Getting Negative About Emissions: Solution or Sop?

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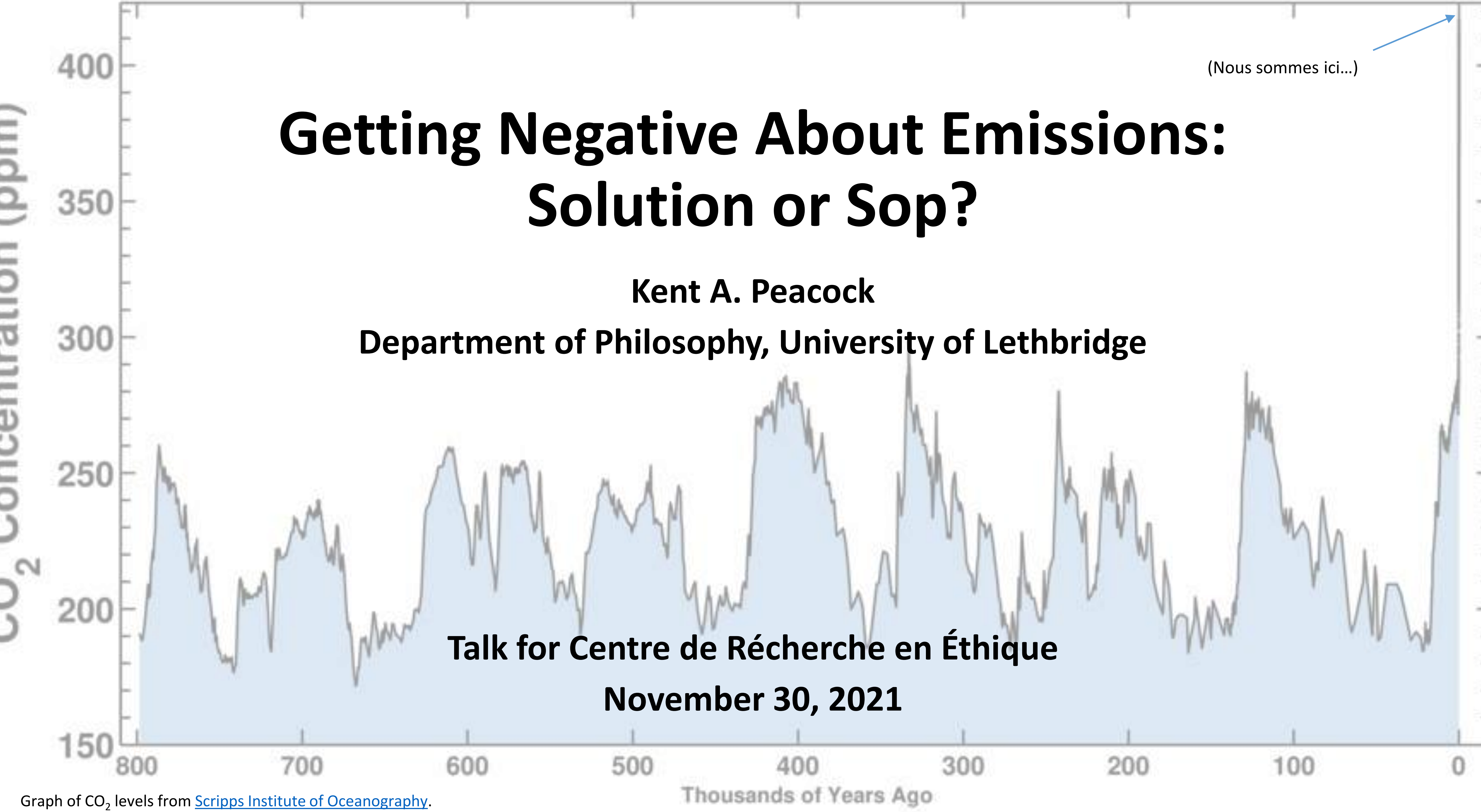

Graph of CO_2 levels from [Scripps Institute of Oceanography](#).

ABSTRACT

There is a *prima facie* scientific case for the employment of negative emissions technologies (NETs) (techniques to reduce atmospheric CO_2 levels). However, there are several objections, some practical and some ethical or political, to the deployment of NETs at scale or to the *assumption* that they will be deployed in the future. I review the *prima facie* scientific case for NETs, which seems to imply that the correct global climate policy target should be not *net zero* but *net negative*. This implies that a key policy goal should be to stabilize and then lower CO_2 concentration, ultimately to close to pre-industrial levels.

What *Are* “Negative Emissions” Technologies?

- Catch-all term for any method of reducing CO_2 concentration in the atmosphere.
- Could include anything from planting trees to hi-tech methods of capturing CO_2 directly from the air (DAC, “direct air capture”).
- Sometimes also referred to as *drawdown*, *carbon removal,* or *carbon dioxide removal* (CDR).
  - *Not* the same thing as Carbon Capture and Storage (CCS), which is the capture of emissions as they are produced (by generating stations, cement plants, etc.).
  - CCS is at best carbon-neutral, not carbon-negative.

A Tangled Web…

- It is difficult to separate the (rapidly evolving) scientific/technical questions from the ethical/political/socio-economic questions in discussing negative emissions, and climate generally.
    - What we *ought* to do is constrained by what we *can* do.
    - No use in wishing for something impossible.
- On the other hand, more things are possible than conventional wisdom acknowledges…!
    - J. S. Bell: "what is proved by impossibility proofs is lack of imagination."

Why Talk About Negative Emissions in the First Place…?

- Despite Paris 2015, and much brave talk, CO_2 emissions continue to increase, over 37 billion tonnes (net) in 2018.
- Current CO_2 level: around 415 ppm.
  - Increases almost 3 ppm/year, though rate of increase is increasing.
  - Increased methane and other greenhouse gasses as well.
- Pre-industrial level: about 280 ppm.
- Peak Ice Age: about 200 ppm.
- We are at the highest CO_2 concentration since the mid-Pliocene, 3—5 million years ago.
  - So what's the problem? The dinosaurs flourished in CO_2 levels over 1000 ppm…

Problems With Anthropogenic Carbonization (AC)

- Warming—to the point at which some regions of the planet could become temporarily or permanently uninhabitable by humans (wet bulb temperature > 35°C).
- Severe weather—stronger cyclones, atmospheric rivers, droughts, heat waves, cold waves, wildfires.
- Widespread crop failures.
- Large though unknown impact on biodiversity.
- Oceanic acidification (from excess dissolved CO_2 in seas); damages base of oceanic food chain.
- Oceanic hypoxia (warmer water holds less oxygen).
- Loss of coral reefs.
- Sea level rise (warm water expands, ice sheets melt and collapse).

The Long-Term "Control Knob"

- Key fact about CO_2: it takes centuries to millennia for it to be drawn down by natural sinks (biological or geological).
  - That is why it's the long term "control knob" for climate.
- So even if we reduce emissions to net zero, or just zero, that will not by itself remove the CO_2 that is *already* in the atmosphere (plus the extra that will be added before we hit net zero).
  - At 415+ ppm, we are already at a level that guarantees major loss of icecaps, as well as extreme weather, unprecedented wildfires, etc.
- Hence the conclusion that *some* way must be found to draw carbon down, in addition to preventing more from being added to the atmosphere.

The 1.5°C Solution

- In 1990s, economist W. Nordhaus proposed a target for climate policy: global mean surface temperature should increase no more than 2°C from pre-industrial levels.
- We now know that this is certainly too high, and Paris 2015 set an “aspirational” target of 1.5°C.
- We are now at about 1.1°C and are already experiencing severe consequences—it may be that even 1.5°C is too high.

What To Do?

- Reduce emissions of fossil carbon from use of coal, oil, gas as energy sources.
- Protect forests.
- Replace fossil fuels as source of energy for human system (currently about 85% of our energy comes from fossil fuels).
  - Can we do it just with renewables (wind, water, solar)?
    - (See Mark Jacobson, *100% Clean, Renewable Energy and Storage for Everything*. Cambridge U Press, 2021.)
  - Or do we need nuclear fission (controversial) or fusion (not yet realized in practice)?
    - (See Oscar Schwartz, "Is nuclear fusion the answer to the climate crisis?" *Guardian*, 28 Dec 2020,)
- Should we try to *remove* carbon from the air as well as *emit less*?
  - A: Yes, no choice.
- And should we employ technological means of removal, or rely on biological/natural sinks?
  - A: Still a matter of expert debate—but we don't have a lot of time to make up our minds.

IPCC's Verdict

- "All analysed pathways limiting warming to 1.5°C with no or limited overshoot use CDR to some extent…"
- *But* "CDR deployed at scale is unproven, and reliance on such technology is a major risk in the ability to limit warming to 1.5°C."
    - IPCC Special Report 2018, Chapter 2, "Mitigation Pathways Compatible with 1.5°C in the Context of Sustainable Development."

A Spectrum of Opinions

- Here is a strong negative on techno-solutions:
  - “Bringing direct air capture to a scale that would have climate-significant impact would mean diverting taxpayer funding, private investment, technological innovation, scientists’ attention, public support and difficult-to-muster political action away from the essential work of transitioning to non-carbon energy sources.
  - **“A proven method: trees, plants and soil:**
  - “Rather than placing what we consider to be risky bets on expensive mechanical methods that have a troubled track record and require decades of development, there are ways to sequester carbon that build upon the system we already know works: biological sequestration.”
    - June Sekera, Neva Goodwin, *The Conversation*, Nov. 23, 2021.
- They do not dispute the need for CDR—just the need for technological means of doing it.

Cautious Yes on NETs

- According to one climate scientist, whether or not we need to use negative emissions technologies (NETs) “depends on the target or course. Obviously, if it’s 1°C we would need negative emission as we’re already past it. For 1.5°C, we probably need it too. For 2.0°C, we can still get there in all likelihood with rapid reduction of carbon emissions. BUT there is uncertainty in all of this, in the climate model projections, in the carbon cycle dynamics, etc., so it comes down to what level of certainty you want, i.e., how risk averse you are.”
  - Michael Mann (private comm., 2020).

Peter Wadhams—An Extreme View, or Just the Way It Is?

- "We no longer have a 'carbon budget' that we can burn through before feeling worried that we have caused massive climate change … *it is not enough to reduce carbon emissions*." (192)
- "… the overwhelmingly important need is to undertake a colossal scientific and technical research programme on geoengineering and on carbon dioxide removal. … Most important of all is the need to find a way to remove carbon dioxide from the atmosphere. …The only thing that can really save us is the direct removal of CO_2 from the atmosphere through some device which sucks ordinary air in at one end and emits it again at the other minus its CO_2 content, and does so at less than impossible price. … If we don't solve [this problem], we are finished." (205—6)
  - —Peter Wadhams, *A Farewell to Ice: A Report from the Arctic*. Oxford University Press, 2017.

Prima Facie Case for NETs

- Paleoclimate evidence shows that we are already at CO_2 levels that very likely guarantee SLR of 20 metres or more (though it would take a few centuries for this to fully cash out). If what happened in the Pliocene is relevant to our time in the way that now seems obvious, that by itself is sufficient to show that it is not good enough merely to cease emissions of fossil carbon—to have a fighting chance of saving the icecaps, we must reduce the present CO_2 concentration to something close to pre-industrial levels.
  - "Although ice-sheet, ocean and continental geometries were subtly different during the mid-Pliocene, our results suggest that major loss of Antarctica's marine-based ice sheets, and an associated GMSL [Global Mean Sea Level] rise of up to 23 m, is likely if CO_2 partial pressures remain above 400 ppm." (Grant et al., *Nature*, *574*(7777), 237-241, 2019)
- At 415 ppm we are *already* dialed in for disastrous sea level rise.
  - 3–5 metres/century is *not* out of the question.
  - But *how soon* could it happen?

Prima Facie Case for NETs

- Under BAU (Business as Usual) scenarios, there is a near-certainty of SLR of a metre or more by 2100.
- There is a risk (though hard to quantify) of catastrophic collapse of grounded marine ice sheets (WAIS, Greenland) leading to the possibility of multi-metre SLR in *this* century or not long after.
    - "West Antarctic ice sheet and CO_2 greenhouse effect: A threat of disaster," J. H. Mercer, *Nature* 271, 26 January 1978, 321—5.
    - See also Siegert et al., "Twenty-first century sea-level rise could exceed IPCC projections for strong-warming futures." *One Earth* 3:691-703, 2020.
- The central basin in WAIS is good for about 3.3 metres of sea level rise.

A Global Tsunami

- "Catastrophic collapse" of West Antarctica means something that could happen in a few weeks or months.
- It would be like a tsunami sweeping around the world, except that it would not go away.
- My view is that the risk of ice sheet collapse is by itself sufficient to justify doing whatever we can to lower CO_2 concentration in the near-term.
    - However, I'm aware that not all climate scientists would agree, and I am not a climate scientist.

Warning from a Glaciologist

- “West Antarctic ice sheet and CO_2 greenhouse effect: A threat of disaster,” J. H. Mercer, *Nature* 271, 26 January 1978, 321—5.
  - “One of the warning signs that a dangerous warming trend is under way in Antarctica will be the breakup of the ice shelves on both coasts of the Antarctic Peninsula, starting with the northernmost and extending gradually southward.”
  - Larsen A (1995), Larsen B (2002), …
  - Mercer also correctly predicted that the centre of WAIS would begin to thin.

John H. Mercer
1922—1987

Ice Over Flotation

- Marine ice sheets such as WAIS (West Antarctic Ice Sheet) formed when snowfall was trapped in a basin faster than it could flow out.
- Marine ice sheets have “ice over flotation”—more ice than could float on their given footprint.
  - Thus, if they melt or collapse they will raise sea level.
  - (Imagine a bathtub with blocks of ice in it stacked up to the ceiling…)
- WAIS is on a hair trigger—paleoclimate evidence that it has collapsed very rapidly during past warm periods (not much warmer than we are now).

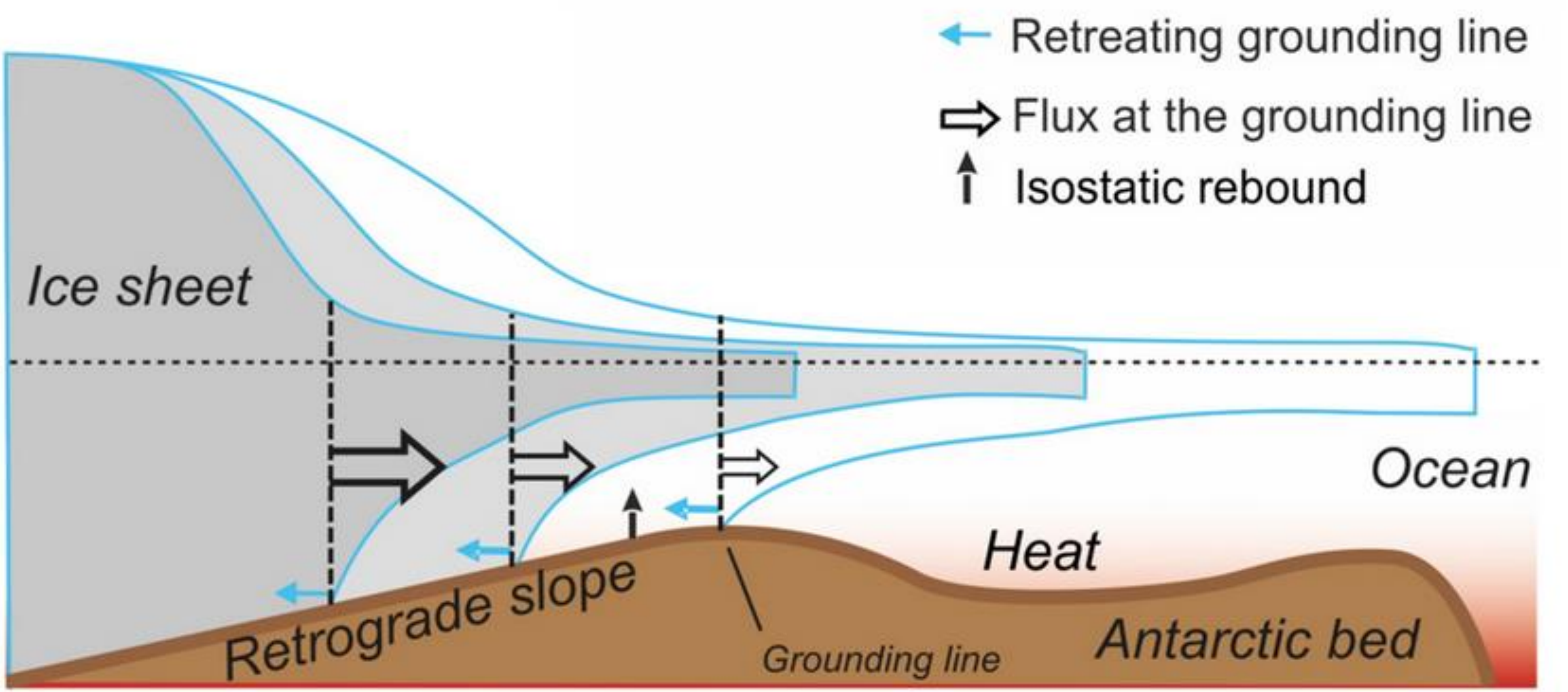

Illustration of Marine Ice Sheet Instability, or MISI. Thinning of the buttressing ice shelf leads to acceleration of the ice sheet flow and thinning of the marine-terminated ice margin. Because bedrock under the ice sheet is sloping towards ice sheet interior, thinning of the ice causes retreat of the grounding line followed by an increase of the seaward ice flux, further thinning of the ice margin, and further retreat of the grounding line. Credit: IPCC SROCC (2019) Fig CB8.1a

Prima Facie Case for NETs

- Modelling (including that cited by IPCC 2018) tends to show that there is little or no hope of holding temperature increases to any tolerable level unless a substantial percentage of the CO_2 already in the atmosphere is somehow removed in the relatively short term (a few decades at most).
- There is already enough excess CO_2 in the oceans to cause a level of acidification that threatens the viability of the oceanic food chain. This needs further study, but we probably should not rely on any further oceanic absorption of CO_2 to solve our atmospheric CO_2 overshoot.
- As we reduce our greenhouse emissions we will also reduce industrial aerosols, which contribute to global dimming (Xu et al., 2018). This question also needs further study, but it may be that this additional warming effect (ironically caused by efforts to clean up the atmosphere) could only be countered by CO_2 drawdown.

Prima Facie Case for NETs

- NETs deployed soon enough and extensively enough could forestall or reduce the need for SRM (Solar Radiation Management), which has numerous technical and ethical disadvantages of its own (Preston, 2012).
    - It is possible that certain kinds of NETs, including DAC, would have less potential for planetary-scale side effects than SRM—though this, again, needs more study.
- Under the most optimistic assumptions about the development and deployment of renewables or other alternative energies, fossil carbon emissions cannot be reduced to zero overnight. Using NETs to hold down CO_2 throughout the transition period could reduce the chance of disastrous overshoot.
- It is not in itself a bad thing that NETs could buy time, so long as it is understood that time is not being bought to eke out the profitability of fossil fuels but rather to move beyond fossil fuels.

The Question of Certainty

- IPCC (Intergovernmental Panel on Climate Change) projections are based on 66% probability (one σ).
  - Would you get on an aircraft if it had only a 66% chance of landing safely?
- If we insisted on a higher probability of meeting climate targets, then (all things being equal) there would be an even greater need for CDR.
- The question of what level of certainty we should accept is ethically charged: by our actions today we pass along risk to our later selves, our children, etc.

How *Much* Carbon Do We Need to Draw Down?

- "To limit the LPHI [low probability high impact] warming below dangerous levels, **the CES (carbon extraction and sequestration) lever must be pulled** as well to extract as much as 1 trillion tons of CO_2 before 2100 to both limit the preindustrial to 2100 cumulative net CO_2 emissions to 2.2 trillion tons and bend the warming curve to a cooling trend."

  —Y. Xu and V. Ramanathan, "Well below 2°C: Mitigation strategies for avoiding dangerous to catastrophic climate changes," *PNAS* 114(39), 10315–10323, 2017.

  - If that much C could be extracted as coal (≈1.5 tonne/m^3), that would be equivalent to a pile of coal about 200 km^3, a smallish mountain range.
  - We would have to extract even more to get to preindustrial level of 280 ppm.
- But wouldn't this solve most of our climate problems? (Or would it?)
- Why would we not simply get to work and extract as much CO_2 as possible, as soon as possible?

W. S. Churchill: "Out of intense complexities, intense simplicities emerge."

How?

- While there are many ways of removing CO_2 from the air, there is (are) no method(s) at present that would allow us to remove CO_2 at the *rate* or *scale* required to prevent climate catastrophe.
- And yet—many policy pathways (Integrated Assessment Models) are predicated on the assumption that negative emissions technologies *will* be developed at scale in the future (say, by mid-century).
- This affects our estimates of how much new fossil carbon emission we can accept *now*—in principle, we can imagine that we can emit more now (put off the reduction challenge until later) because we will have massive drawdown technologies in the future.
    - It would be as if an overweight person put off reducing food intake on the expectation that an instant weight-loss pill *will* be developed some years in the future.

Scientific Questions to be Answered

- How much negative emissions can we expect from natural sinks (oceans, forests, minerals, etc.) if we reduce positive emissions to near-zero by a certain date?
- If [CO_2] could be reduced to (say) 280 ppm, how *quickly* would this have to be done in order to forestall dangerous consequences of heat and CO_2 lingering in the oceans?

What About Planting Trees?

- Good idea, and it will help a lot.
  - Reforestation: replanting areas that have been deforested in historical times.
  - Afforestation: planting areas that can allow for tree growth.
  - Proforestation: managing existing forests to maximize their biodiversity and carbon-drawdown potential.
    - Moomaw et al., "Intact Forests in the United States: Proforestation Mitigates Climate Change and Serves the Greatest Good." *Frontiers in Forests and Global Change* 2(27).
- Soil rebuilding techniques can also be used to absorb carbon.
  - Potential for soil restoration not generally appreciated—it is *not necessarily true* that it "takes 1000 years to grow an inch of topsoil".
    - E. H. Faulkner, *Plowman's Folly*, 1943.
- Some research seems to show that it is not possible to pull down enough carbon, fast enough, merely with land management/restoration.
    - Bastin, J.-F., et al., (2019). The global tree restoration potential. *Science*, *365*(6448), 76-79.
- Is something else needed?

BECCS: Bio-Energy with Carbon Capture and Storage

- Basic idea:
  - Grow wood or other plant matter (e.g., *Miscanthus*, elephant grass).
  - Combust it directly to release energy, or convert to biofuel.
  - Capture the CO_2 thereby generated, and bury the CO_2.
  - Economically viable (in principle) if the amount of energy required for the process is less than the total energy released.
  - Incorporated into IPCC pathways—taken that large-scale BECCS will be deployed 2050 or later.

Problems With BECCS

- The colossal land requirement.
  - "Across IPCC scenarios with a 66% or better chance of limiting temperature increase to 1.5°C, median CO_2 removal by BECCS is 12Gt of CO_2 per year … This massive deployment of BECCS would require between 0.4 and 1.2 billion hectares of land (25% to 80% of current global cropland)."
    - Fajardy, M., et al., 2019. *BECCS deployment: a reality check*. London: Imperial College.
- In effect, we turn much of the planet's arable land into a plantation to produce biofuel.
  - Not a very green solution!
  - Major problems of justice: co-opts land used for food production, indigenous lands, habitat needed to preserve biodiversity.
- IMHO: BECCS is a non-starter.
  - The only reason it has taken such a prominent position in current planning is that we *imagine* that it is feasible with present technology.

Direct Air Capture (DAC)

- Increasing attention is being paid to possibilities for DAC.
  - Draw air (or possibly seawater) over sorbent which captures CO_2.
  - Captured CO_2 could be used for chemical feedstock, synthesis of hydrocarbon fuels, plant fertilization, etc.
    - Keith, D. W., et al., (2018). A Process for Capturing CO_2 from the Atmosphere. *Joule*, *2*, 1573-1594.
  - However, most must simply be mineralized and buried—whole point is to take carbon *out* of the carbon cycle.
  - Pilot plant (in Iceland) has been constructed which captures carbon, dissolves it in water; pumps water into basalt formation where it is mineralized.
    - Cartier, K. M. S. (2020). Basalts turn carbon into stone for permanent storage. *Eos*, *101*
    - Snæbjörnsdóttir, S. Ó., et al., (2020). Carbon dioxide storage through mineral carbonation. *Nature Reviews Earth & Environment*, *1*(2), 90-102.

Some Recent Developments in DAC

- Geologist Peter Keleman et al. have shown that the mineral peridotite seems to have been designed to absorb CO_2.
- Peridotite is a mantle rock, and only occurs on the surface in a few areas.
  - Certain basalts work almost as well (pilot plant in Iceland).
- However, there is in principle enough of it available to draw down all the carbon we need to draw down, and more.
  - (Ironically, the method uses fracking technology to inject CO_2-laden water into the rock formation.)
- Experiments in Oman show promise.
- However, it is energy-intensive, and would require construction of a vast industrial infrastructure to work at required scale.
    - See Douglas Fox, "The Carbon Rocks of Oman," *Scientific American*, July 2021.

Prima Facie Arguments *Against* NETs

1. They would divert and distract resources from deployment of renewable energy technology and afforestation etc.
2. They would be a “moral hazard”.

Key Scientific/Technological Questions

- Could biological and other natural sinks (the oceans, forests, etc.) draw down enough carbon, with a sufficient degree of confidence, to generate enough negative emissions to meet the < 1.5 °C target without overshoot?
  - I am not convinced that this question is yet settled scientifically.
- Could DAC + mineralization be made to work at the needed scale (10-20 + Gtonne/year), in the time required, without disastrous side-effects, and at a bearable cost?

Pros and Cons of DAC

- Pro:
  - Could in principle remove a large amount of carbon in a smallish footprint, thus having minimal planetary ecological side-effects compared with BECCS or SRM.
  - Another advantage of intensive, localized methods of drawdown is that we do not have to have everyone onside in order for them to work.
    - (Some people will save the world, while others will think it's all a hoax or will not even notice.)
  - Could contribute significantly to our portfolio of responses to AC.
    - There is *no serious possibility* that DAC *by itself* could balance our annual emissions (~40 GT CO_2) any time soon enough to matter.
- Con:
  - Demands significant investment in R & D to scale up to level required (10+ gigatonnes/year drawdown).
  - Significant energy requirement—where does that energy come from?
  - It might distract resources that would be better spent on alternative energies, other forms of mitigation and adaptation.
    - (Same criticism has been leveled against other forms of NETs.)

Economics of NETs

- Some of the carbon captured by NETs can be used to synthesize fuels, or in industry in various ways.
- However (!), most of the hundreds of Gtonne of carbon we extract has to simply be buried.
- Hence, NETs cannot be predicated on their short-term commercial viability.
  - If they are needed, they are needed as a matter of survival, and the cost must be borne by those who can afford it.
  - IMF estimates (2020) that $9 trillion spent to fight Covid-19.
  - Compare also to military expenditures, which are considered affordable by some countries.
    - (E.g.: cost of UK's upgrade of Trident nuclear submarines estimated at well over £200 billion…)

The Ethical Picture

- Several kinds of ethical concerns have been raised about NETs:
  - Could be used as an excuse for mitigation deferral—this marvellous technology is going to exist in the future, so we don't have to worry as much now about reducing emissions, and we can have a larger "carbon budget".
  - (And hence continuing profitability for the fossil fuel industry.)
  - Ethical problem: a classical "moral hazard" (I benefit, someone else pays).
    - (These worries have been raised by H. Shue, K. Anderson, G. Peters, and several other authors.)
  - Raises a suspicion that climate policy currently based on *future* NETS deployment is not entirely honest…

It's a Real Problem, But What, Precisely is the Problem?

- The risk of using future NETs as an excuse to defer emission reduction is real.
  - Could even be used as an excuse to defer R & D on NETs themselves *now*!
- The promise of future emission *reductions* could also be used as an excuse to defer reductions now!
  - The problem is mainly deferral, not the technology used as an excuse for it.
  - This is a subset of the age-old problem of free-ridership, and there is probably *no way* to entirely prevent it.
  - We have to find ways to ensure that the right and necessary things are done, *despite* the fact that some will inevitably cheat.

Rational Responses to Deferral

- Risks of climate harm rise non-linearly, the longer action is deferred (“uncertainty is not our friend”).
  - A gram of carbon drawn down, or the emission of a gram of carbon prevented *now* prevents more harm than the same gram drawn down or prevented thirty years from now.
    - Lenton, T. M., Rockström, J., Gaffney, O., Rahmstorf, S., Richardson, K., Steffen, W., & Schellnhuber, J. (2019). Climate Tipping Points —Too Risky to Bet Against. *Nature 575*, 28 November 2019, 592–595.
- The promise of future NETs cannot be used to prolong the life of the fossil fuel industry, because a necessary condition for NETs at sufficient scale is innovative energy technology—which guarantees the demise of the fossil fuel industry.
- There is no moral hazard so long as we grasp that development and deployment of NETs must be done *as soon as possible* in conjunction with emission reduction and replacement of fossil fuels as energy sources.

A Policy Instrument

- Rational persuasion can only go so far.
- We need a policy instrument that can incentivize actions that will reduce the probability of climate risk.
    - This may be more difficult than the technical problems around DAC + mineralization!

Setting Goals for Climate Policy

- "Net zero" is based on dubious comparison of emission measurements or claims, and still leaves us with dangerous [CO_2].
  - (For critique of net zero, see Holly Jean Buck, *Ending Fossil Fuels: Why Net Zero Is Not Enough*. Verso, 2021.)
- Temperature goals, although scientifically based, are indirect and deferred by several years.
  - Modelling can show what the temperature will *probably* be by, say, 2030, given the path we're on now.
  - But we need a more immediate target to frame policy.
  - We need a target that allows for faster feedback and adjustment of policy, and that is politically clearer.

CO_2 Concentration as a Policy Target

- A suggestion:
  - As suggested by Hansen et al. (2008), let it be an explicit goal of climate policy to stabilize and reduce CO_2 concentration ($[CO_2]$).
  - According to Hansen et al., it should be reduced to no more than 350 ppm a.s.a.p. to have any hope of saving the ice sheets.
    - Ideally, it should be reduced to pre-industrial levels (280-300 ppm).
  - This should be an *immediate* goal—we do not allow $[CO_2]$ to continue to rise for some years on the presumption that at some point we finally begin to make a genuine effort to reduce it.
  - The main justification for immediacy is the Precautionary Principle—the risk of existential outcomes rises *nonlinearly* the longer action is delayed.
- Net zero is not good enough—we need *net negative*.
  - Setting "net negative" as our policy target does not by itself settle the question of how much investment we should make in any particular carbon removal method.
  - *Whatever works* is the criterion.

Advantages of [CO_2] as a Policy Target

- [CO_2] is closer to the base of the causal chain than temperatures or other measures of climate outcomes (as important as these are).
- Stabilizing and then reducing [CO_2] is a clear policy goal that is a *necessary* condition for meeting all other climate targets (such as temperature regimes).
- [CO_2] responds quickly (scale of a few years or less) to changes in CO_2 absorption or emission.
  - Thus, we can tell quickly which methods and policies are effective, which are not.
- It can be measured on a daily basis.
- It can be measured by relatively direct, well-established, *public* means, compared to claims of emission reductions or offsets which often can't be checked.
- It is a *global* climate parameter and thus everyone's problem (even if not everyone contributes equally to its solution).
- It is *simple* and thus probably a more effective political goal.
- Results matter the most, not merely statements of good intentions.

A Large Caveat

- I have no clear idea how to get the world to agree on and enforce the net negative goal, especially when it is presently so difficult even to craft effective agreement on net zero.
  - (The agreed NDCs from COP26 are far from sufficient even to achieve net zero.)
- However, I prefer to assume that there is some point in discussing what would be an optimal policy, even if it is very hard to achieve.

Larger Ethical Concerns with NETs

- Hubris:
  - Aren't we way past our pay grade if we set out to tinker with the planet's climate?
  - Response: it is a bit too late to worry about this.
    - The only question can be to do it well.
  - Steffen et al. (2018) argue that a Stabilized Earth pathway "can only be achieved and maintained by a coordinated, deliberate effort by human societies to manage our relationship with the rest of the Earth System, recognizing that humanity is an integral, interacting component of the system."
      - Steffen et al., "Trajectories of the Earth System in the Anthropocene", *PNAS* 115 (33):8252-8259.

Another Ethical Problem

- An unease with technosolutions to problems that are in important part social, economic, political, ethical, and philosophical—that is, behavioral, broadly speaking.
- I think it is obvious that there is no way out of the present climate crisis that does not involve a heavy dependence upon high technology.
    - Think of the advanced scientific and engineering that has to go into renewable energy systems in order for them to work at scale.
    - E.g., battery technology, microelectronics, world-wide smart grid, novel photovoltaic materials…
- I am not saying that high technology is *sufficient*, rather that it is *necessary*.
    - We need what Thomas Homer-Dixon called for (*The Ingenuity Gap*, 2001): both *technological* and *social* ingenuity.

What if it Doesn’t Work?

- We are roughly in the same position with respect to NETs and climate as the world was with respect to coronavirus vaccines around February, 2020:
  - They might not work!
  - But if they don’t work we are in very deep trouble.
  - So we better try as hard as we can to make them work!
  - Fortunately, they do work pretty well (so far).

Upshot

- What concessions should we make to human unreasonableness?
  - The entire point of our environmental problems is that it is not just all about us.
  - The melting icecaps are not going to patiently wait for us to sort out our differences and get everyone on board.
- If it were possible for humanity to be concerned only with doing whatever it would take to steer ourselves away from the climate crisis, then of course it would be only reasonable for us to want to draw down as much carbon as possible, as soon as possible—
  - among a suite of measures we could and should be taking to mitigate and deter the effects of anthropogenic carbonization.
- It would be ironic indeed if overcoming the behavioral barriers to doing the reasonable things end up being more difficult than the substantial technical barriers that must already be surmounted in order to do those things.

If You'd Like to Know More…

- kent.peacock@uleth.ca — Comments or questions, please contact!
- This talk will be posted on my website: http://scholar.ulethbridge.ca/kentpeacock
- See my paper:
  - Kent A. Peacock, "As much as possible, as soon as possible: Getting negative about emissions." *Ethics, Policy and Environment* 24, https://doi-org.ezproxy.uleth.ca/10.1080/21550085.2021.1904497, 4 May, 2021.