

Opinion piece



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Mitigation gambles: uncertainty, urgency and the last gamble possible

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A rejection by current generations of more ambitious mitigation of carbon emissions inflicts on future generations inherently objectionable risks about which they have no choice. Any gains through savings from less ambitious mitigation, which are relatively minor, would accrue to current generations, and all losses, which are relatively major, would fall on future generations. This mitigation gamble is especially unjustifiable because it imposes a risk of unlimited losses until carbon emissions cease. Ultimate physical collapses remain possible. Much more ominous is prior social collapse from political struggles over conflicting responses to threatened physical collapse. The two most plausible objections to the thesis that less ambitious mitigation is unjustifiable rely, respectively, on the claim that negative emissions will allow a later recovery from a temporary overshoot in emissions and on the claim that ambitious mitigation is incompatible with poverty alleviation that depends on inexpensive fossil fuels. Neither objection stands up. Reliance on negative emissions later instead of ambitious mitigation now permits the passing of tipping points for irreversible change meanwhile, and non-carbon energy is rapidly becoming price competitive in developing countries like India that are committed to poverty alleviation.

This article is part of the themed issue 'The Paris Agreement: understanding the physical and social challenges for a warming world of 1.5°C above pre-industrial levels'.

1. Introduction

This paper is a normative analysis of the structure of the risks created by any decision about how ambitiously to mitigate the primary factor forcing climate change,

carbon dioxide (CO₂). Rather than discussing a dichotomy between attempting to limit the temperature rise to 2°C and to limit it to 1.5°C, the paper presents the decision more flexibly as choices among degrees of ambition in mitigation. Mitigation is more ambitious insofar as it eliminates emissions of CO₂ at an earlier date and, therefore, at a lower final level of cumulative atmospheric accumulation [1]. The theses are that (i) all decisions about the degree of ambition for emissions mitigation are unavoidably decisions about how to distribute risk across generations and (ii) the less ambitious the mitigation is, the more inherently objectionable the resulting intergenerational risk distribution is. This normative structural analysis of risk thus has strong implications for the standards by which national implementation of the 2015 Paris Agreement ought to be assessed.

Philosopher John Rawls [2] called attention to situations for choice that have three features, which I have modified in important respects, partly following Stephen Gardiner [3]. One can be in a situation in which one must choose between two alternatives. Alternative A has a high probability of producing a satisfactory outcome. Alternative B has three features: (i) it might produce trivial relative gains compared with the first, (ii) it might produce significant relative losses compared with the first, and (iii) knowledge of the probability that it will produce the trivial gains rather than the significant losses ‘is impossible, or at best extremely insecure’ [2]. Obviously choosing the second alternative would be imprudent—the second alternative is a very bad gamble, risking a substantial loss for the sake of a trivial gain in circumstances of uncertainty.

Everyone’s fundamental choice with regard to climate change is how ambitious to be about mitigation—about when to bring carbon emissions to zero globally and leave behind the era of fossil fuels, the extraction and transport of which pollutes land, water and air, and the combustion of which pollutes the air in multiple ways and, specifically through the release of CO₂, undermines the climate to which humans and other living things have adapted. While a few of the national mitigation pledges—the nationally determined contributions (NDCs)—made at Paris 2015 may have been adequate tentative first steps, most of the NDCs ranged from the merely minimal to the paltry. The ‘ambition’ of a national commitment to mitigation refers not only to the extent of the de-carbonization to be conducted within a nation’s own borders but also to the extent of the same nation’s pledged support for de-carbonization to be carried out elsewhere, which together have been aptly called its ‘dual obligation’ for mitigation [4]. A nation’s responsibility to bring about mitigation may exceed its economically realistic capacity to reduce its own domestic emissions; in that case, it ought to provide financial or technological transfers that enable the reduction of emissions elsewhere to the extent of its remaining unfulfilled responsibility. ‘Ambition’ in the sense discussed here, then, combines a nation’s NDC regarding reduction of its internal emissions with its financial and technological commitments in support of reduction of emissions elsewhere. How the ambition of individual nations should be divided between internal emissions reductions and external emissions reductions may be heavily dependent on efficiency considerations, but its total effort should reflect its national responsibility.

As people ordinarily think of generations, at any given time three generations are alive: grandparents, parents and children. Here these will be referred to simply as ‘the current generations’. More ambitious mitigation will clearly impose some costs on some segments of the current generations. Nevertheless, insofar as contemporaries have in place fair distributive mechanisms, everyone whose life would be satisfactory with less ambitious mitigation could also have a satisfactory life with more ambitious mitigation. Any sacrifices necessary for the sake of more ambitious mitigation must simply be shared fairly. In the final section, ‘Poverty alleviation’, I return to this crucial issue of fairness among contemporaries, especially international justice.

2. Structure

On the assumptions just sketched, we can compare the situation of current generations (taken together) with the situation of the individual described at the beginning. Like that individual, current generations must also choose between two tendencies in mitigation, more ambitious and

less ambitious. More ambitious mitigation by current generations with fair institutions—a crucial assumption—could allow satisfactory outcomes for everyone. On the other hand, to the extent that mitigation was unambitious, it would tend to have three features: (i) it might produce trivial relative gains compared with more ambitious mitigation by avoiding some expense, effort and disruption; (ii) it might produce significant relative losses compared with the first by postponing the date of zero carbon and thereby allowing climate change to become worse than it would if mitigation were more ambitious; and (iii) knowledge of the probability that it will produce the trivial gains but not the significant losses ‘is impossible, or at best extremely insecure’ ([2] revised edition, p. 134; first edition, p. 154). David Weisbach has described what I take to be the same gamble between more and less ambitious mitigation as follows: ‘uncertainty about the effects of climate change strengthens these conclusions because the uncertainty is not symmetric: if we do nothing or act too slowly, the bad cases if things turn out worse than expected are far worse than the good cases are good if things turn out better than expected’ [5]. The gamble on less ambitious mitigation is clearly at least as bad a gamble as the paradigm imprudent gamble that could have been taken by the individual described at the start by Rawls [2]. And the less ambitious the mitigation, the worse the gamble because the longer climate change has to grow worse, or even catastrophic.

The parallel between the alternatives in the Rawlsian case and the alternatives in the climate case is not perfect. Rawls simply compares two fixed alternatives, A and B. Mitigation involves degrees: relatively more ambitious and relatively less. But the other parallels reveal two monumental moral differences between the structures of the two gambles. In the Rawlsian case, first, the possible gains or possible losses would go to the same individual; and, second, the recipient of the possible gains and losses is the person who decides whether to take the bad gamble. By contrast, in the mitigation case the possible gains and possible losses would go, respectively, to different generations: the gains would go to current generations, who would avoid whatever expense, effort and disruption would be involved in speeding up the energy transition through more ambitious mitigation, but the losses would go to future generations, who would suffer whatever consequences resulted from worsened climate change allowed by less ambitious mitigation. So the gamble is: possible gains for us, possible losses for them. And the decision whether to make the gamble is entirely in the hands of the generations who can only gain, current generations—the potential winners have all the power—while the future generations who can only lose have no say whatsoever—the potential losers have no power. These two differences turn what was already a bad gamble into a genuinely awful gamble in which for the sake of possible trivial gains the current generations impose upon future generations whatever losses might come from climate change worsened by half-hearted mitigation. And this objectionable structure would be present even if we had no reason to think that those losses for future generations were especially likely or particularly serious.

Every risk, as Hermansson and Hansson noted, involves ‘three roles, namely the risk-exposed, the decision-maker and the beneficiary’ [6]. The three roles may be occupied, respectively, by one, two or three parties. How the roles are allocated among parties gives the risk what I am calling its ‘structure’. In the individual gamble sketched at the beginning here, all three roles were occupied by the same person. If, for example, the decision-maker is one party and a single other person is both the beneficiary and the risk-exposed, the structure of the choice is paternalistic [7]. The legislature requires motorcycle helmets, and a motorcyclist both benefits from greater safety and suffers the loss of the thrill of danger. In the instance of the choice between less ambitious and more ambitious mitigation, the three roles are again occupied by only two parties, but differently distributed among the roles. One party, the current generations, is both decision-maker and potential beneficiary. The risk-exposed is every future generation. This structure, in which one party decides and potentially benefits itself while another party is risk-exposed, is exploitative. The decision-maker uses the risk-exposed as a means of potential benefit to the decision-maker itself. This exploitative structure is the same as the structure of the choice by a firm to externalize the environmental costs of its operations. The firm is the decision-maker about how much to pollute, and it is itself the beneficiary of the reduced costs relative to controlling the pollution,

while third parties suffer from the pollution. The public is used for pollution disposal in order to reduce production costs for the firm.

We can, therefore, make three normative judgements about the intergenerational gamble that chooses less ambitious mitigation, even before we know anything about how likely or how serious the potential losses for future generations are. First, what would be a bad gamble for an individual to take upon himself could be, at the very best, an equally bad gamble for one set of generations to impose on another set of generations. The less ambitious the mitigation, the worse the gamble. The intergenerational case, however, is far worse than merely being a bad gamble. For, second, a widely shared normative principle is that while one is at liberty, with some qualifications, to choose for oneself to run whatever risks one likes, one is not at liberty to impose all the same risks on others without their consent. Accordingly, I am free to take a bad gamble if I wish, but I am not free to impose a bad gamble on others who have no voice in the situation. I am instead bound to exercise due care on behalf of others. One need not be risk-averse on one's own behalf, but one has a duty to be risk-averse towards others. Generations that choose less ambitious mitigation fail in their duty of care. The less ambitious, the greater the failure. Third, I am all the more not free to impose on others a bad gamble on which only I can gain and they can only lose—this would constitute my using them strictly as a means to my own purposes with no regard or respect whatsoever for their purposes. Well beyond a simple failure of due care, this constitutes pure exploitation. This much is clear simply from the structure of the choice.

3. Seriousness

A fourth objection to an intergenerational gamble on less ambitious mitigation arises from the degree of seriousness of the possible loss in the particular case of climate. Some of the losses possible from a gamble on less ambitious mitigation are particularly objectionable in this respect: the possible losses are unbounded—there is no limit yet on how great they could turn out to be. It is well established that, as long as the atmospheric concentration of greenhouse gases—and especially of CO₂—continues to increase, climate change will continue to become more severe [8,9]. And as long as CO₂ is emitted in amounts that produce net additions to the atmospheric concentration, that concentration will of course continue to expand. Accordingly, until global carbon emissions reach near-zero, no outer limit on the maximum severity of climate change has been set. The severity of climate change will worsen indefinitely until carbon emissions approach zero and stay there. De-carbonization must be thorough and prompt, which requires more ambitious mitigation. The less ambitious mitigation is, the later the date that the atmospheric accumulation will be capped and the longer that climate change remains unlimited.

The most elementary advice usually given to someone who plans to visit a gambling casino is: decide while you are still at home how much is the maximum amount you could afford to lose and take only that much with you. In other words, put a firm limit on maximum losses. Those who opt for less ambitious mitigation are ignoring this basic advice. They are leaving the door through which dangers of uncertain magnitude for future generations can enter open for longer.

In what respects exactly is climate change left unbounded for longer, and why is being unbounded for longer so morally unacceptable? Choosing to leave climate change unbounded is choosing to leave open the possibility that, before climate change ceases to worsen, it will have reached a degree of severity that makes ordinary human society impossible. This conclusion can be reached by way of two initially different kinds of paths, although the two kinds quickly converge. The first are simple physical paths, like the biological path: the human body cannot tolerate heat beyond a certain level because its physical capacity to cool itself has an absolute adaptability limit. Temperature can reach a point at which heat stress will 'induce hyperthermia in humans and other mammals, as dissipation of metabolic heat becomes impossible' [10, p. 9552]. However, long before the biological limit imposed by heat stress is reached generally, sea levels will rise sufficiently that many coastal cities will have to be abandoned—including scores of cities on the Indian Ocean coast of India (e.g. [11,12]). The physical limits on areas for human habitation

will tighten around the human population because of encroachment by the oceans and expansion of the range of violent storm surges.

An initial optimistic response to both cases, heat stress and ocean encroachment, is that societies will adapt as necessary if they are resilient and imaginative. For example, we know how far above sea level virtually every square foot of land on the planet now is and we can predict the minimum level of sea-level rise. So, it may be suggested, we simply must do the numbers, get organized and build the new cities to replace the coastal cities in time for them to be ready when needed by the fleeing coastal dwellers. But this response soon turns out to be politically and sociologically naive.

Who is the 'we' who are going to finance and construct the inland replacement cities? Is the European Union or the UK, for example, going to subsidize the new Indian cities while India itself continues to finance the most rapid possible replacement of coal-generated electricity with renewably sourced electricity so that temperature rises and eventual consequent sea-level rises are not meanwhile made even worse by insufficient Indian mitigation during its adaptation to the loss of current cities to the seas? Where precisely are these replacement cities for coastal dwellers to be located? Where in India is empty, habitable territory? If uninhabited areas are not available and the coastal refugees must live among prior residents of the interior, how welcome will they be? Where will the additional food be grown? If countries currently face social conflicts over migrants, imagine the conflicts possible when national territories shrink inward.

The second kind of path to breakdown of ordinary human society consists of the social paths through conflicts over the costs and the benefits of the proposed solutions to the physical stresses. The physical paths soon converge with social paths. Any transition from human society as we know it today to an imagined social arrangement that would, for example, substitute inland cities for today's harbour cities, or, say, protect against heat stress by enclosing cities in air-conditioned bubbles [13], would create enormous stress on the bonds of civilized society. Who is admitted first? Who is admitted if there is not room for everyone? Who pays? Do the first places go to those who can pay? How are those whose entrance is deferred or who are excluded going to react? Is it realistically conceivable that such radical transitions could be navigated without extreme violence, civil wars and international wars (including perhaps even nuclear exchanges) [14]? The shattering of the social structure as the result of extreme physical stress is a perfectly general threat. Such a collapse of civilized social existence seems reasonably considered to be a loss of supreme magnitude.

That physical stresses lead to conflicting political demands, and conflicting political demands can lead to tears in the social fabric, is hardly a new insight. One may have supposed that Thomas Hobbes [15] was displaying a capacity for dystopian imagination when he wrote: 'there is no place for industry, because the fruit thereof is uncertain, and consequently no culture of the earth; no navigation, nor use of the commodities that may be imported by sea; no commodious building; . . . no arts; no letters; no society. And, which is worst of all, continual fear and danger of violent death; and the life of man, solitary, poor, nasty, brutish and short.' But according to Geoffrey Parker's [16] monumental global history, *Global Crisis: War, Climate Change & Catastrophe in the Seventeenth Century*, Hobbes actually needed only to look around at the state of the world in what we now have realized was 'the Little Ice Age'—approximately the 1640s to the 1690s. The Little Ice Age consisted of climate change of only a single degree of average global temperature—downward, not upward, of course—but this modest bit of climate change, and especially the resultant disturbances to agricultural production and food prices, were one side of what Parker aptly calls a 'fatal synergy' that was an exacerbating factor in a global smorgasbord of troubles, ranging from the Civil War in England to the violent Ming/Qing Transition in China. Long before large numbers of individual people collapsed from heat stress, their societies would be liable to disintegrate in conflicts over places to live and places to grow food and over priorities for their distribution [16].

That such dangers wait at some unknown distance along the path we are currently on is a powerful reason why we ought to switch to a better path sooner and why it is irresponsible to continue with anything approximating the energy-business-as-usual, as the least ambitious

mitigation does. It is unacceptable not to choose to move away promptly from a gamble involving potential losses with no definite limit. Why unacceptable? In writing about one kind of anthropogenic climate change that could lead to human extinction and came to be called ‘nuclear winter’, a sustained fall in temperature resulting from the long-term blockage of sunlight by soot from the fires of multiple burning cities after massive exchanges of nuclear weapons, Jonathan Schell put the reason compellingly: ‘Up to now, every risk has been contained within the frame of life; extinction would shatter the frame. It represents not the defeat of some purpose but an abyss in which all human purposes would be drowned for all time. We have no right to place leaving open the possibility of this limitless, eternal defeat on the same footing as risks that we run in the ordinary conduct of our affairs in our particular transient moment of human history. To employ a mathematical analogy, we can say that although the risk of extinction may be fractional, the stake is, humanly speaking, infinite, and a fraction of infinity is still infinity. In other words, once we learn that a holocaust might lead to extinction we have no right to gamble, because if we lose, the game will be over, and neither we nor anyone else will ever get another chance’ [17].

The argument here need not presuppose a possibility of human extinction, although, until a firm ceiling is imposed on climate change by actually achieving zero carbon emissions, the extinction of no species can actually be ruled out. However, it also seems appropriate to judge that ‘the game will be over’ if *Homo sapiens* faces the kind of social collapse that might, well before extinction for itself became likely, result from the violent conflicts generated by competition for a radically insufficient supply of secure places during the transition from social life as we know it today to whatever social forms needed to be constructed to deal with unprecedentedly new physical realities. It seems fair to say that ‘human purposes would be drowned’ if civilized social practices degenerated into barbaric struggles for land and food. Occasional isolated breakdowns in law and order now, like the looting after some natural disasters, reveal glimpses of the fragility of civilization [18]. Perhaps we should not be confident about the results if social breakdowns were occurring simultaneously in societies around the planet. A gamble on less ambitious mitigation might be the last gamble possible.

At the very least, it is clear that it is unacceptable to steer anywhere near the edge of that cliff merely in order to avoid the effort, expense, inconvenience and disruption of more ambitious mitigation, provided these burdens can be distributed fairly. It is unacceptable to avoid temporary disruption at the cost of forcing future generations to risk irretrievable slides into anarchy. Social institutions now are far better able to withstand any strains of moving from less ambitious mitigation to more ambitious mitigation than any social institutions in future are likely to be to withstand the far greater strains of massive movements of populations, radical disruptions in food production and other economic arrangements, and the insecurity and fear likely to result. Because the severity of climate change is driven by the total cumulative amount of carbon emissions, and the total atmospheric accumulation will not stop expanding until significant emissions cease, the possible maximum extent of climate change will remain unlimited until the global energy system has been de-carbonized.

Two objections against the argument being made here, quite different from each other, seem most promising. The first is presented as essentially empirical, although it turns out to have deep ethical presuppositions that are troubling. The second is presented as essentially ethical, although it turns out to make important empirical assumptions that are dubious. The two are considered in turn in the remaining two sections.

4. Irreversibility

Obviously, however, whether the ultimate extent of climate change has been limited or not—whether a maximum ceiling has been set on climate change by reaching zero carbon emissions—is far from the only consideration that matters to the vital choice today between less ambitious and more ambitious mitigation. It is also critical at what level of severity of change any ceiling is finally set. Indeed, what we have just seen is that, if the severity of climate change is beyond the degree to which societies can adjust without violent tensions, it might as well be literally unlimited because

the pre-conditions of civilized life would already have been undermined by the stresses of the attempt to adapt.

It may be objected, however, that there is no such thing as firmly setting the maximum degree of climate change because any total atmospheric accumulation of CO₂ can subsequently be reduced. If there is ‘overshoot’, this can be corrected by ‘negative emissions’. The great majority of the Intergovernmental Panel on Climate Change scenarios that provide for the rise in average global temperature to be kept to 2°C or 1.5°C rely on precisely such a ‘recovery’ from an ‘overshoot’ in cumulative emissions thanks to one or more kinds of negative emissions technologies (NETs) [19,20].

Now, it is perfectly reasonable for modellers to examine various alternative scenarios employing various types of NETs deployed at different dates and with different degrees of ambition. The danger concerns the conclusions that may be drawn by unwary policy-makers for the appropriate level of ambition for mitigation from the imagined scenarios relying on NETs. The thesis in this section is that it would be a fatal error to relax mitigation from the most ambitious possible level because of a misguided confidence in what may be able to be accomplished by way of a ‘recovery’ from an ‘overshoot’ through negative emissions. That is, the ambition of actual mitigation now ought not to be reduced on the basis of reliance on assumed later negative emissions.

That it might be safe to rely on a subsequent recovery from excessive emissions is far from clear for a number of quite different kinds of reasons, including serious grounds for doubting the feasibility of deployment of NETs at sufficient scale [19,21]. However, the failing of all NETs that we especially need to note here is the ratchet effect of passing tipping points during the process of ‘overshoot’. If some types of NETs can be made to work at global scale, then the atmospheric accumulation of CO₂ can go down as well as up. But if that accumulation, even if it ultimately turns out to have been transitory itself, drives some crucial factor affecting the climate past a point of no return, that change in climate will be permanent in spite of the fact that its cause was temporary. Temporary changes can produce permanent effects.

For example, the cryogenic scientists who have concluded that the West Antarctic Ice Sheet (WAIS) probably is now irreversibly melting think that the reason why the melting is irreversible is that the crucial Thwaites Glacier is a marine-based ice sheet: it rests on land but that land is under water [22,23]. And as the land on which the ice rests moves away from the ocean, it slopes downwards under the ice sheet. The forward edge of the glacier at its grounding line—the last point at which the ice sheet rests on land—is in contact with ocean water. This opens the glacier to ‘basal melt by ocean heat flux’—warm ocean water can melt the front of the bottom edge of the ice sheet. If, as is the case with the Thwaites Glacier, the land on which the ice rests slopes downwards as it moves inland, the melting is able to move downhill, reducing the friction with the land under the ice sheet and allowing the ice to slide more rapidly into the sea. No one has been able to see what would stop this process of enhanced melting.

It has recently been discovered that the Totten Glacier, which is a pivotal feature of the East Antarctic Ice Sheet (EAIS) just as the Thwaites Glacier is for WAIS, is also a marine-based ice sheet that several lines of evidence now suggest is also susceptible to basal melt by ocean heat flux [24]. No one is claiming that the melting of EAIS has already become irreversible. But consider the following scenario—this is not a prediction, simply a hypothetical scenario to illustrate why there is less to negative emissions than meets the eye. Suppose that the atmospheric concentration of CO₂ continues to rise more than it would need to rise because of a policy choice to gamble on less ambitious mitigation. Later, this ‘overshoot’ in CO₂ is reduced through negative emissions. But during the temporary period of ‘overshoot’ the additional atmospheric accumulation drives an increase in the temperature of the ocean water that bathes the Totten Glacier at its grounding line sufficient to precipitate the start of irreversible melting. The Totten Glacier contains roughly the same amount of water as the entire WAIS—equivalent to at least 3.5 m of global sea-level rise—so adding the melting of Totten to the melting of WAIS would double the amount of sea-level rise globally to 7 m. That sea-level rise would of course endure for millennia—from a human perspective, forever. This despite the fact that the amount of atmospheric

CO₂ that launched the melting was ‘corrected’ later by negative emissions. Can we count on nothing like this hypothetical scenario happening? That is the gamble taken by less ambitious mitigation.

In the current context, what is particularly striking about this scenario is the following. Prior to any awareness of the apparent possibility of ‘recovery’ from emissions ‘overshoot’ through negative emissions, certain generations might have decided to be less ambitious about mitigation simply out of preoccupation with themselves and a simple desire to avoid expense and disruption and to continue to enjoy convenience. We saw in the first section that this would have amounted in fact to those generations taking a gamble in which they themselves can only gain and future generations can only lose. But those generations certainly might not have conceived of their actions in this way or been conscious that they were imposing such a bad gamble on future generations.

By contrast, choosing less ambitious mitigation now precisely because one is aware that it allows current generations to continue to produce avoidable emissions that we know will need to be reversed, only because we think future generations might be able to reverse them through negative emissions, seems much worse. Mitigating less now in full consciousness that, and precisely because, later generations might be able subsequently to reverse the additional emissions produced by the current less ambitious mitigation would be a clear case of choosing knowingly to make a problem worse, when one could easily have made it better, merely because the additional risks knowingly created can be transferred on to other generations. Even if the reversal of ‘overshoot’ by means of negative emissions were entirely possible and completely acceptable, such actions are the height of callous self-preoccupation and disregard of vulnerable others. If, instead, as illustrated by the scenario above, the ‘overshoot’ cannot be simply cancelled out because in the interim tipping points are passed and more severe climate effects are ratcheted in, such actions are outrageous. Why outrageous? Because worse than merely knowingly passing off the costs of one’s own benefits to others, one is knowingly passing off risks that are likely to compound and mushroom and may pass the limits of social adaptation.

5. Poverty alleviation

The one decisive objection to more ambitious mitigation in fulfilment of intergenerational justice would be its incompatibility with robust alleviation of poverty, which is a clear moral imperative of international justice. So far, I have simply assumed that any efforts or sacrifices by current generations could be fairly shared internationally. Is this actually true? Two entirely independent considerations, one of principle and one of fact, strongly support the hypothesis that ambitious mitigation and ambitious poverty eradication can be fully compatible.

With regard to principle, an admittedly now-dated study is still highly suggestive [25]. It seems reasonable that those individuals whose emissions are the greatest, whatever their country, should be the first to reduce their emissions (or, alternatively, pay for emissions reductions of the same amount by others). If the income distributions of individuals in every country are converted into emissions distributions using natural assumptions about elasticity, it turned out, using 2003 data, that a global reduction in emissions of 13 GtCO₂ in 2030 would require reductions in emissions by only the 1.13 billion high emitters from all regions of the world, which was less than 15% of the projected 2030 global population [25].

Obviously, the total amount of the global reduction in emissions ought to be set with reference to the latest scientific findings, and a consensus target for 2030 now would be more than 13 GtCO₂. But these calculations done in 2009 are illustrative of the realistic possibilities for a particular decision procedure. Once the total global reduction necessary has been specified on scientific grounds, the procedure is: ‘a universal cap is imposed on the global individual emission distribution, such that eliminating all emissions above that cap achieves the target. . . . The universal emission cap achieves equity and fairness in the climate context in the sense that: (i) countries with a larger proportion of high emitters do more, and (ii) countries with similar

emission profiles have similar commitments' [25]. This is not a full understanding of climate justice [26], but it could be one reasonable step towards it. 'Nations derive their obligations from the emissions of their high-emitting citizens, but are left free to decide on implementation policies at national and international levels' [25]. In effect, this procedure focuses on fairness, on one reasonable understanding, among the highest-emitting individuals across nations within the current generations; each national government is then left to articulate policies that would produce a fair distribution of emission cuts among all its own individual citizens.

Actual implementation of this approach clearly would depend on national political leadership with the integrity and courage to tackle the energy consumption of its wealthiest citizens. National governments that have been captured either specifically by fossil-fuel interests or more generally by the wealthiest citizens would not even consider following such a procedure. The point here, however, is that large reductions in global emissions can in principle be brought about without asking poorer citizens with low emissions anywhere to reduce their emissions at all. Indeed, this procedure can easily be modified to place a guaranteed floor under individual emissions. In the illustrative calculations made in 2009, the imposition of a floor of 1 tCO₂/yr per person would only have required lowering the universal cap on individual emissions enough to increase the number of designated 'high emitters' from 1.13 billion to 1.30 billion. Such a floor would protect what might be considered to be 'subsistence emissions' while making large total reductions in emissions [27]. 'Addressing climate change mitigation and meeting the basic energy needs of the global poor are nearly decoupled objectives' [25, p. 11886]. More ambitious mitigation in the form of domestic emissions reductions need not conflict with poverty alleviation, on 2003 figures. It would be worthwhile to update the calculations using the most current data to see if the general conclusions still hold.

The procedure sketched by Chakravarty *et al.* [25] is an approach to only one of the 'dual obligations' [4] constituent of a full account of international justice with regard to climate change, namely the domestic reductions in emissions. The other essential component of international justice, as indicated earlier, is financial and technological transfers that enable the reduction of emissions elsewhere to the extent of each nation's remaining unfulfilled responsibility. If such transfers are targeted to replace fossil fuel with non-carbon energy affordable by and accessible to the poor, they will mitigate in a manner that enhances, even if it is not fully adequate to, poverty alleviation.

When we turn from principle to fact, the picture is if anything even clearer. The absence of any necessary conflict between ambitious mitigation and poverty alleviation could be shown at a time, such as 2009 when Chakravarty *et al.* did their illustrative calculations, at which it was tacitly assumed that the cheapest sources of energy were fossil fuels, so that any reduction in energy poverty by the poorest would have to mean increased carbon emissions by them. They would be able to afford only carbon energy, it was assumed, so any alleviation of their poverty would necessarily require additional carbon emissions. And certainly the reductions in poverty in China over the last two decades have come at the painful planetary price of the burning of massive amounts of coal and the release of enormous amounts of CO₂. But it is now increasingly widely recognized that, thanks in part to China's own large investments in non-carbon energy, China could be the last nation to have to follow the old coal-based nineteenth-century model from the Industrial Revolution originally followed by Europe and North America.

We no longer have good reason to assume that energy from fossil fuels will for very long remain less expensive and more accessible than non-carbon energy for the poorest citizens in rapidly developing countries like India. The highly respected energy specialist for the *Financial Times*, Pilita Clark, observes: 'China and India have picked up the [green energy] baton and are driving a sector that has spread to every continent' [28]. The chief investment officer of the UK's state-backed workplace pension provider advises: 'For institutional investors with long-term horizons, the debate is not whether there will be a transition to a lower-carbon economy, it is about how quickly it occurs' [29]. Writing for the Institute for Energy Economics and Financial Analysis, Tim Buckley notes that 'India solar tariffs have been in freefall for months' and concludes 'the Indian energy market transformation is accelerating under Energy Minister

Piyush Goyal's leadership. The most recent and most persuasive evidence is the collapsing cost of solar electricity—a collapse that has gone beyond anyone's expectations The global energy market implications are profound' [30].

Even if one discounts some of the preceding views as reflecting journalistic enthusiasm, one finds that Climate Action Tracker has concluded: 'with China continuing to reduce its coal and CO₂ emissions, the ongoing growth of renewable energy and slowdown of coal in India is the most important development underway globally today India is already set to overachieve its 2030 NDC emissions intensity target The Draft Electricity Plan projects that, despite the increasing electricity demand, no new coal capacity, apart from the capacity already under construction, would be needed after 2022. If the Draft Electricity Plan is implemented, India will achieve its NDC's 2030 40% non-fossil capacity target before 2022, and will reach 57% by 2027!' [31]. Meanwhile, 'China's CO₂ emissions appear to have peaked more than a decade ahead of its Paris Agreement commitment to peak its CO₂ emissions before 2030' [32]. And distinguished energy economist Dieter Helm suggests more generally: 'the conventional fossil fuels are gradually being forced out of their main markets It is in electricity that the major technological progress is being made It is now possible to at least *imagine* a world in which . . . almost everything was electric, and most electricity was solar The fossil fuel industries are doomed in the long run. There is not much of a long-term future in this business' [33].

Plainly, too many complexities and complications are involved for a thorough discussion of the energy transition in the space available here. To the extent that it is becoming cheaper to pursue more ambitious mitigation by substituting renewables, the mitigation gambles become pointless as well as morally unjustified. It seems safe to conclude, at least, that our previous worries about facing a tragic dilemma between controlling climate and reducing poverty are increasingly being undercut by technological developments with their own powerful momentum. A commitment to poverty alleviation is no reason for less ambitious mitigation—in fact, quite the contrary—but a reason for just international burden-sharing.

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