Journal of Human Rights and the Environment, Vol. 8 No. 2, September 2017, pp. 203–216

Climate dreaming: negative emissions, risk transfer, and irreversibility

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The integrated assessment models used by the Intergovernmental Panel on Climate Change rely heavily on negative emissions technologies (NETs) for scenarios that keep global temperature rise to 2°C or lower. One favoured NET is bio-energy combined with carbon capture and storage (BECCS). Firstly, it is not established that BECCS is feasible at a scale sufficient to matter, nor that BECCS at sufficient scale is compatible with sustainable development. Secondly, substituting the prospect of BECCS later for ambitious mitigation of emissions now unjustifiably transfers risks from the present to the future. Thirdly, no NET can 'buy time' for unambitious mitigation because the later reduction of 'over-shoots' in emissions cannot reverse the passing of tipping points in the interim. The substitution of the dream of later negative emissions for immediate mitigations is therefore completely unjustified.

Keywords: *BECCS, climate change, integrated assessment models, justice, negative emissions, Paris Agreement, risk, sustainable development*

1 INTRODUCTION: SOMETHING WILL TURN UP?

Perhaps the most endearing character in the film, *Shakespeare in Love*, is the drama producer played by Geoffrey Rush, who lurches from one financial crisis to the next reassuring everyone unconvincingly, 'Something will turn up'. Of course, since this is a romantic film, in fact something does always turn up. But, while a certain amount of optimism is instrumentally valuable, 'something will turn up' is not a good rule of thumb for life in general – and certainly not for dealing with the dangers in climate change. Yet, several aspects of the Paris Agreement of 2015 have the hopeful but vaguely empty character of 'something will turn up'. Most notably, as many commentators have recognized, the means so far adopted do not lead even close to the admirable ends officially adopted. The official goal of the Paris Agreement, 'holding the increase in the global average temperature to well below 2°C above pre-industrial levels and to pursue efforts to limit the temperature increase to 1.5°C above pre-industrial levels' (Article 2(1)(a)) is more appropriate to our plight than might have been expected in light of previous disappointing negotiations, but the Nationally Determined Commitments (NDCs) made by the signatories in 2015 cannot be expected

* I am grateful to Pete Smith and Joshua Wells for generously providing careful readings that both enriched and tightened the text. I also benefitted from the discussion at an outstanding workshop sponsored by the Leverhulme Programme in Climate Justice at the University of Reading. I of course remain responsible for any remaining errors of fact or logic.

even to hold the temperature increase below 3°C.[1] The United States federal government committed itself to doing only what could possibly be slipped past a legislature controlled tightly by fossil fuel interests; Russia committed itself to doing nothing meaningful; Poland forced the EU to scale back its ambition in order to keep burning Polish coal; many national commitments – some reasonably and some unreasonably – are to make only relative, not absolute, reductions in emissions, and so on. On the other hand, 'a Party may at any time adjust its existing nationally determined contribution with a view to enhancing its level of ambition …' (Article 4(11)). What are needed now are mechanisms to lock in prompt and regular sharply progressive enhancements of ambition.

However, the Paris Agreement faces an even deeper political problem than the political issue of the distinctly un-ambitious levels of 'ambition' displayed so far in the NDCs. The Integrated Assessment Models (IAMs) that the Intergovernmental Panel on Climate Change (IPCC) uses to show how it is possible to hold global temperature rise to 2°C, not to mention 1.5°C, depend heavily on extensive 'negative emissions', that is, the removal of substantial amounts of carbon from the atmosphere to reverse the effects of carbon emitted. In an extensive assessment of the prospects for negative emissions technologies (NETs), Pete Smith and a large number of collaborators make the following observations: 'The Fifth Assessment Report (AR5) by the Intergovernmental Panel on Climate Change (IPCC) database includes 116 scenarios that are consistent with a >66% probability of limiting warming below 2°C (that is, with atmospheric concentration levels of 430–480 ppm CO_2eq in 2100). Of these, 101 (87%) apply global NETs in the second half of this century'.[2] So 87% of the IPCC's scenarios that allow the target of 2°C to be achieved rely on NETs. This dependence on NETs is not widely appreciated.

In their subsequent penetrating and highly accessible two-pager, Kevin Anderson and Glen Peters make a similar observation about preponderant reliance on negative emissions, using a somewhat different reference point:

> The IPCC has assessed 900 mitigation scenarios from about 30 IAMs. Of these, 76 scenarios from five IAMs had sufficient data to estimate the carbon budget for a likely chance of not exceeding 2°C … Using the 76 scenarios consistent with a likely chance of not exceeding 2°C … two key features are immediately striking. First, the scenarios assume that the large-scale rollout of negative-emission technologies is technically, economically, and socially viable. In many scenarios, the level of negative emissions is comparable in size with the remaining carbon budget … Second, there is a large and growing deviation between actual emission trends and emission scenarios.[3]

1. J Rogelj, M den Elzen, N Höhne et al., 'Paris Agreement Climate Proposals Need a Boost to Keep Warming Well Below 2°C' (2016) 534 Nature 631–9. doi:10.1038/nature18307. For a reading of this article accessible to non-scientists, see C Mooney, 'The World has the Right Climate Goals – but the Wrong Ambition Levels to Achieve Them' (2016) Washington Post, 29 June, <https://www.washingtonpost.com/news/energy-environment/wp/2016/06/29/a-sweeping-new-analysis-shows-why-our-planetary-carbon-math-is-still-falling-short/?utm_term=.b0a0796ac2e3> accessed 29 April 2017.
2. P Smith, S Davis, F Creutzig et al., 'Biophysical and Economic Limits to Negative CO_2 Emissions' (2016) 6 Nature Climate Change 42–50, at 43. doi:10.1038/nclimate2870.
3. K Anderson and G Peters, 'The Trouble with Negative Emissions' (2016) 354(6309) Science 182–3, at 182. doi:10.1126/science.aah4567. This article is highly accessible to non-scientists, but for a perceptive interpretation of its significance see C Harvey, 'We're Placing Far Too Much Hope in Pulling Carbon Dioxide Out of the Air, Scientists Warn' (2016)

That the level of negative emissions in some models is comparable in size with the remaining carbon budget means that as much carbon must somehow be extracted as may still be emitted! The feasibility and moral acceptability of heavy reliance on NETs are clearly major, but relatively little discussed, issues.

2 A PROMISE THAT MAY NOT BE FULFILLED: IS BECCS LIKELY TO WORK ON A LARGE ENOUGH SCALE?

Most NETs are not yet proven at scale, and serious obstacles of various types stand in the way of scaling any of them up to a level at which they could produce the required global impact. To rely on them as a matter of policy is to gamble that something will turn up to solve all the problems confronted by at least one of them. Most NETs are hypothetical solutions, not confirmed solutions. Smith and his collaborators have examined the respective strengths and weaknesses of several leading contenders among the NETs in their impressive study, and I will merely mention briefly a very few illustrative worries here, starting with some concerns specific to the NET invoked in the most scenarios, BECCS: bio-energy (BE) combined with carbon capture and storage (CCS).

An alternative NET currently being seriously explored is direct air capture (DAC), but DAC makes large energy demands. The energy requirements in 2100 for amine DAC, for example, to remove a sufficient amount of carbon (3.3 Gt Ceq yr^{-1}) to make a difference would be 'equivalent to 29% of total global energy use in 2013 (540 EJ yr^{-1}), and a significant proportion of total energy demand in 2100'.[4] By contrast, BECCS would have the great merit that it actually produces net energy – this is the bio-energy part – while removing carbon from the atmosphere in two steps, through the photosynthesis involved in the initial growth of the biological material that is the feedstock for the combustion, and through the CCS that captures most of the emissions from the combustion of biomass that produces the energy.

But BECCS has high land-use intensity. To remove the same significant amount of carbon (3.3 Gt Ceq yr^{-1}) looked at in the case of DAC, the feedstocks would need, depending on exactly which crops were grown, 'a land area of approximately 380–700 Mha in 2100',[5] which Anderson and Peters later note is 'one to two times the area of India'![6] And BECCS also makes large demands on water, which Smith estimates for 2100 as '~3% of the freshwater currently appropriated for human use'![7] If less of the land is irrigated, water demand goes down, but land demand goes up; if more of the land is irrigated, land demand goes down, but water demand goes up. The question that the calculations by Smith makes obvious is: given the likely global population in 2100 and the consequent likely food demand, how are operators of BECCS going to find the equivalents of one or two Indias' worth of land and of 3% of the current human use of water?[8]

Washington Post, 13 October, <https://www.washingtonpost.com/news/energy-environment/wp/2016/10/13/were-placing-far-too-much-hope-in-pulling-carbon-dioxide-out-of-the-air-scientists-warn/?utm_term=.8d48f85a3e60> accessed 29 April 2017.

4. Smith et al. (n 2) at 47.
5. Ibid at 46.
6. Anderson and Peters (n 3) at 183.
7. Smith et al. (n 2) at 47.
8. It could only be done through demand management – largely by a move away from livestock products in diets toward plant-based foods – and cutting current levels of food waste: B Bajželj,

So, after exploring many more complications than I have hinted at here, Smith and colleagues not surprisingly make the following strong recommendations:

> emission reductions must continue to be the central goal for addressing climate change. … A heavy reliance on NETs in the future, if used as a means to allow continued use of fossil fuels in the present, is extremely risky, as our ability to stabilize the climate at <2°C declines as cumulative emissions increase. A failure of NETs to deliver expected mitigation in the future, due to any combination of biophysical and economic limits examined here, leaves us with no 'plan B'. … 'Plan A' must be to immediately and aggressively reduce GHG emissions.[9]

Calling NETs 'a moral hazard par excellence', Anderson and Peters draw complementary normative conclusions:

> 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. If the emphasis on equity and risk aversion embodied in the Paris Agreement are to have traction, negative-emission technologies should not form the basis of the mitigation agenda.[10]

I believe these conclusions, from both Smith and colleagues and from Anderson and Peters, are correct and important as applied to BECCS. I will now lay out more explicitly some of the implicit reasoning behind the normative recommendations in these two important articles by leading scientists.

3 IS BECCS AT SCALE COMPATIBLE WITH SUSTAINABLE DEVELOPMENT?

'Extremely risky' for whom? 'An unjust and high-stakes gamble' for whom? Besides suffering from highly uncertain feasibility, as we have just seen, BECCS has completely unacceptable moral costs, as we can see next. These moral costs come at two levels. First, political pressure in subsequent decades to recover from the emissions 'over-shoot' produced by half-hearted mitigation occurring now and continuing into the next few years, currently rationalized by the prospect of recovery later using BECCS, is likely to grow. The damage wrought by escalating climate change will become increasingly graphic and increasingly difficult for politicians to brush aside as many do now. Publics in affluent democracies who are now paying no attention to climate change will impatiently demand decisive action. If BECCS has by then become the NET of choice and BECCS requires more land and more water in order to remove carbon at a sufficient scale to reverse enough of the earlier emissions, the public will say that land and water must be found.

A political imperative to find more land and more water for BECCS can go wrong in two ways. First, in so far as the land, the water, or both are removed from agricultural production, the prices of foods are likely to rise. This could be avoided if some now unpredictable and tragic reduction in the growth of global population occurred,

K Richards, J Allwood, et al., 'The Importance of Food Demand Management for Climate Mitigation' (2014) 4 Nature Climate Change 924–9. doi: 10.1038/nclimate2353. Thanks to Pete Smith for this reference.

9. Smith et al. (n 2) at 48–9.
10. Anderson and Peters (n 3) at 183.

reducing food demand, or some unforeseeable revolution in food production was created, radically increasing the food supply that could be grown with any given amount of land and water.[11] If population growth and food production continue more or less as expected, pressures on land and water are liable to grow more intense even without BECCS. Food supply might continue to be adequate in aggregate if the productivity of agriculture continued to increase in the intervening decades or, better, if demand were managed to reduce over-consumption and waste.[12] With BECCS at a scale sufficient to make a substantial difference in global carbon levels, the land and water removed from food production seem almost certain to drive up prices. And as Amartya Sen showed decades ago, famines can result, not from absolute aggregate insufficiency of food, but from skewed distribution of food, because the poorest people are priced out of the market as the better-off drive up the prices when the supply tightens.[13]

Second, however, if enough land and water were taken out of food production, absolute shortages of food could of course result. Many factors would be relevant, including what percentage of people were by then living on vegetarian diets that require considerably fewer resources than diets centred on meat, and how much agriculture was as water-intensive as, for example, California agriculture in areas that are naturally dry. But whatever the type of food and method of production, barring genuinely radical technological changes, some considerable amount of both land and water must be devoted to food production for any given number of people on the planet.

Obviously, then, either price-driven mal-distribution or absolute shortages of food could undermine food security and disrupt sustainable development, especially if over-consumption and waste by the affluent had not meanwhile been tackled. Worse still, if the emissions 'over-shoot' had been great enough, the negative emissions might by then be no more optional than the food production. Indeed, if climate change became severe enough without the negative emissions, climate change itself might undermine food production. The choice would then become, not between food production and climate stabilization, but between undermining food production by removing too much land or water from food production and undermining food production by not removing enough land or water from food production to produce the negative emissions necessary to keep the climate from undermining the food production. That could constitute a 'Sophie's Choice', a forced choice between two terrible alternatives, which is a situation we should never knowingly contribute to creating or even allow to arise.[14] The only way out at that point would be to weave a way between the horns of a dilemma. Adopting BECCS is gambling on being able to walk a narrow tight-rope: take over enough land and water to stabilize climate but not so much land and water as to cause malnutrition. Gambling on 'surgical precision' in public policy is foolhardy.

11. See, however, J Gillis, 'With an Eye on Hunger, Scientists See Promise in Genetic Tinkering of Plants' (2016) New York Times, 17 November, <https://www.nytimes.com/2016/11/18/science/gmo-foods-photosynthesis.html?_r=0> accessed 29 April 2017.
12. See note 8.
13. A Sen, *Poverty and Famines: An Essay on Entitlement and Deprivation* (Oxford University Press, Oxford 1983).
14. S Gardiner, *A Perfect Moral Storm: The Ethical Tragedy of Climate Change* (Oxford University Press, New York 2011) 385–9.

4 RISK TRANSFER

This brings us to the second level of unacceptable moral costs. The first level of unjustifiable costs discussed above is that we might in fact undermine food security or sustainable development by causing absolute shortages or mal-distributions of food as a result of appropriating land or water for BECCS. But someone might respond that this is all quite speculative. Who knows how much the global population will grow? Who knows what changes in diet or food production methods or water purification methods might occur so that even the extensive withdrawal of water or land from food production would do no harm? I acknowledge that the case for this danger is somewhat conjectural – we certainly do not have firm knowledge about all dimensions of the human situation decades hence. On the other hand, most of the key conjectures seem quite plausible, and I think it is reasonable to rely on them until specific reasons not to rely on one of them arise.

A deeper point, however – and the second level of unacceptable moral costs – is that, as Anderson and Peters claim, it is unjust to create a gamble in which, if it goes badly, the losers are people who are totally vulnerable to us, the poorer people of the future whose food supply we are gambling with, and, if it goes well, the winners are ourselves, the well-off of the present who might otherwise invest more heavily in ambitious mitigation now to try to guarantee that excessively extensive BECCS is not necessary later to stabilize future climate. It would not only be wrong in fact to create food deprivation – it is also wrong to gamble on producing a situation in which creating food deprivation is one of only two extremely bad alternatives, the other being severe climate change, both of which might occur.

The BECCS gamble shares four crucial structural features with the following analogy. Suppose I propose that you take a six-shot revolver with a bullet in one chamber, spin the chambers, and pull the trigger with the barrel against the head of a sleeping person. If the revolver does not fire – most likely, of course – I will pay you £750 (I find watching this gamble exciting!); if it fires, you receive nothing (and the sleeper will probably be killed). First, this is not a gamble in which the same person will either win or lose; instead, one person may win and a different person may lose. Second, the person who runs the risk does not receive the reward. The reward goes to someone who ran no risk but imposed the risk on the other – a situation of all risk, no possible reward. Third, the winnings of the potential winner, while not utterly inconsequential, are relatively minor, while the loss of the potential loser is grave. Fourth, the potential loser has not consented to the gamble, and the winner could not possibly compensate the loser. To take (or offer) this gamble is outrageous, bordering on psychotic.

Compare the climate gamble, which consists of some people of the present saving themselves the extra effort and expense that would be required by more ambitious mitigation now at the risk that some people of the future, who have no say in the gamble and are entirely at the mercy of what people in the present decide to do, may be forced to endure either extremes of climate that their current BECCS is not adequate to prevent or extremes of deprivation of their food security because of the water and land required to raise BECCS to an adequate scale. In this gamble too the people of the present may gain something inconsequential, the people of the future may suffer grave losses, and the people of the future are completely vulnerable to decisions by people now. This too would have been an unjustly outrageous gamble to have taken, even if in fact everything turned out well.

'Turning out well' in this case could mean at best that people now avoid some extra effort and expense, and people in future suffer no grave damage because, in

spite of the half-hearted mitigation now, the amount of BECCS consequently required in the future to reduce the 'over-shoot' in emissions and keep the temperature low enough does not require more land or water than is compatible with future food security. Such a risk transfer from present to future is not justified.[15] But we have so far assumed that if the gamble did in fact 'turn out well', no damage would have been done by the shortfall in mitigation in the present. The prospect of BECCS later would have 'bought us time' so that humanity could get away with mitigating less now. But, could it?

5 A PROMISE THAT CANNOT BE FULFILLED: COULD ANY NET 'BUY TIME', EVEN IF IT WOULD WORK?

What we have seen so far suggests that the positive case in favour of reliance on BECCS in particular is quite weak, resting more on wish than on evidence. Moreover, two arguments in the negative case consist of the danger of failure and the injustice of gambling that this technology will rescue later people from the results of excessive avoidable emissions now. Reliance on BECCS that compromises the ambitiousness of mitigation now and in the immediate future has two kinds of severe moral costs: potential damage and actual injustice in taking the gamble. That negative case against relying on negative emissions will next turn out to contain another strong argument, the third. And this third consideration is not specific to BECCS alone, but is applicable to all NETs.[16]

The beguiling allure of all NETs rests on the fantasy that they 'buy the world more time when it comes to reducing our overall greenhouse-gas emissions'.[17] These (not yet proven) technologies will provide, it is hoped, an 'insurance policy' against any untoward consequences from our current relaxed approach to mitigation. They are thought, or at least hoped, as Peters observed to journalist Harvey, to provide 'get-out-of-jail cards' valid in the future in case our choice of half-hearted mitigation now seems to have locked the planet into too high a temperature level. I want to explore now a powerful reason why such wishful thinking is both deeply illusory and unjust, not simply for BECCS but for all NETs – and indeed for any form of geo-engineering that motivates less ambitious mitigation now.

The fundamental reason against reliance on 'un-doing' an 'over-shoot' from insufficient mitigation with any NET is that some effects of high cumulative emissions – even some supposedly 'temporary' effects – simply cannot be undone: these effects are irreversible by humans, even in the cases in which they are not literally permanent but may gradually be cancelled out by planetary dynamics over a time-scale of centuries that is far too protracted to be beneficial to any humans except perhaps those in far, far distant generations. The irreversible consequences of excessive cumulative emissions can be clustered loosely into relatively longer and relatively shorter effects, although the distinction between these two is obviously only in degree, and the distinction makes no discernible difference to any humans for centuries.

15. The concept of risk transfer was insightfully applied to warfare in M Shaw, *The New Western Way of War* (Polity Press, Cambridge 2005).
16. I am grateful to Joshua Wells for underlining the importance of distinguishing general objections to all NETs from objections specifically to BECCS.
17. Harvey (n 3).

5.1 Does the melting ever stop?

Some of the irreversible effects of allowing carbon emissions to continue for too long result from what are usually referred to as 'tipping points': points of no return. 'No return' is obviously relative to some time-scale. Some conditions may revert to what humans now consider to be normal after millennia, or after millions of years. We know from the geological record that this planet passes through deep cycles over vast periods of time: ice forms, sea-levels decline, and dry land expands; ice melts, sea-levels rise, and dry land shrinks.[18] Here I will refer to a change that persists for many centuries as permanent and will say that passing the threshold for such a change is passing a point of no return. This focuses the argument on changes that affect human interests that we can conceivably be concerned about. For other purposes one could adopt different criteria for 'irreversibility' and understand 'no return' with even longer time-frames.

The lists of potential tipping points for climate that may lie in the near future usually include disruption of the Atlantic meridional overturning circulation, the melting of Arctic permafrost releasing both carbon dioxide and methane in positive feedback of earlier warming, and the melting of the massive ice sheets of Greenland, West Antarctica, and East Antarctica that currently withhold vast amounts of water out of the oceans and for now free up many square miles of coastal land all over the planet that would otherwise be submerged under oceans. We can glance briefly at the melting of ice sheets that would drive rises in sea-level.

In 2014 the scientific world was electrified by the dramatic news that two independent studies by teams of eminent cryospheric scientists had concluded that the West Antarctic Ice Sheet (WAIS) is probably already melting irreversibly.[19] In other words, the tipping point for West Antarctica has probably already been passed, which means that over the coming centuries the sea-level will rise by 3 metres. This much sea-level rise will inundate scores of coastal cities. Subsequent examination of the two initial studies by other leading specialists uninvolved in them has confirmed their conclusions.[20]

One of the most dramatic elements of these findings is the specification of the working of a mechanism by which the ice sheets are undercut from below – literally – by warming ocean water in addition to the effects of the warming atmosphere above. Ice sheets rest on land; this is what distinguishes them from ice shelves, which by definition float on the ocean, often immediately in front of ice sheets, which they 'buttress' – hold back from sliding into the sea. But although ice sheets by definition rest on land, in some cases that land is itself far below the surface of the ocean so the

18. D Archer, *The Long Thaw: How Humans are Changing the Next 100,000 Years of Earth's Climate* (Princeton University Press, Princeton 2009).

19. I Joughin, B Smith, and B Medley, 'Marine Ice Sheet Collapse Potentially Under Way for the Thwaites Glacier Basin, West Antarctica' (2014) 344 Science 735–8, doi:10.1126/science.1249055; E Rignot, J Mouginot, M Morlighem, H Seroussi, and B Scheuchl, 'Widespread, Rapid Grounding Line Retreat of Pine Island, Thwaites, Smith, and Kohler Glaciers, West Antarctica, from 1992 to 2011' (2014) 41 Geophys. Res. Lett., 3502–9, doi:10.1002/2014GL060140. A non-technical account of the significance is found in T Sumner, 'No Stopping the Collapse of West Antarctic Ice Sheet' (2014) 344 Science, 683, doi:10.1126/science.344.6185.683.

20. R Alley et al., 'Oceanic Forcing of Ice-Sheet Retreat: West Antarctica and More' (2015) 43 Annual Review of Earth and Planetary Sciences 207–31, doi:10.1146/annurev-earth-060614-105344.

point at which the ice last rests on land – the 'grounding line' – is under water. So these are labelled marine-based ice sheets: they rest on land under water. This obviously means that the forward edge of the ice sheet at the grounding line is in contact with ocean water. If the ocean water is warm enough, it can melt the front of the bottom edge of the ice sheet. Scientists sometimes refer to this as 'basal melt by ocean heat flux'. If, worse, the land at the grounding line slopes downward as it goes inland, any melting can proceed downhill. This is what makes the process seem to be irreversible. Nothing is known that would stop the water from going downhill, 'lubricating' the base of the ice sheet, and allowing its pre-existing slide toward the sea to speed up. The glacier that is the 'keystone' for the West Antarctic Ice Sheet is a marine ice sheet with its grounding line on inwardly sloping land with a downward incline.

Now multiple lines of evidence have been found that this same mechanism may be beginning to work on the Totten Glacier, which is the keystone helping to hold back a huge portion of the East Antarctic Ice Sheet (EAIS). 'The Totten Glacier drains more ice than any other glacier in the EAIS and contains a volume of marine-based ice above flotation equivalent to at least 3.5 metres of global sea-level rise, comparable to that of the WAIS'.[21] An intrepid team of scientists led by researchers from the University of Tasmania sailed on the *RSV Aurora Australis* right up to the front edge of the ice shelf buttressing the Totten Glacier – the 'Totten calving front' – and directly measured deep warming water that is flowing in underneath 'through a newly discovered deep channel'. They conclude that the same general mechanism at work in West Antarctica – basal melt by ocean heat flux – is also at work in the East:

> several lines of evidence support the conclusion that rapid basal melt of the TIS [Totten Ice Shelf] is driven by the flux of warm mCDW [modified Circumpolar Deep Water] into the cavity: the presence of warm water at the ice front, the existence of a deep trough providing access of this warm water to the cavity, direct measurements of mass and heat transport into the cavity, the signature of glacial meltwater in the outflow, and exchange rates inferred from the heat budget and satellite-derived basal melt rates.[22]

Now, no one is claiming that the melting of the Totten Glacier is also already irreversible. That it is not yet irreversible is the point here, after all – what happens may depend on what we do. What we do now is supremely important for the extent of ocean invasion of now-dry land. New marine sediment evidence regarding the last interglacial period from 129,000 to 116,000 years ago has led a leading cryospheric scientist not involved in this particular new research to conclude: 'The big ice sheets are really sensitive to just a little bit of warming. That's a really powerful message'.[23]

21. S Rintoul, A Silvano, B Pena-Molino, et al., 'Ocean Heat Drives Rapid Basal Melt of the Totten Ice Shelf' (2016) 2 Science Advances e1601610, 1. An account of the article for laypersons is: C Mooney, 'Scientists Confirm that Warm Ocean Water is Melting the Biggest Glacier in East Antarctica' (2016) Washington Post, 16 December <https://www.washingtonpost.com/news/energy-environment/wp/2016/12/16/warm-ocean-water-is-slamming-into-and-melting-the-biggest-glacier-in-east-antarctica/?utm_term=.e103e52049f9> accessed 30 April 2017.
22. Ibid at 4.
23. Robert DeConto, quoted in Hannah Devlin, 'Sea Levels Could Rise by Six to Nine Metres Over Time, New Study Warns' (2017) The Guardian, 19 January. The underlying study is J Hoffman, P Clark, A Parnell, and F He, 'Regional and Global Sea-surface Temperatures during the Last Interglaciation' (2017) 355 Science 276–9, doi:10.1126/science.aai8464. Also see R DeConto and D Pollard, 'Contribution of Antarctica to Past and Future Sea-level Rise' (2016) 531 Nature 591–7, doi:10.1038/nature17145. An accessible account of the significance of

Totten is also specifically a marine-based ice sheet, and the Tasmania-based research team found, as we have seen, hard physical evidence that the mechanism of basal melt by ocean heat flux is at work under the ice shelf that buttresses the ice sheet. Several years ago I introduced the concept of a 'threshold likelihood' of catastrophic human losses, which obtains when '(a) the mechanism by which the losses would occur is well understood, and (b) the conditions for the functioning of the mechanism are accumulating'.[24] Both WAIS and the Totten Glacier have unfortunately turned out to be paradigm cases of threshold likelihood.

I argued then that when such massive losses had threshold likelihood, we should take action to prevent them in spite of not being able to calculate a probability of their occurrence, provided only that the costs were not excessive. Knowledge of a calculable probability is unnecessary when threshold likelihood has been established for a possible human catastrophe that can be prevented at non-excessive cost. Lauren Hartzell-Nichols has subsequently incorporated threshold likelihood into her carefully constructed Catastrophic Precautionary Principle.[25] A rise in sea-level of an additional 3 metres from the melting of the Totten Glacier, especially in combination with the 3 metres from the melting of the WAIS, would undoubtedly constitute a human catastrophe for every nation with a sea-coast.

To choose not to mitigate our emissions now at the maximum affordable rate, but instead to rely on the possibility (with no calculable probability!) of somehow fully adequate future negative emissions would be to choose to ignore the threshold likelihood that between now and when BECCS, or whatever turned out to be the NET of choice, took a substantial bite out of the emissions 'over-shoot' at the global scale our lack of ambition would have opened the door to – allowed the planet to pass the threshold for – the beginning of the irreversible melting of the Totten Glacier. Gambling that the tipping point for the irreversible melting of Totten would not be passed would be an outrageously reckless act – an utterly unjustified risk transfer. To save ourselves some trouble and expense, and whatever they might risk for us, we would risk catastrophe for future generations from sea-level rise.

5.2 Do the oceans ever forget?

Some other irreversible – or if you like, very long-term – effects last 'only' for centuries, not millennia, and are not usually included in the customary lists of tipping points. But they affect foreseeable human interests just as decisively. For example, researchers – including Susan Solomon of MIT, a former chair of the IPCC working group on the basic science of the climate (Working Group I) – have recently drawn a striking conclusion about the famously 'short atmospheric life-time' of the greenhouse gas methane, a conclusion which Solomon has summarized informally as

DeConto and Pollard is B Dennis and C Mooney, 'Scientists Nearly Double Sea Level Rise Projections for 2100, because of Antarctica' (2016) Washington Post, 30 March, <https://www.washingtonpost.com/news/energy-environment/wp/2016/03/30/antarctic-loss-could-double-expected-sea-level-rise-by-2100-scientists-say/?wpisrc=al_alert-hse> accessed 30 April 2017.

24. H Shue, *Climate Justice: Vulnerability and Protection* (Oxford University Press, Oxford 2014), 265.

25. L Hartzell-Nichols, *A Climate of Risk: Precautionary Principles, Catastrophes, and Climate Change* (Routledge, New York and London 2017).

'the ocean never forgets'.[26] Popular writing about climate change routinely points out that significant percentages of emitted carbon dioxide remain in the atmosphere for centuries, while emitted methane persists for only a decade or two. Accordingly, carbon dioxide continues to produce its bad effects for a much longer period of time than methane does. The implication is that if we had to choose, we ought to choose to cut carbon dioxide rather than cutting methane.[27] But we do not have to choose: it is perfectly possible to work on both fronts simultaneously, especially since fossil fuels are one source of large amounts of methane as well as of most anthropogenic carbon dioxide. And, thanks to the oceans, the indirect effects of methane – the effects of its effects – are very long-lasting.

The greenhouse effect of methane is short and sharp. The methane does not remain in the atmosphere for very many years, but during its atmospheric residence it powerfully forces temperature upwards. A constant process of equilibration occurs between atmospheric temperature and ocean temperature. When atmospheric methane drives atmospheric temperature up, some of the heat moves into the ocean. But because of the complex processes sketched by Zickfeld, Solomon, and Gilford, the heat only slowly circulates through the various depths of the world's interconnected oceans, remaining out of the atmosphere for centuries but meanwhile driving thermal expansion of the ocean water – water expands as it is heated. This thermal expansion will exacerbate sea-level rise. And the amount of heat added to the oceans by human activity is turning out to be far greater than previously suspected.[28]

In addition, as we saw above, warming oceans will speed basal melt of marine-based ice sheets, which exist in Greenland as well as in West and East Antarctica, providing a stunning illustration of reverberating positive feedbacks allowing climate change to feed upon itself. And when, after centuries, the process of equilibrating temperatures eventually releases some of the heat from the ocean into a cooler atmosphere, it will again heat the atmosphere. Thus, the brief but sharp initial rise in atmospheric temperature produced directly by the greenhouse effect of the methane translates, via the slow grinding of oceanic processes, into (i) atmospheric temperature rise centuries later, as well as earlier (ii) thermal expansion of ocean water and (iii) basal melt of ice sheets.

Negative emissions produced decades after any particular methane emissions – irrespective of whether the NET is BECCS in particular – leave the effects, direct and indirect, of that methane untouched. With regard to methane emissions in the

26. C Harvey, 'Methane May Not Last Long in the Atmosphere – but It Drives Sea Level Rise for Centuries' (2017) Washington Post, 13 January, <https://www.washingtonpost.com/news/energy-environment/wp/2017/01/09/methane-may-not-last-long-in-the-atmosphere-but-it-drives-rising-seas-for-hundreds-of-years/?utm_term=.774974544c34> accessed 10 May 2017. See K Zickfeld, S Solomon, and D Gilford, 'Centuries of Thermal Sea-level Rise Due to Anthropogenic Emissions of Short-lived Greenhouse Gases' Proceedings of the National Academy of Sciences. doi:10.1073/pnas.1612066114.

27. H Shue, 'Mitigation: First Imperative of Environmental Ethics' in S Gardiner and A Thompson (eds), *The Oxford Handbook of Environmental Ethics* (Oxford University Press, New York 2017), 465–73.

28. L Cheng, K Trenberth, J Fasullo, et al., 'Improved Estimates of Ocean Heat Content from 1960 to 2015' (2017) Science Advances 3, e1601545 (10 March 2017). For an appreciation of the significance of these estimates, see C Harvey, 'The World's Oceans are Storing Up Staggering Amounts of Heat – and It's Even More Than We Thought' (2017) Washington Post, 10 March 2017, <https://www.washingtonpost.com/news/energy-environment/wp/2017/03/10/the-worlds-oceans-are-storing-up-staggering-amounts-of-heat-and-its-even-more-than-we-thought/?nid&utm_term=.957e4a297ccd> accessed 10 May 2017.

short-term, negative emissions in the intermediate term buy no time. With or without the later negative emissions, the methane emissions in the next decades do their damage – both the resulting thermal expansion and the basal melting of ice sheets will, each by its own mechanism, produce higher sea-levels and contract the land area safe for humans. 'Buying time' on mitigation is a scientifically naive fantasy. Peters is correct that no NET is a 'get-out-of-jail-free card'.

6 MORAL CORRUPTION

In sum, we have seen two serious objections to any reliance on BECCS that underwrites a compromise of the ambitiousness and urgency of the mitigation of carbon emissions in the near and intermediate terms: (I) BECCS may either simply not work at a sufficiently large scale to make enough difference globally or work at scale only at unacceptable costs to food security or sustainable development caused by diversion of land, water, or both; and (II) in any case reliance on future BECCS unjustly transfers risk to vulnerable people of the future who are at our mercy. Moreover, (III) even if some NETs worked at scale with acceptable costs, none of them could 'buy time' that would make current inaction cost-free, but all would instead simply permit long-term climate changes to proceed apace in the interim.

In so far as the purpose for counting now on deploying NETs in the future is to avoid causing expense or inconvenience to those of us who can easily afford far more ambitious mitigation now, our self-regarding plan blocks the future provision of necessities to the less well-off in order to preserve the existing conveniences of us better-off. Sacrificing the poorer to benefit the richer is the clearest possible case of injustice. As I put it in 1992, 'even in an emergency one pawns the jewellery before selling the blankets'.[29] To keep our own jewellery now we risk forcing others to sell their blankets later. In so far as it is future poorer people who are sacrificed for present richer people, this constitutes specifically one kind of blatant intergenerational injustice.

Scientists are not to be faulted for exploring all options, including plans B, C, etc. But how can policy-makers lazily indulge in patently unfair policies that *de facto* substitute dreamed-of future NETs for actual current mitigation? This may be an especially clear example of what Stephen M Gardiner calls 'moral corruption'. Moral corruption is actually corrupt reasoning, but the reasoning is corrupted by a moral failing constituted by assigning inordinate weight to one's own well-being at the price of the well-being of others that justice would require one to respect. The 'core case of corruption' is 'illegitimate taking advantage of a position of superior power for the sake of personal gain'.[30] Living people have superior power over future people, rich people have superior power over poor people, and humans have superior power over non-human lives. Moral corruption takes the form of buck-passing: the living passing sacrifices on to future people, the rich passing burdens on to the poor, and humans advancing their interests at great costs, including extinction, for non-humans. Risk transfer may be one form of buck-passing. The buck-passing is licensed by corrupt reasoning such as self-deception or rationalization that 'prevents us from even seeing the problem in the right way',[31] which Gardiner beautifully illustrates with a detailed reading of the reasoning by which the characters John and Fanny

29. Shue (n 24) 46.
30. Gardiner (n 14) at 304.
31. Ibid at 301.

Dashwood in Austen's *Sense and Sensibility* gradually convince each other that John owes his stepmother and half-sisters far less than he initially took himself to have promised his father, worsening their poverty in order to enhance his own wealth while convincing himself that he has kept his promise. Gardiner observes:

> if we are tempted by buck-passing, but reluctant to face up to moral criticism for succumbing to it (our own, or that of others), we are likely to be attracted to weak or deceptive arguments that appear on the surface to license such behaviour, and so to give such arguments less scrutiny than we ought.[32]

Moral corruption seems to be intellectual sloth, serving self-interest.[33] This lazy thinking allows one to settle for a comforting false conclusion when harder thinking would uncover inconvenient truths. If we realized that if we do not ambitiously pursue radical reductions in carbon emissions immediately, future generations are likely to suffer grave – potentially catastrophic, in fact – threats to their basic well-being, we might feel badly (either about the likely suffering in the future, or about the heartless kind of person we see that we have let ourselves become – affective empathy or shame – or both), unless we spring into action in support of ambitious mitigation. But becoming serious about mitigation might be at least somewhat expensive (although progressively less so at a rapid rate), time and energy consuming, or inconvenient. Luckily, we may think, people are building NETs into future climate scenarios, and it seems plausible that if emissions can be reversed in future, it will not hurt anything if we do not exert ourselves now but merely engage in symbolic mitigation to show that our hearts are in the right place, and leave the technologically heavy lifting to the people of the future. In short, it looks as if NETs may buy time for emissions reductions later – by other people. That's a comforting thought.

But, of course, as we have seen, the thought is comforting but groundless. And, as Gardiner pointed out, climate change is a case in which many costs must be borne by the current generation (because if action is not taken now, it will be too late – again, we often cannot in fact 'buy time'), but the benefits will be enjoyed only by people in the future. Who wants to pay now so that others can benefit in future? So there is a strong temptation for generational buck-passing: let's not pay – since they will benefit, it may seem fair to let them pay. But if we can see that delay will set severe dangers irretrievably in motion, it may be more difficult – for some people, at least – to stick to the hard-headedly self-interested strategy while maintaining their self-respect. Much better for our self-respect if delay will not be deadly – and it would not if over-shoots in emissions could be corrected later by NETs (and nothing untoward happened meanwhile).

So, in order to face uncomfortable facts such as the fact that BECCS may not be compatible with food security for the poor and the fact that a number of very untoward events will be set in motion during any delay in aggressive mitigation, one must actively resist wishful thinking. Such resistance is perfectly possible, but it does require a desire to face facts and a willingness to respond to reality. Nothing heroic is required, only a fundamental sense of justice, a little study, and a little hard thinking.

President Donald Trump has surrounded himself with what appear to be morally corrupt men. They would, they say, gladly take action on climate change if it were really clear what needs to be done. But while climate change is occurring to some

32. Ibid 302.
33. Cf Daniel Kahneman, *Thinking, Fast and Slow* (Farrar, Straus and Giroux, New York 2013) 46.

extent and anthropogenic carbon emissions seem to be playing some kind of role, they admit, it is so uncertain, they claim, how great the human role is and consequently what action, if any, needs to be taken to restrict the use of fossil fuels that it would be unreasonable to impose inconvenience or cost on those with vested interests in coal, oil, and gas. We should just wait and perhaps matters will become clearer later (when they can be dealt with by other people, perhaps employing NETs).[34]

This might be lazy ignorance and superficial thinking in the service of unbridled self-interest – moral corruption. A different explanation of their behaviour would be that they know better and are simply lying to the public while promoting fossil fuel interests, as ExxonMobil has done for decades – presenting what Trump's Orwellian propagandist Kellyanne Conway called 'alternative facts'. Whichever it is – morally corrupted thinking, bald lying, or a muddled mixture of both – we ought to fight against it in every effective way. The people of this planet need to confront facts: ambitious mitigation is urgent now. If Washington is for now lost in self-serving dreaming, the rest of the world, including state and city governments in the US, must engage reality all the more firmly. As Jerry Brown, the Governor of California, put it in response to current Washington myth-making, 'above all else, we have to live in the truth. When the science is clear … we must say so, not construct some alternate universe of non-facts that we find more pleasing'.[35]

34. C Mooney, 'Trump Appointees on Climate Change: Not a Hoax, But Not a Big Deal Either' (2017) Washington Post, 13 January 2017, <https://www.washingtonpost.com/news/energy-environment/wp/2017/01/13/trump-appointees-on-climate-change-not-fake-not-a-big-deal-either/?utm_term=.b37e797c8069&wpisrc=nl_green&wpmm=1> accessed 2 May 2017.
35. K Tumulty, 'Trump's Disregard for the Truth Threatens his Ability to Govern' (2017) Washington Post, 24 February, <https://www.washingtonpost.com/politics/trumps-disregard-for-the-truth-threatens-his-ability-to-govern/2017/01/24/945c81aa-e272-11e6-a453-19ec4b3d09ba_story.html?utm_term=.fb32e9a9c545> accessed 30 April 2017.