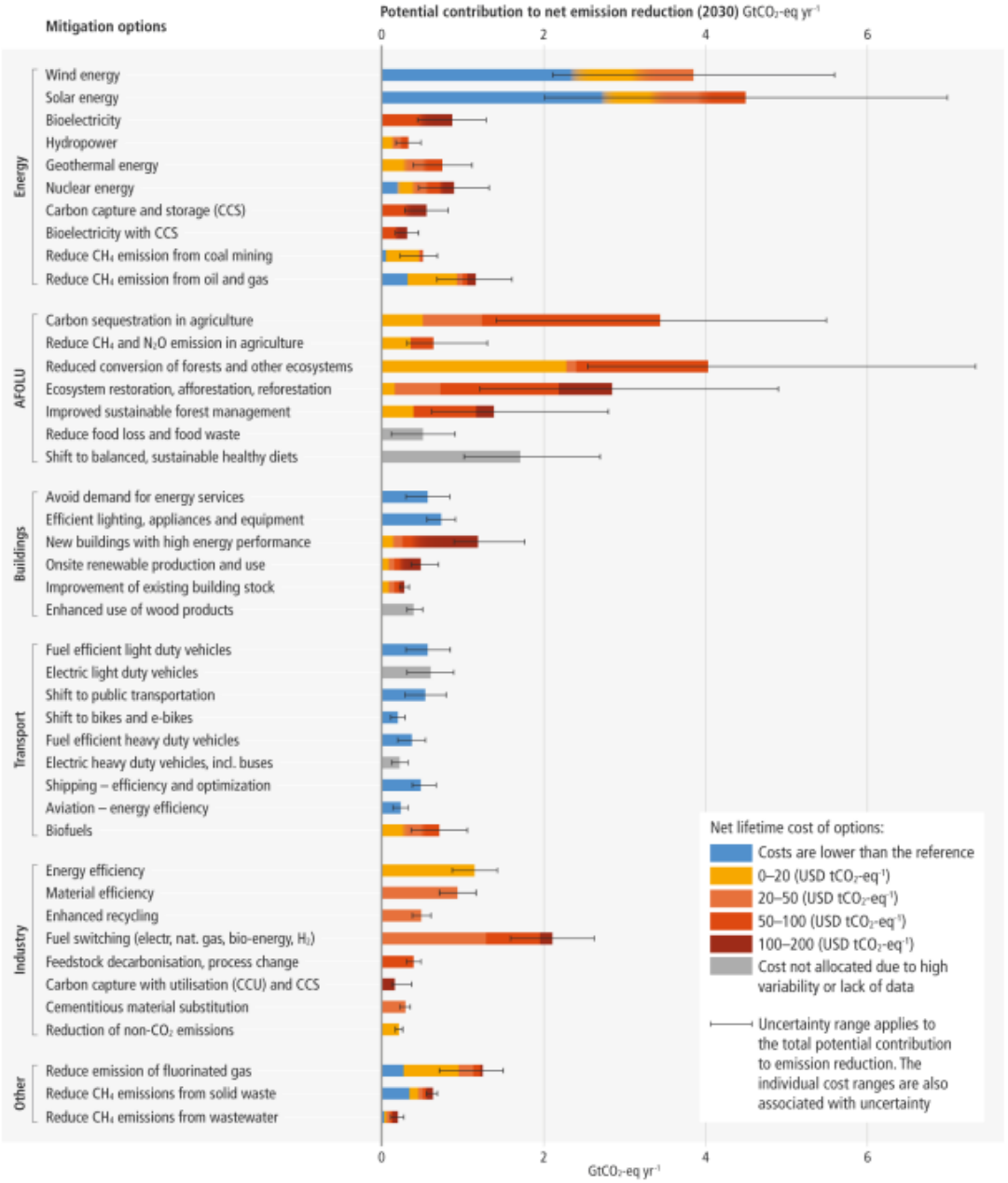
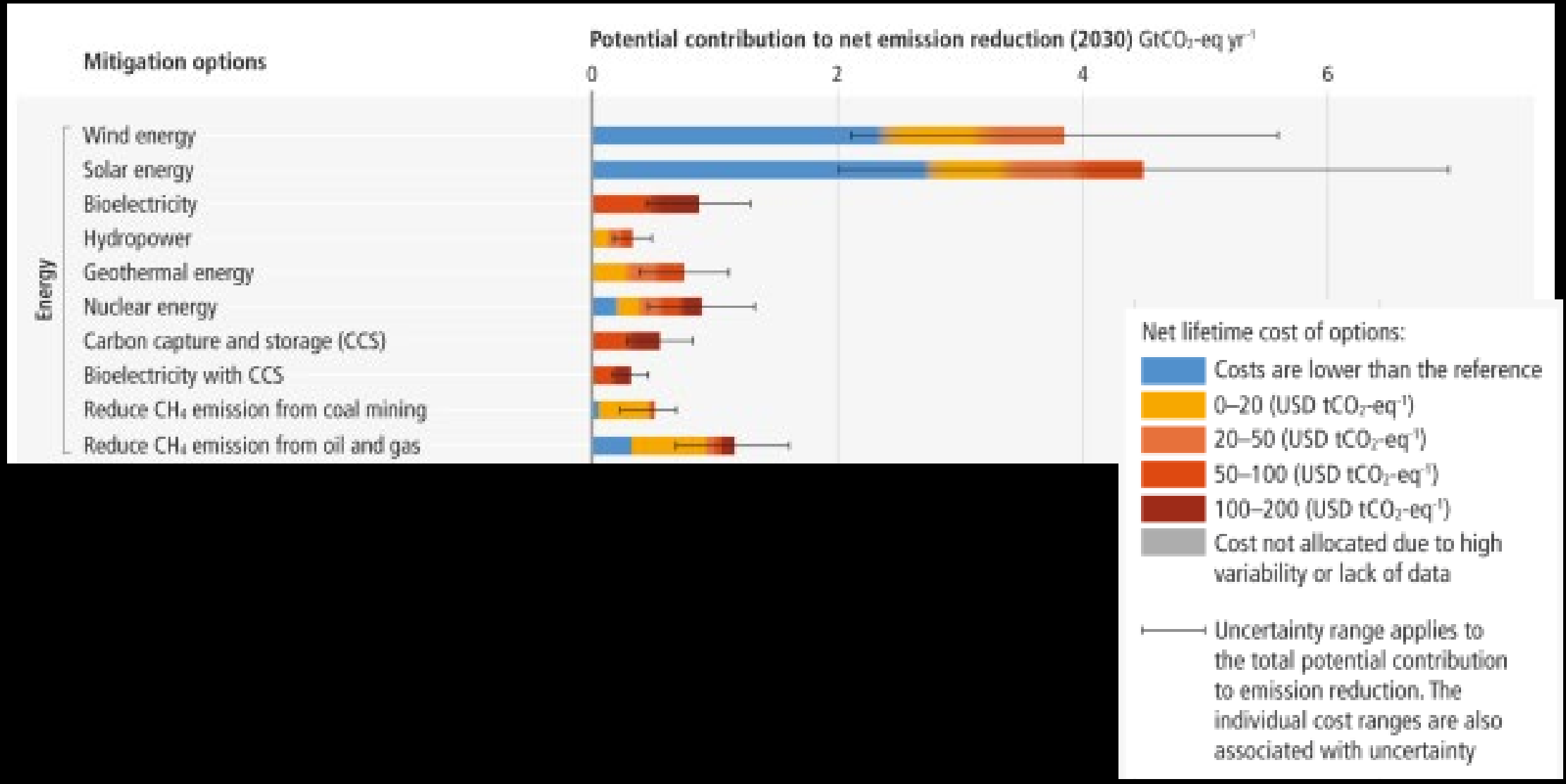
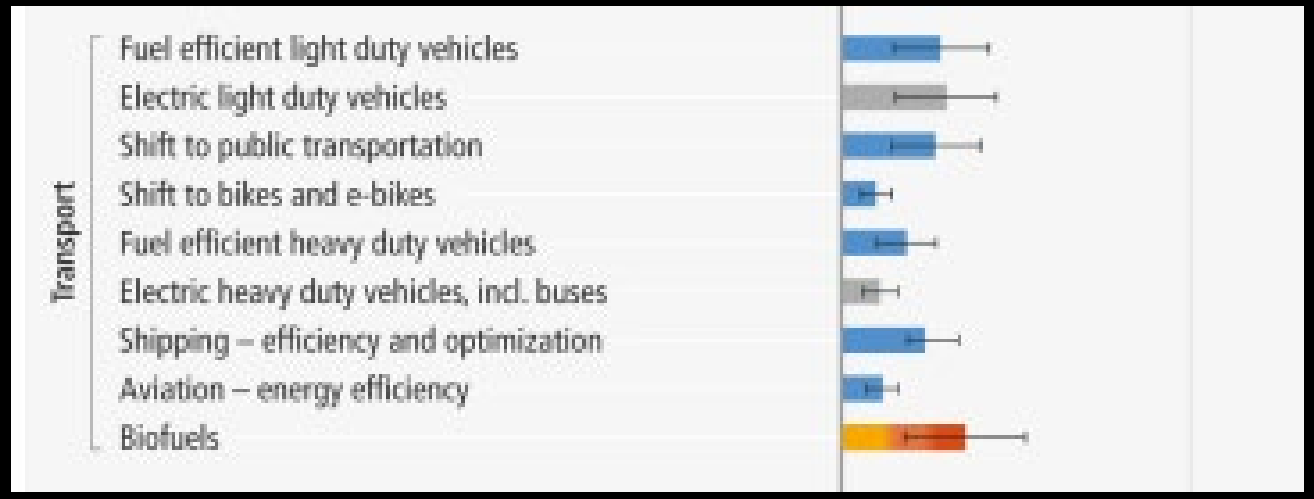


Figure SPM.7: Overview of mitigation options and their estimated ranges of costs and potentials in 2030.

IPCC AR6 WGIII, ipcc.ch/report/ar6/wg3



IPCC AR6 WGIII, ipcc.ch/report/ar6/wg3



IPCC AR6 WGIII, ipcc.ch/report/ar6/wg3

Stop burning fossil fuels. Sell more electric cars. Make buildings greener. Save more forests. The world is already awash in scientific advice on how to address the widening risks of global warming. Yet this week's report from the UN's Intergovernmental Panel on Climate Change is different. At nearly 3,000 pages, it is the most comprehensive analysis of what can be done to ward off dangerous levels of warming since the Paris climate accord was agreed in 2015. It will help to shape climate policy debates for years to come.

Its message is both stark and compelling. The window for limiting global warming to 1.5C is closing fast. Global emissions should ideally peak within just three years. Greener lifestyles can help, but more sweeping structural changes are needed. Gas, oil and especially coal use must fall steeply.

The good news is that a lot of what is needed is under way. The study shows prices of green alternatives to fossil fuels have not merely dipped, but plunged. Between 2010 and 2019, solar power and lithium ion battery costs fell by 85 per cent, while wind energy dropped by 55 per cent. Solar panels and wind turbines can now compete with fossil-fuelled power generation in many places and the deployment of green technologies has ballooned.

Some of this growth is due to an impressive expansion of climate policies and laws since the last big IPCC assessment was finalised in 2014. This in turn has led to the avoidance of emissions and pumped up investment in low-carbon infrastructure.

At least 18 countries have reduced their emissions for more than a decade, sometimes by 4 per cent a year, a rate in line with what is needed globally to keep temperatures at safer levels. If all countries acted to limit warming to 2C or less, the authors say global GDP would be just a few percentage points lower by 2050. And that calculation does not take account of the economic benefits of avoiding climate damage and lowering the cost of adapting to higher temperatures.

Most encouragingly, the growth in greenhouse gas emissions has slowed, from an annual average of 2.1 per cent at the start of this century to 1.3 per cent between 2010 and 2019. Yet this is not nearly enough. Progress in some countries has been outweighed by soaring emissions elsewhere. Climate finance for poorer countries is lacking. For all the vows of action, the authors say the world is on track for a catastrophic 3.2C of warming by the end of the century — more than double the 1.5C limit agreed in the Paris accord.

To have a chance of meeting that 1.5C goal, emissions need to peak by 2025 at the latest and fall by an unprecedented 43 per cent by 2030. Even then, the report says it is "almost inevitable" that the 1.5C threshold will be exceeded, at least temporarily — a sobering prospect given the weather extremes that have occurred at just 1.1C of warming.

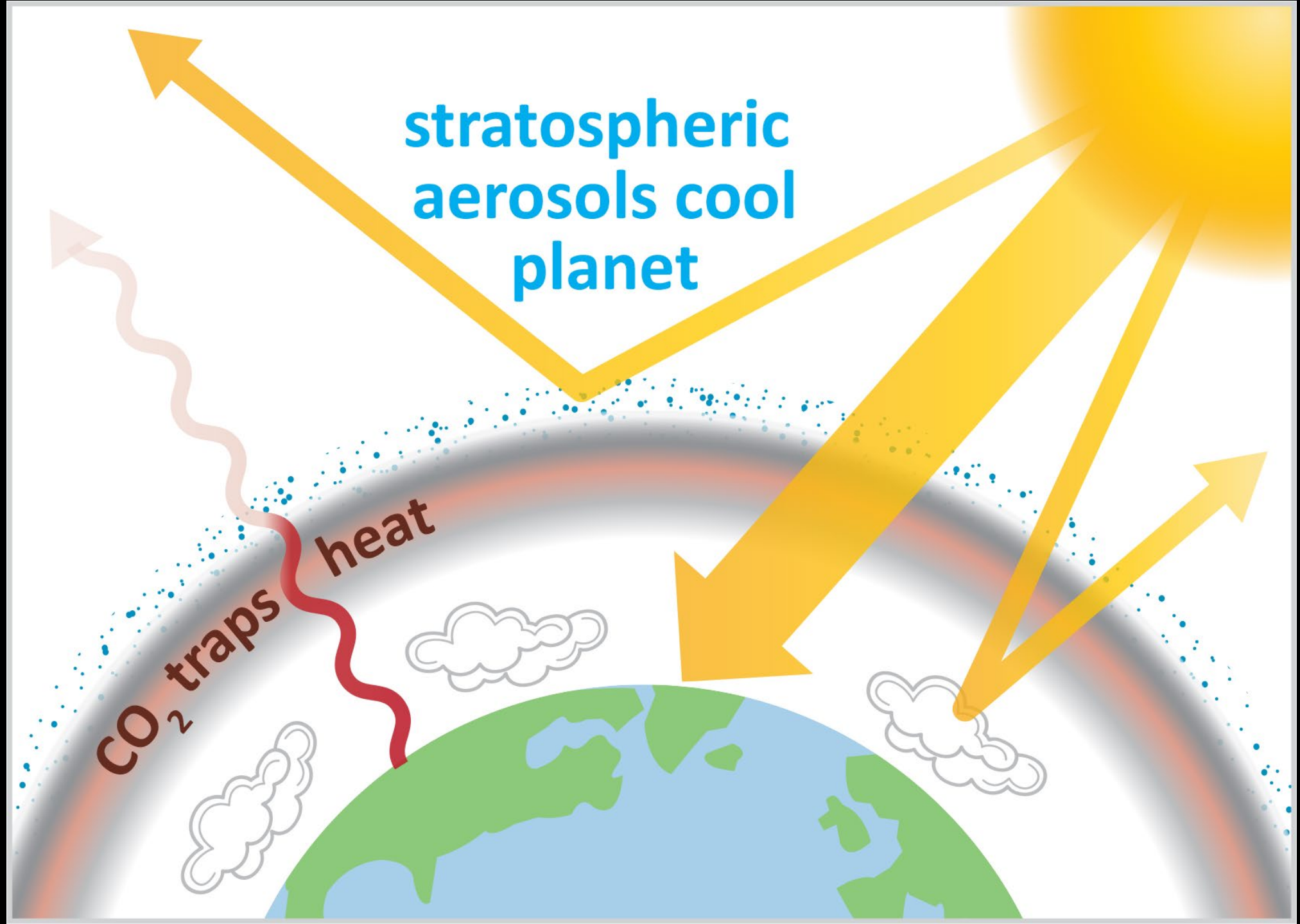
The scale of change needed is colossal. Aiming for 1.5C requires coal use to drop by 95 per cent, oil by 60 per cent and gas by 45 per cent by 2050. These goals look even harder to reach at a time of high inflation, though the war in Ukraine might conceivably speed up a green transition as western markets cut off Russian fossil fuels.

The science of climate change is now well understood, as are the technical solutions. The larger problem is politics, as the IPCC itself showed. Its report was held up by wrangling among the 195 countries approving it, some of which depend heavily on fossil fuels or lack the resources to build a greener economy. After more than a century of unsustainable energy and land use, the world has begun to turn. New ways of shifting even faster must now be found.

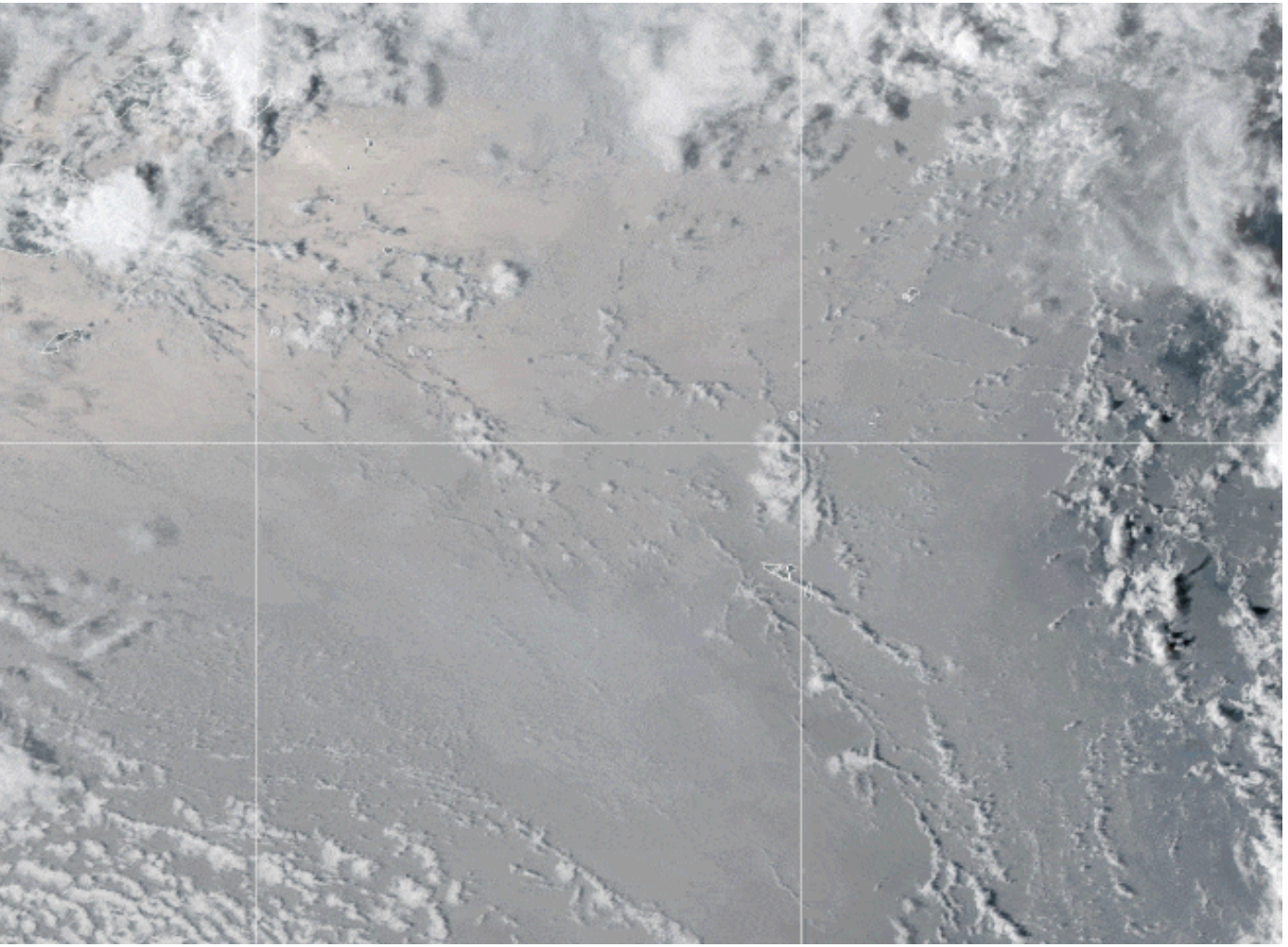
CO_2

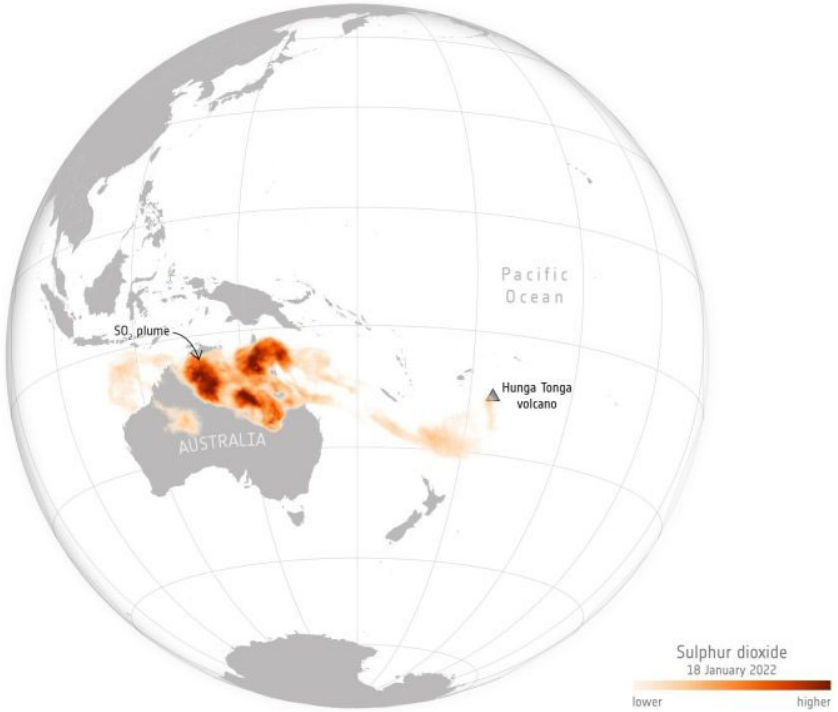
CO_2

SO_2

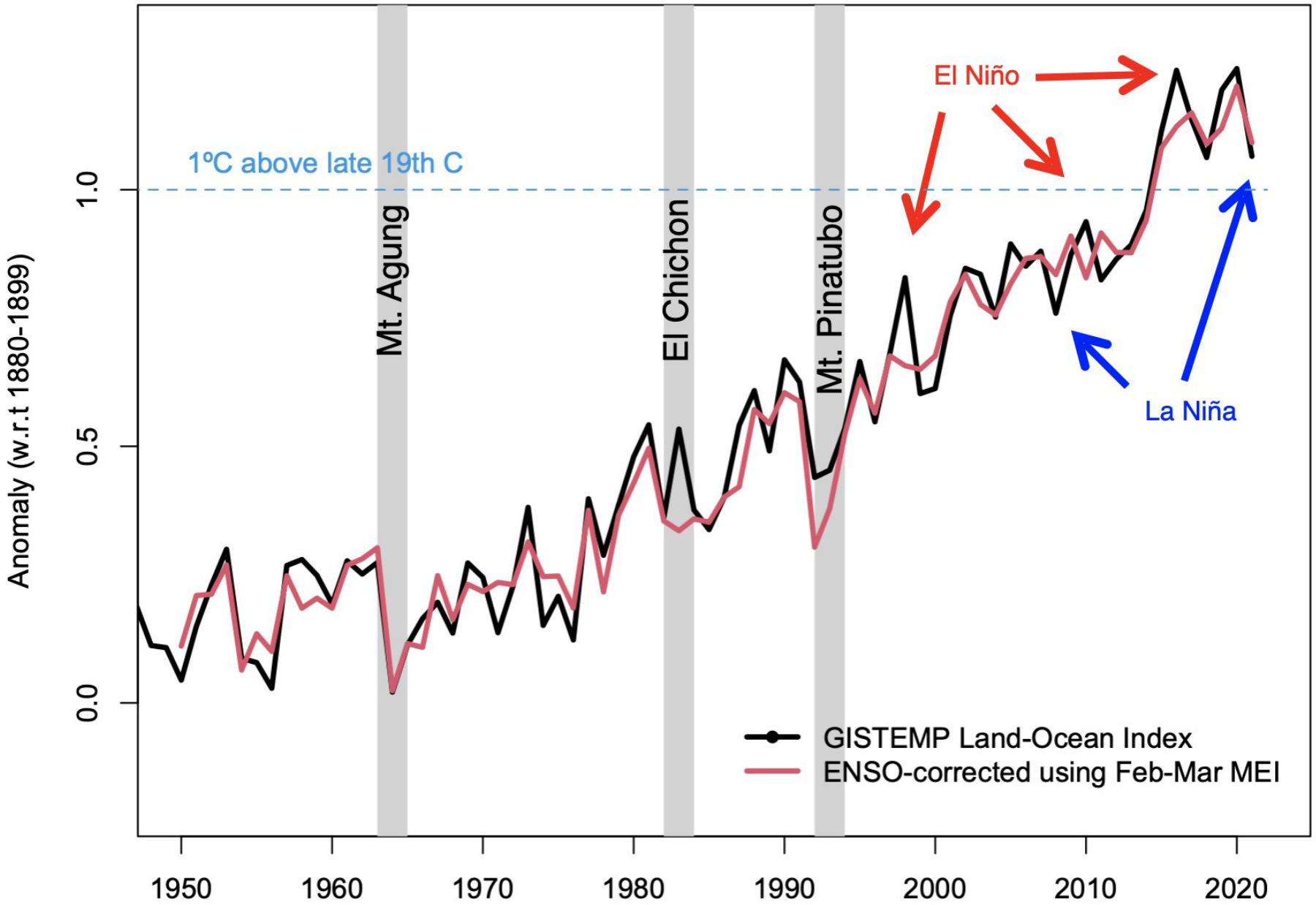

stratospheric
aerosols cool
planet
CO_2 traps heat

The 2022 Hunga Tonga Eruption





Source: Peter Irvine, UCL


Anomaly (w.r.t 1880-1899)
0.0
0.5
1.0
1950
1960
1970
1980
1990
2000
2010
2020
1ºC above late 19th C
Mt. Agung
El Chichon
Mt. Pinatubo
El Niño
La Niña
GISTEMP Land-Ocean Index
ENSO-corrected using Feb-Mar MEI

Offsetting 1°C would cost as little as tens of billions of dollars per year

$1.4 Billion per Mt per year

Table 2. Cost and capabilities comparison of lofting technologies.

Platform	Cost ('000 $/t)	SAIL multiple	Source
Mission capable			
SAIL[a]	1.4	1×	
McClellan New High Altitude Aircraft	1.5[b]	~1×	McClellan *et al* (2010, 2012)
Delft SAGA[c]	4.0	~3×	Delft Report[c]
McClellan Modernized Gun	19	~14×	McClellan *et al* (2010, 2012)
Balloons	~40	~28×	Near Space[d]
NASA WB57	43	~30×	NASA[d]
NASA ER2	50	~35×	NASA[d]
NASA Global Hawk	70	~50×	NASA[d]
SpaceX Falcon Heavy Rocket	71[e]	~50×	Chang (2018)
Gun Mark 7 16'	137	~100×	McClellan *et al* (2010, 2012)
Vector Rocket	1180[e]	~850×	Chang (2018)
Virgin Orbit Rocket	2000[e]	~1400×	Virgin Orbit[d]
Mission incapable			
Existing Commercial Aircraft	Not capable of reaching ~20 km[f]		
Modified Commercial Aircraft	Not capable of reaching ~20 km[g]		
Existing Military Transporters[h]	Not capable of reaching ~20 km[g]		
Military Fighters	Not capable of sustained flight at ~20 km[g]		
Tethered Hose	Not sufficiently mature technology[g]		
Aerostats/Airships	Not sufficiently mature technology[g]		

Source: Smith & Wagner *ERL* (2018).

“Free rider”

Source: Every economist ever

“Free rider”

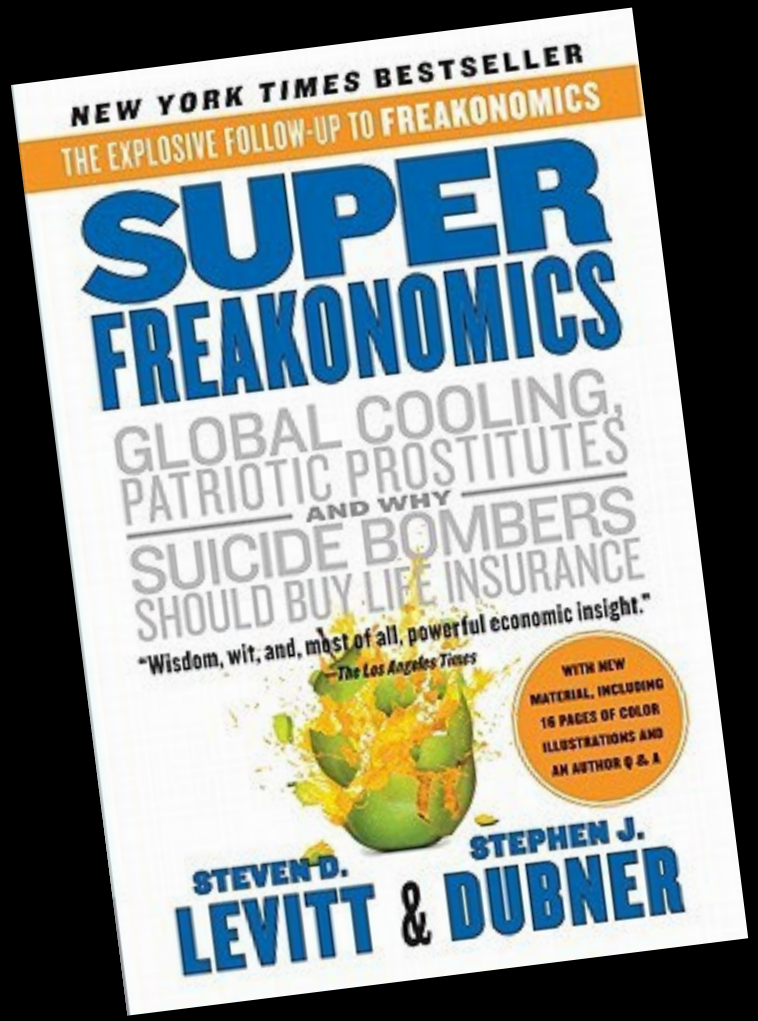
→ “Free driver”

Wagner & Weitzman, *Foreign Policy* (2012)

Not *if* but *when*

Source: Wagner *Geoengineering: the Gamble* (2021)

There is no Plan B



"Geo-engineering holds forth the promise of addressing global warming concerns for just a few billion dollars a year," said Newt Gingrich, former speaker of the US House of Representatives, in 2008. "We would have an option to address global warming by rewarding scientific innovation. Bring on American ingenuity. Stop the green pig."

Plan A

Cut CO_2, methane et al.

Adapt

Carbon removal

→ “net-zero” emissions

Plan A

Cut CO_2, methane et al.

Adapt

Carbon removal

→ “net-zero” emissions

Suffer

Plan A+

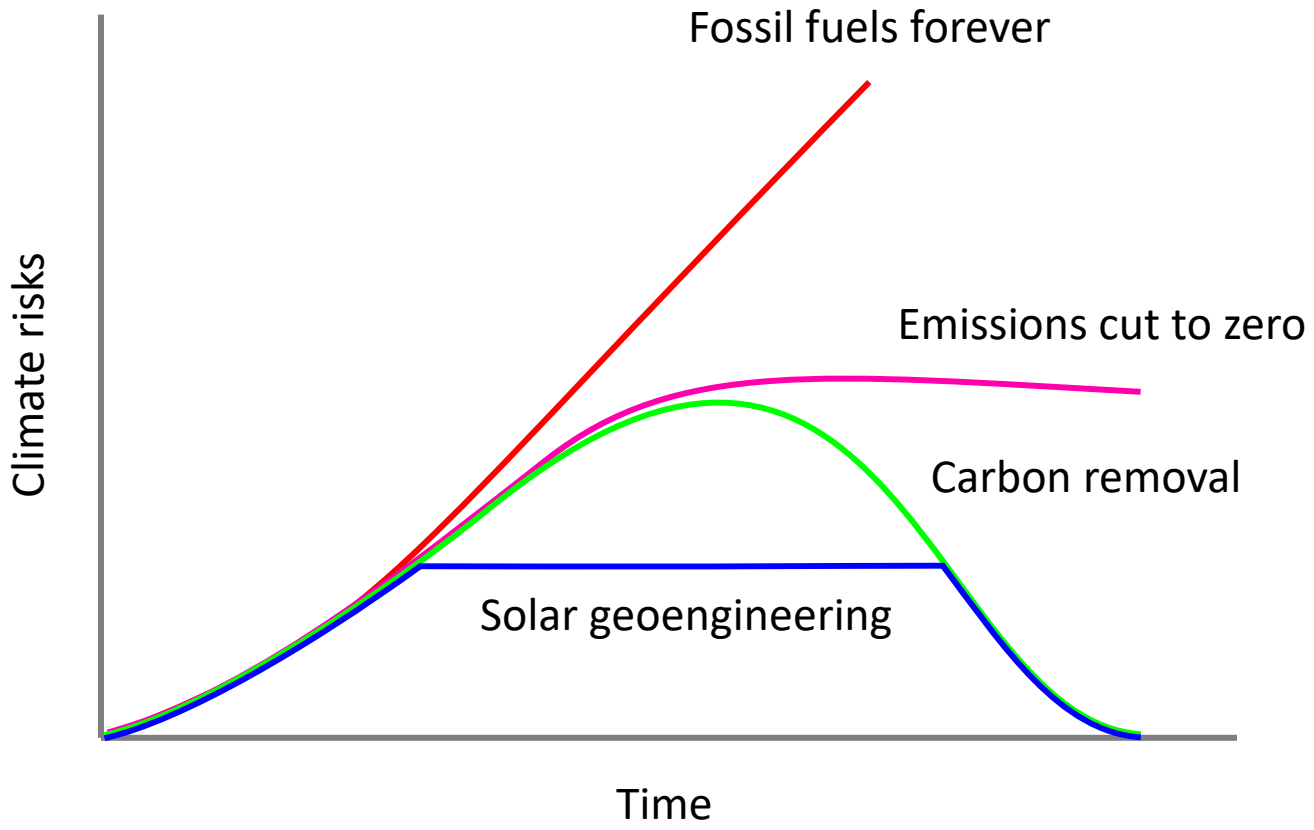
Cut CO_2, methane et al.

Adapt

Carbon removal

→ “net-zero” emissions

Solar Geoengineering(?)


Fossil fuels forever
Emissions cut to zero
Carbon removal
Solar geoengineering
Climate risks
Time

Solar geoengineering risk and efficacy

Risks (of stratospheric sulfates)

- Stratospheric ozone loss
  - Direct Cl and Br activation
  - NOx cycle
- Warming of lower stratosphere
  - increased water vapor
  - changes in stratospheric dynamics
- Impacts in the troposphere
  - Health impacts of particulates
  - Acid rain
  - Upper tropospheric cirrus
- Increase in diffuse light
  - Ecosystem changes
  - Tropospheric chemistry impacts of increased fluence

Efficacy (of SRM)

- Regional response
- Precipitation
- Variability
- Cryosphere
- “Standard” climate impacts:
  - Crops
  - Hydrology
  - Unmanaged ecosystems.
  - Air quality

What's the low-probability, high-consequence way SG could go wrong?

Prior: SG good for crop yields due to lower temps

2018 *Nature* cover identifies negative effect due to diffuse sunlight from Pinatubo

But *Nature* study is wrong, too; e.g. misses CO_2 fertilization effect!

How much of what SG will produce is known, not *yet* known, or simply unknowable?

Source: Proctor et al 2018 *Nature* cover

Balloon

Recovery Parachute

Equipment Gondola

Balloons generally considered too costly, cumbersome for deployment

Experimental platform ≠ deployment technology

Table 2. Cost and capabilities comparison of lofting technologies.

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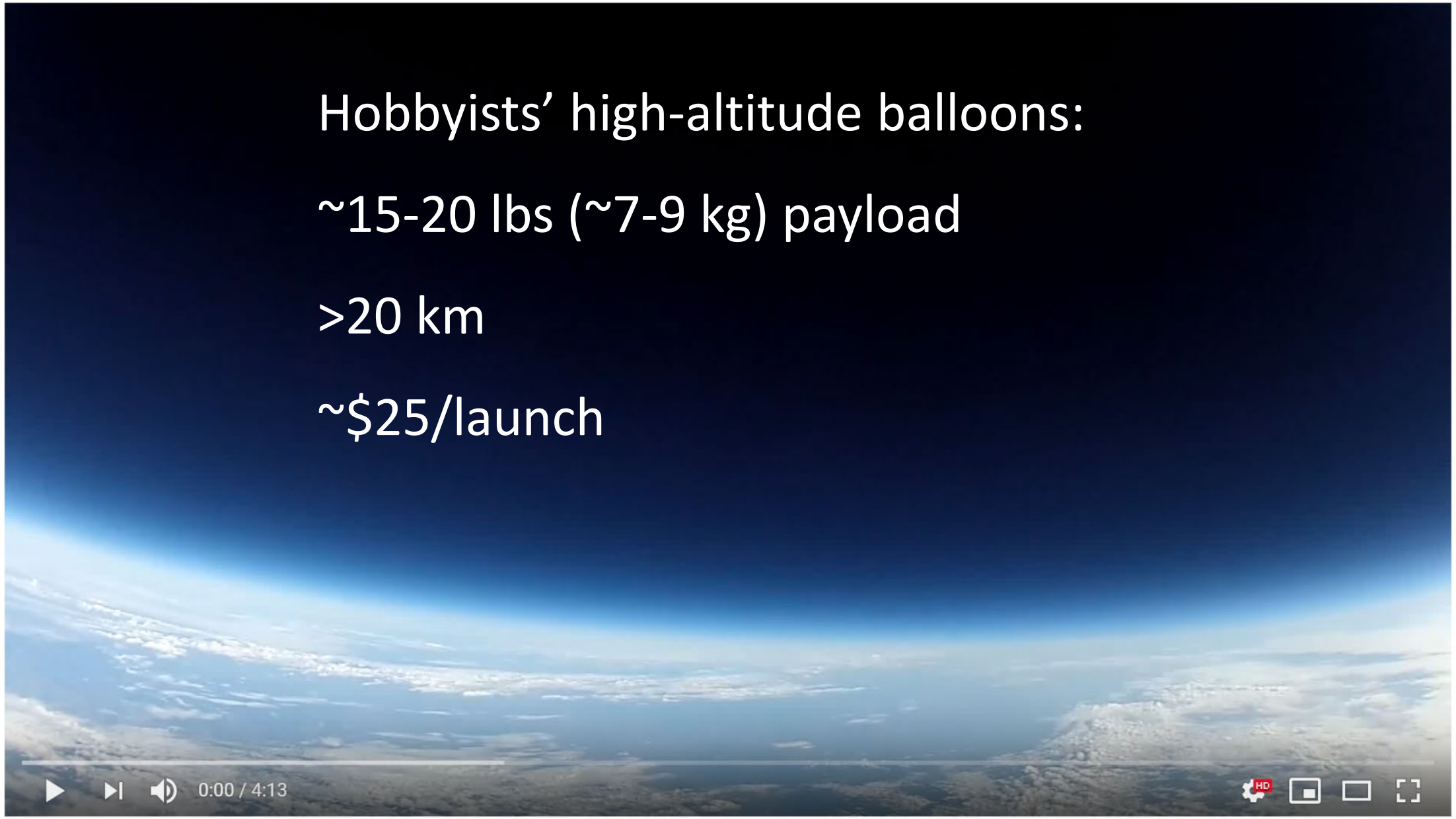
Aerostats/Airships	Not sufficiently mature technology[g]		

Source: Smith & Wagner, "Stratospheric aerosol injection tactics and costs in the first 15 years of deployment," *ERL* (2018).



Space Balloon, GoPro on a journey to the stratosphere

86,298 views

745 13 SHARE SAVE


[Our] satellite will collect data about pollution that is warming the planet. We will put that data in the hands of people who can make simple fixes that will change the course of global warming in our lifetime.
—Fred Krupp, President, EDF
TED

Highly decentralized nonstate solar geoengineering

High-altitude balloons with ~5 kg payload, at ~$5/kg SO_2 (**?!**)

TABLE 1. Categorization of solar geoengineering deployment by type and number of entities involved in deployment

	Order of magnitude of number of entities deploying solar geoengineering				
Character of deployers	1	~10	~100	~1000	> ~10,000
State	Unilateral	Minilateral	Multilateral	n/a	n/a
Nonstate	"Greenfinger"	Moderately decentralized nonstate solar geoengineering			Highly decentralized nonstate solar geoengineering
Probable means of delivery	Aircraft or possibly large tethered balloons (deployment costs ~$1.4/kg SO_2)[a]				Small balloons (~$5/kg SO_2)[b]

Source: Reynolds & Wagner, "Decentralized nonstate environmental intervention: the case of solar geoengineering" (*mimeo*), gwagner.com/decentralizedSG

from

Cutting CO_2 vs. (Solar) Geoengineering

to

Cutting CO_2 and (Solar) Geoengineering*

*Solar geoengineering *research*

from

“Moral Hazard”

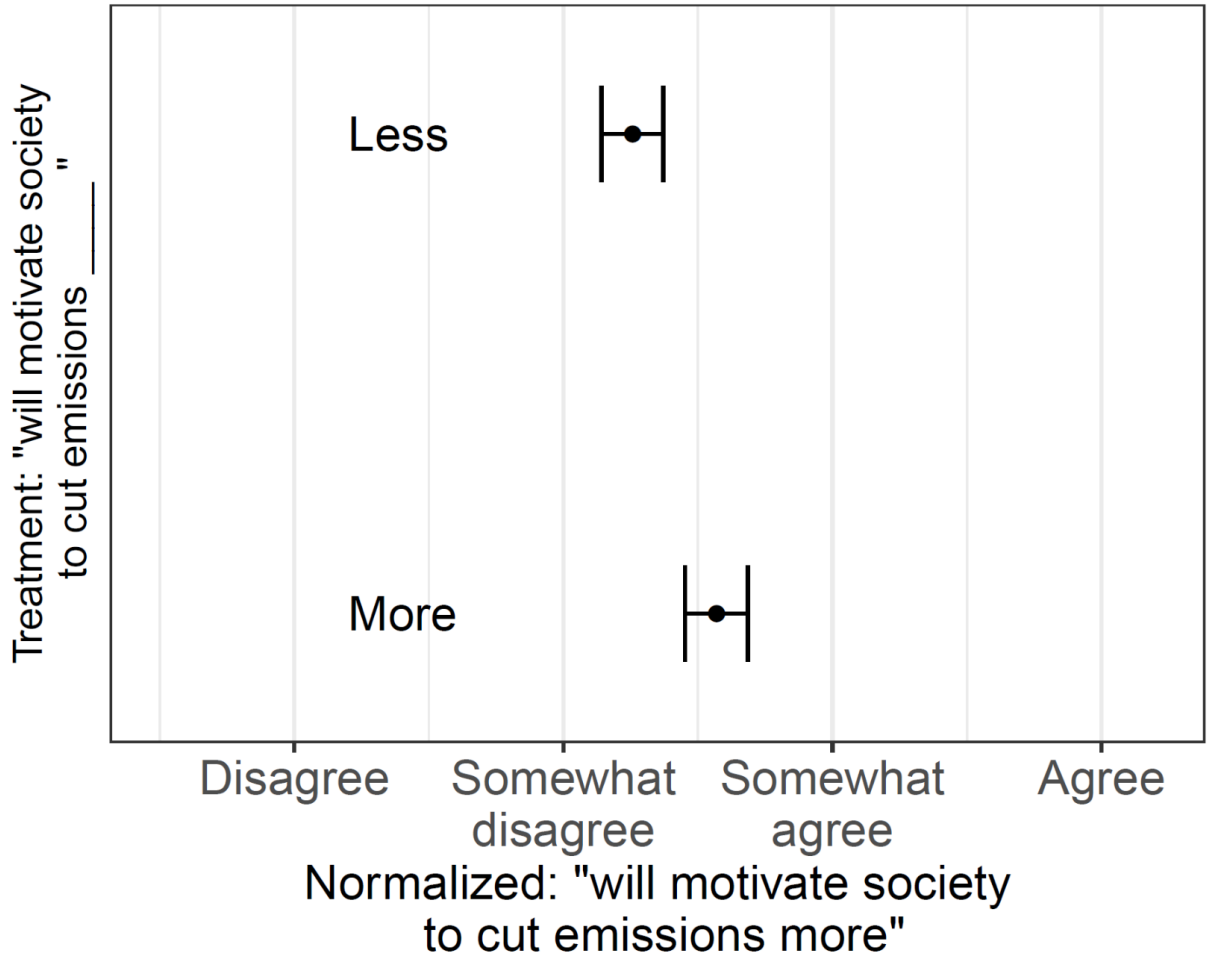
to

a risk-risk framework, or perhaps even
“Inverse Moral Hazard”

Acquiescence bias may dominate any “moral hazard” finding

n=1,000, part of 36,000-subject 2016 Cooperative Congressional Election Study of US electorate, Oct-Nov 2016

Ask whether solar geoengineering “will motivate society to cut emissions *less*”, get (weak) agreement.
Ask whether it will cut emissions “*more*,” get (weak) agreement.



Mahajan, Tingley, Wagner, “Fast, cheap, and imperfect? U.S. public opinion about solar geoengineering” (*2018*)

“Inverse moral hazard”

Germans (n=658) increase voluntary offset purchases when told about stratospheric aerosol injection (SAI)

Table 1. Tobit regression explaining the amount of purchased VCOs.

Dependent variable: amount of purchased VCOs	Average marginal effect (AME)
Treatment group	
SAI	0.774**
AUG	0.033
Climate change	
(1) Perception of impacts	0.029
(2) Daily mitigation	0.016
(3) Moral obligation to mitigate	0.782***
Experiment characteristics	
(4) VCO effectiveness	1.145***

Merk, Pönitzsch & Rehdanz, *Environ. Res. Lett.* (2016)

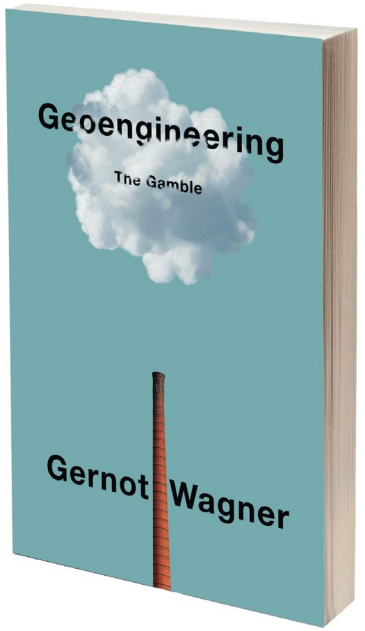
Green
Risky Climate

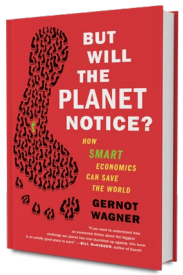
Fear of Geoengineering Is Really Anxiety About Cutting Carbon

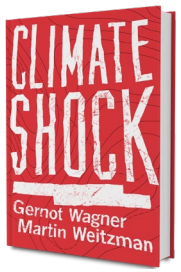
Research into unproven technofixes isn't a replacement for eliminating emissions, even if the debate over geoengineering is stuck on that concern.

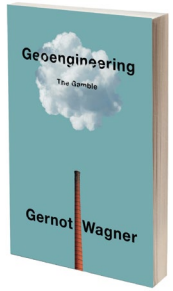
The geoengineering debate is caught in false choice between cutting emissions, like those from cars, and researching the dire possibility of resorting to technofixes such as reflecting back a portion of sunlight. *Photographer: Samuel Corum/Bloomberg*

By Gernot Wagner
June 25, 2021, 6:00 AM EDT









Gernot Wagner
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