The right to development in a climate constrained world

The Greenhouse Development Rights framework

A climate protection framework designed to support an emergency climate stabilization program while, at the same time, preserving the right of all people to reach a dignified level of sustainable human development free of the privations of poverty

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*This paper argues that an **emergency climate program** is needed, that such a program is only possible if the international climate policy impasse is broken, and that this impasse arises from the inherent − but surmountable − conflict between the climate crisis and the development crisis. It argues that the best way to break this impasse is, perhaps counter-intuitively, by expanding the climate protection agenda to include the protection of **developmental equity**. To that end, the Greenhouse Development Rights (GDRs) framework is designed to hold global warming below 2ºC while, with equal deliberateness, safeguarding the right of all people everywhere to reach a dignified level of sustainable human development. This standard of living, which we might say is that of a 'global middle class,' is higher than the global poverty line, but lower than the northern middle-class standard.*

To be explicit, we see this right to development, and the corresponding right to be exempt from global climate obligations, as belonging to poor people, not poor countries. And, indeed, the GDRs framework proceeds transparently from this premise, first defining an emergency stabilization pathway, then quantifying national responsibility and capacity to act, and finally calculating national obligations to pay the costs of both an emergency mitigation program and strenuous adaptation efforts. Moreover, it does this for all countries, and in a manner that takes income disparities within nations into explicit account. By so doing, it seeks to secure for the world's poor the environmental space and resources needed for low-carbon development.

Given this goal, the Greenhouse Development Rights framework inevitably allocates to the wealthy and high-emitting, in both the North and the South, the costs of the necessary mitigation and adaptation, and does so no matter how large (or small) these costs turn out to be. Such an approach may appear improbably ambitious, but we nevertheless see Greenhouse Development Rights is being 'realist,' albeit in a new way. Rather than treating short-term political constraints as immutable, we've sought to construct a transparent framework capable of catalyzing and then supporting an emergency climate program that could actually meet the long-term challenge before us.

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* The principal authors of this report are Paul Baer and Tom Athanasiou of EcoEquity and Sivan Kartha of the Stockholm Environment Institute. This report, and other materials related to Greenhouse Development Rights, can be found at www.ecoequity.org/GDRs. Please cite as: Baer, P., T, Athanasiou, S. Kartha, 2007, 'The Right to Development in a Climate Constrained World: The Greenhouse Development Rights Framework.' Address correspondence to GDRs@ecoequity.org.

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1 Introduction to the GDRs framework

The climate crisis is upon us. Indeed, it's long past time for an emergency program designed to stabilize the global climate and minimize the now inevitable destruction. Most all of us know this, yet despite our knowledge, the pace of our response has been profoundly inadequate. Nor is this slow pace entirely attributable to the intransigence of the current US Administration and its allies. There are deeper problems as well, and it's time for them to take center stage. This paper thus begins with some clear assertions about the climate challenge, and the global climate policy impasse that must be broken if we're to face it successfully. We believe that all of these assertions are true. If so, they are also quite inconvenient.

First, the science now tells us that we're pushing beyond '*dangerous* anthropogenic interference with the climate system,' and are on the verge of committing to *catastrophic* interference. For example, even the more aggressive of today's 'realist' scenarios (which seek to stabilize atmospheric greenhouse-gas concentrations at about 450 CO_2-equivalent) accept a significant likelihood that we'll soon lock in the melting of the Greenland ice sheet, and with it a seven meter rise in the sea level.[1] If we want a good chance of preventing that melting, and a *high likelihood* of staying below the widely endorsed 2ºC threshold (and this would hardly mean that we were 'safe'), then global emissions must peak very soon, and concentrations must be brought back to 400 ppm CO_2-equivalent or below. The best remaining path to such a goal requires that emissions peak within ten years – the sooner the better – and then decline precipitously.[2] As implausible as this may seem, it's the trajectory that the climate science is forcing us to accept, if we actually want a high likelihood of keeping below 2ºC. To achieve such a trajectory, however, we'll have to be far more aggressive than even the most ambitious of the current EU and US proposals.[3]

Second, we confront the climate crisis, and the consequent need for an emergency program, in a profoundly divided world characterized by both staggering levels of poverty and enormous (and growing) wealth. This is a world in which the usual path from poverty to prosperity is via a development process that entails dramatic increases in the per capita use of fossil fuel energy and other non-renewable resources. And this path, alas, must be closed. Indeed, any future in which it is taken by even a significant fraction of the world's poor is a future in which dramatically rising carbon emissions make a mockery of emergency rhetoric. Nor will finding our way to an alternative be easy. Yet, if we're to have any chance at all – if any emergency program is to have any hope of being embraced – we must take care that it does not threaten to lock in today's vast disparities of wealth and income. Rather, it must show that it can drive down emissions, globally, even while ambitious development goals are met and surpassed.[4] To this end, it must slash the emissions of the already wealthy and, at the same time, prevent the unbounded emissions growth of those rising out of poverty, *and it must do so without stifling their development aspirations*.

It's a tall order, and it leads us, inevitably, to the intersection of the climate crisis and the development crisis, and to the core of the climate challenge: The world's wealthy minority has left precious little space for the poor majority. Even if industrialized country emissions were to be suddenly and magically halted today, the climate crisis calls for such a dramatic reduction in global emissions that the developing countries would *still* urgently have to decarbonize their economies, and indeed do so while they were still combating endemic poverty. This conclusion – a direct consequence of the implacable mathematics of our vanishing emissions budget − is not only the core of the physical challenge, but also the crux of the international political impasse that has overtaken the climate negotiations.

As long as there is no acceptable burden sharing proposal on the table, that ensures that an emergency program can be executed without stifling development in the South, developing country negotiators can be forgiven if they conclude that their countries have more to lose than to gain from earnest engagement. Because a true emergency program would not be free. We might be smart, and lucky, and rapid mitigation might actually be cheap, or even be so stimulating to the overall economy that overall costs would be negative.[5] But so far, we confess, such outcomes don't strike us as being particularly likely. Indeed, a great deal of time has been wasted and each day we waste more, and we may not be lucky at all. Given this, and given particularly the social, sectoral and political dynamics that would attend any true emergency mitigation program, its costs may in the end be quite large. And to them must be added the costs of adaptation, as essential as mitigation in any true emergency program and quite possibly even more costly.

Conventional wisdom, alas, tells us that the world's wealthier citizens cannot be expected to pay more than a trivial amount for climate change, and even less if the payments go to people outside their particular national borders. In fact, given today's extremely limited 'willingness to pay,' the costs of a true emergency program may be unsupportable even if the costs of mitigation turn out to be quite low, and even if we yield to the temptation to put adaptation aside (a temptation that will be very great indeed). Thus southern negotiators may be forgiven if they fear that a stringent global climate agreement would saddle them with unacceptable costs and permanently constrain their development. Recent history, after all, is one in which high sounding schemes, celebrated in the halls of global power, seldom resolve, in the villages and megacities, into just and adequate results. Given this, the reticence of southern negotiators has been a useful habit, and even a wise one. In any case, poor countries, if they see mitigation as unfairly competing with development and poverty alleviation, will simply balk at it. Which is why, before finally throwing their support behind an emergency program, southern negotiators will need to see a proposal that, above all else, safeguards the right to development, explicitly and conclusively.

Nor will an 'equal per capita emissions right' serve as an acceptable substitute. This is a long story, but it comes, in the end to the simple fact that, given the high current levels of greenhouse gas concentrations, it's too late for *emissions rights* of any kind to offer, let alone protect, the *developmental equity* that's at issue here.[6] The way through the international climate policy impasse lies rather in direct strategies that actually reconcile the twin challenges of climate and development. It lies in a climate regime that acknowledges the right to development, and then

goes beyond acknowledgement to place that right at its structural core. The essential fact is that such a regime must secure for the developing nations a viable portion of the scant remaining atmospheric space, and do so in a manner that allows them to prosper within it.

In this context, we offer 'Greenhouse Development Rights' as a reference framework for just such a regime. We do so with the full knowledge that it will be difficult to accept. This is inevitable, for the GDRs framework demands the willingness to see that it is people – and not nations or economies – that possess the right to development. And this, inescapably, means taking inequality *within* countries as seriously as inequality *between* countries. It's a difficult step, but also, we believe, the key to breaking the climate impasse. So, because 'development' is a badly overloaded term, let's be clear from the outset: The GDR framework does not, ultimately, aim to protect the rights of countries to unfettered economic growth, but rather the rights of *people* within countries to a 'global middle class' level of sustainable human development.

To be specific, the GDRs framework embodies the right to development as a 'development threshold' below which individuals, by definition poor, are not expected to share the burden of mitigating the climate problem. This threshold reflects a level of welfare beyond basic needs, but well short of today's levels of 'affluent' consumption. People below it have development as their proper priority, and cannot be saddled with the costs of keeping society as a whole within the starkly limited global carbon budget. They have, in any event, little responsibility for the climate problem and relatively little capacity to help pay to solve it.

Those people above the development threshold, the ones who have arguably realized their right to development, face the corresponding responsibility to preserve that right for others. It's they who must share the burden – in accordance with the UNFCCC's broad principle of 'common but differentiated responsibility and respective capabilities' – of implementing the emergency program. [7] It's they who must bear the costs of not only curbing the emissions associated with their own consumption, but also of ensuring that, as those below the threshold rise towards and then above it, they are able to do so along sustainable, low-emission paths.

In practice, of course, obligations and commitments within a climate regime would have to be aggregated and allocated on a national level. But it still makes sense, and is more transparent and justifiable, to define and quantify those commitments in terms that recognize the stark intranational differences in responsibility and capacity.

In all this, 'responsibility' and 'capacity' are not mere pretty words, featured because they are so prominently embodied in the Framework Convention. Rather, they are built deeply into the GDRs burden sharing system, and this for the very pragmatic reason that they specify a viable and defensible foundation for a true emergency program. There's a lot to say about this – from the limits of per capita approaches to the need for a principle-based framework to the necessity of a system that can support adaptation as well as mitigation. But ultimately, this is largely a pragmatic matter. The resources for an emergency program have to come from somewhere, and it's the world's wealthy who have the necessary 'ways and means.' That's the capacity side of the equation. As for responsibility, we may soon find, with the brunt of the impacts falling on

innocent people around the world, that it counts a great deal, not only morally but politically as well. As matters worsen, the rich and the responsible will not be able to stand aloof.

In the discussion below, we show indicative calculations that illustrate the implications of the GDRs framework. In particularly, we calculate a national Responsibility and Capacity Indicator (RCI), in a manner that takes explicit account of the distribution of income and emissions – inequality – within countries. We then use this RCI to quantify national mitigation and adaptation obligations corresponding to an emergency program. And we demonstrate a critical, even decisive fact: The world's wealthier citizens could easily bear the costs of an emergency global climate stabilization program; in fact they could do so with relatively modest reductions in their luxury consumption.

1.1 A reference framework

We of course realize that the GDRs framework, as such, is outside the spectrum of proposals now being considered for a post-2012 regime. But at the same time, it's plainly true that the negotiations need a bit of honesty and boldness. In this context, we believe that the GDRs framework can serve as a useful standard of comparison − a 'reference framework' that clearly marks out a set of essential core elements, elements that must be part of any even potentially successful climate regime.

The GDRs framework, more particularly, aims to highlight the deep structure of the climate problem, and by so doing to illuminate the structure of the necessary solution. It refuses to prejudge solutions based on today's passing standards of political acceptability. Against this reference, more 'realistic' – or expedient – regime proposals can be measured to determine how realistic they really are, from the standpoint that really matters: enabling equitable, sustainable development and thereby having a real chance of preventing climate catastrophe.

2 The urgency

It is not our task here to justify the 2ºC threshold. There can be little doubt that even before the temperature increase reaches that level, our ability to meet critical objectives – such as the protection of food production and water availability in poor countries, or the preservation of ecological diversity – will be severely challenged. Adaptation can help with some of these concerns, and indeed it will be an absolute necessity if the worst effects of even the most immediate impacts are to be avoided. The Fourth Assessment Report of Working Group II of the IPCC, released in April 2007, makes clear that we are already experiencing the impacts of climate change, and that increasingly severe consequences are largely inevitable, given the warming that is already 'in the pipeline.'

Thus, it's with some reluctance that we suggest that, even with our rather expansive view of what is possible in terms of mitigation, humanity has already passed the point at which we can with certainty stay below the 2ºC threshold. Nevertheless, we must try our best to meet it, for if we don't, we will soon make 2ºC inevitable, and catastrophic impacts disturbingly likely. Figure 1 is designed to illustrate this situation. It shows three progressively ambitious global emission reduction trajectories, the weakest of which is just barely stringent enough to be called an emergency trajectory.[8] And, following current understanding of the relevant scientific uncertainties, it shows estimates of the probabilities that each trajectory would actually lead to more than 2ºC of warming.[9]

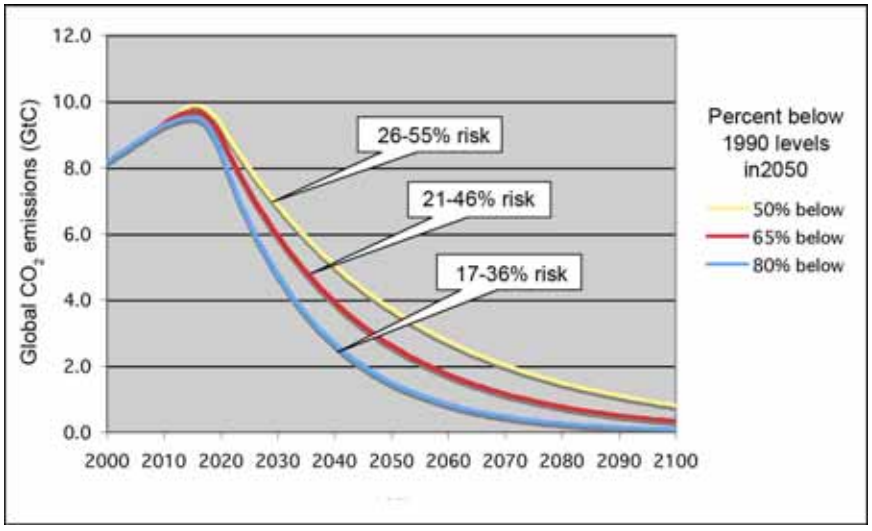

Figure 1. Emissions pathways for three emergency scenarios, peaking in 2015, and falling to roughly 50%, 65%, and 80% below 1990 levels in 2050, along with each scenario's estimated risk of exceeding the 2°C threshold.

The most stringent of these trajectories is, as you can easily see, heroic indeed. It shows emissions peaking in 2015 and dropping off at a resolute six percent per year, reaching a level of 80 percent below 1990 levels in 2050. Along the way, CO_2 concentrations peak at about 425 ppm (with CO_2-equivalent levels[10] reaching about 470 ppm) before they begin to fall. Yet, even with this effort, almost inconceivable[11] in today's political environment, we'd still be exposed to an alarming 17-36 percent risk of exceeding 2ºC.

The least radical of these trajectories also peaks in 2015 at a somewhat higher level and reaches 50 percent below 1990 levels in 2050, with reductions at about 3.4 percent annually after 2020. Carbon dioxide concentrations peak at about 445 ppm-CO_2 (with CO_2-equivalent levels reaching about 500 ppm), leaving us with a roughly 26-55 percent risk of exceeding 2ºC before 2100.

This least radical trajectory represents an important benchmark in the current debate, for it marks the border between trajectories that scientists and activists can accept as being even plausibly precautionary, and trajectories that 'realists' consider economically plausible. NASA scientist James Hansen, for example, warns that 'We have to stabilize emissions of carbon dioxide within a decade' or the temperature 'will be warmer than it has been for half a million years, and many things could become unstoppable.'[12] Thus, unsurprisingly, this trajectory is only barely consistent with the highest acceptable targets suggested by the Climate Action Network International in a recent submission to the UN process[13], and with the similarly daunting conclusions of the Scientific Expert Group convened by Sigma Xi for the United Nations Foundation.[14] Yet, this trajectory is roughly the lowest target deemed economically feasible by the Stern Review.[15]

Thus, these three trajectories mark a very important band, the one that, if we're serious, we have to aim for. Consider them to define the 'honest emergency trajectories,' and note that, as such, they essentially span the lowest category of modeled scenarios reported in the IPCC's 2007 assessment.[16]

We willingly admit that a 2015 peak in global emissions will be received by some as unrealistic, and that some will judge it unwise or unhelpful to alarm people with such low emissions scenarios. The point, however, is to inject some honesty into the debate. Too often, earnest calls to avoid 'dangerous climate change' by keeping the warming below 2ºC are accompanied by apparently sanguine recommendations for emissions pathways or reduction targets that have virtually no chance of meeting that goal. Frankly, the Stern Review's litany of climate impacts can almost certainly *not* be prevented by stabilizing greenhouse gas concentrations within most of its own recommended range of 450-550 ppm CO_2-equivalent. And though most G8 governments are, at least officially, committed to meeting the 2ºC target, it will almost certainly *not* be attained by the global reduction target (50 percent reductions by 2050) recommended in 2007's G8 declaration. These may be inconvenient truths; they may indeed be obvious ones, but they are truths nonetheless, and bracing ones. And given how soon and how quickly emissions need to drop, there's no real alternative to clearly repeating them. Certainly the ecosystems – and many

of the people – that are most at risk are unable to do so for themselves. If they could, they'd no doubt find even our most stringent scenario to be unacceptably dangerous.

For these reasons, we will use the lowest of these pathways – which we will refer to as the '2ºC emergency pathway' as our reference. This makes sense because, of the three trajectories, it has the lowest risk of exceeding 2ºC, and because the necessary transformation will be no less profound − though certainly less precautionary − in the two less stringent cases. It is, in other words, our proper marker trajectory, the one that best stands for 'an honest reckoning' and thus the one most appropriate to our needs. Besides, our results do not change significantly unless we relax to a trajectory that is far weaker, and far more dangerous, than even the least radical of our plausible emergency pathways.

Emergency action demands heroic efforts. And we still have a chance of holding the 2ºC line. Already existing technologies − if implemented and disseminated with Manhattan Project urgency − can very quickly win us huge emissions reductions, and buy us time to develop new technologies and adopt lower-impact lifestyles, which will themselves require wide-scale social and political changes in wealthy nations. But we can't afford any more delays, not even those associated with 'realism' as we know it today, which seems to demand that each small increment of progress be made to appear economically unthreatening and politically 'win-win.' Given the speed at which we now have to move, there are going to be costs, and losers, and its time to admit it. And plan for it. Costs, after all, can be fairly shared, and losers can be supported and compensated.

In short, we truly need an emergency program, and the costs of such a program, while affordable, are likely to be considerably greater than is our current willingness to pay. In the next section, we'll further explore the background conditions – in particular, the global and national divisions between the wealthy and the poor that undergird both the development crisis and the climate crisis, and that must necessarily inform all serious efforts to reconcile them.

3 Human development and climate protection

Even as we grow increasingly anxious about an impending climate crisis, many of the world's people are necessarily preoccupied with another, even more immediately pressing crisis: that of poverty. Much can be and has been said about this crisis – scandalously high infant mortality rates, horrific though easily preventable disease as a miserable fact of life and death, physical insecurity and a denial of opportunity and the right to a productive, fulfilling and dignified life; all in a world of extreme affluence and growing middle-class wealth. We shall not attempt to repeat it all here.

But there are things that must be said about poverty – and therefore inequality and wealth – and the climate crisis. First, there is no road to development, however conceived, that does not greatly improve access to energy services. Yet, as economies are now structured, as development is now envisioned, and as long as we rely on today's energy technologies, this will imply increases in CO_2 emissions that are entirely incompatible with a precautionary climate policy. And thus our dilemma: there is simply not enough 'environmental space' for the still-poor to develop in the same way – or in anything even approaching the same way – as that which was taken by the already-rich.

It is no mystery where this environmental space has gone. The 15 percent of the world's population that today live in the roughly 40 high-income countries use about half the world's energy, produce about half the world's CO_2, and consume about half the world's goods and services. Further, as they developed into this current resource-intensive state, the world's wealthy consumed so great a fraction of its carbon budget that, today, we're faced with the grim task of allocating an inadequate remainder.

And thus our current climate dilemma: If we're to keep within the scant remaining budget, global emissions must peak in the next ten years, and then precipitously decline. Yet, with today's technologies, if the poor majority's per capita energy consumption reaches even half the level of the wealthy minority's current consumption, then world CO_2 emissions would nearly double. Herein lies the essential tension between the aspirations of the world's poor – and even the minimal demands of basic human development – and, on the other side, the climate challenge. Any climate regime that ignores it is doomed to failure.

Figure 2 expresses this tension graphically by way of a comparison of emissions trajectories. The three 'peak and decline' trajectories are the same as those shown above in Figure 1, but here we compare them to the 'South's B1 pathway,' which is a rather optimistic reference projection of the South's future emissions (derived from the IPCC's 'sustainable' B1 scenario).[17] The result is a simple but striking comparison that unambiguously demonstrates that a truly precautionary trajectory is radically inconsistent with even this relatively green reference projection. Because,

if we're to avoid bursting through the most precautionary of the three pathways, the South's emissions must leave their projected path almost immediately, and will be dropping precipitously by 2025.[18] And even with the B1 storyline's optimistic assumptions about both equity and economic growth, many people in the South would still be struggling against poverty when its emissions began this steep decline.[19] Moreover, the less stringent pathways – despite accepting substantially higher risks of catastrophic climate change – provide only another few more years for emissions growth. All of which raises a crucial question. What manner of climate regime can enable such a rapid emissions decline while at the same time enabling the nations of the South to not only continue, but even step up, their fight against poverty?

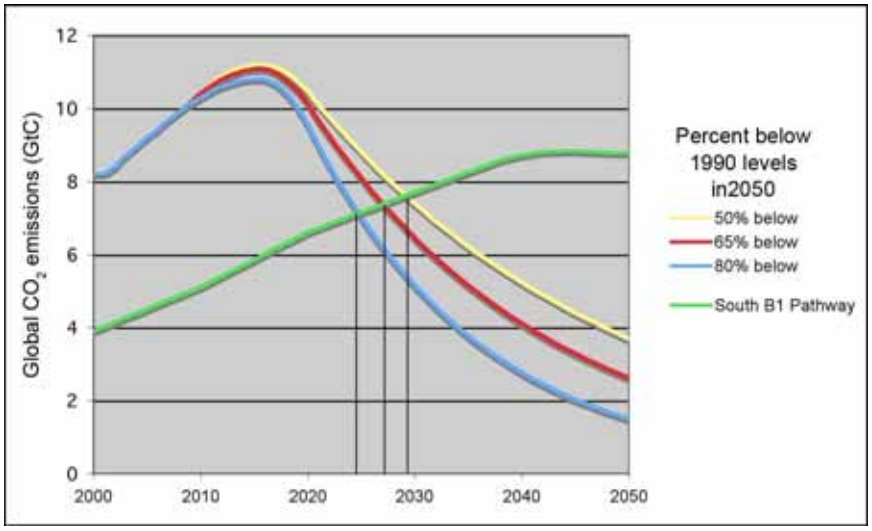

Figure 2. Available global emissions budget under three increasingly stringent reduction scenarios. All peak in 2015, and fall, respectively, to 50%, 65%, and 80% below 1990 levels by 2050. (See section 2). All are plotted along with southern emissions (according to the IPCC's B1 scenario).

This is the crux of the climate-development dilemma. Under a global emergency pathway, carbon constraints would be so tight that, in the absence of explicit efforts to enable low-emissions development, the poor would be badly squeezed. In effect, they would lose their right to development. More precisely, the emergency pathway would be seen as demanding that development be deferred, and that limited resources be invested instead in mitigation, and as such it would be resisted. Nor would this resistance be merely intransigence or brinksmanship. In many cases, it would be a rational accounting of necessity.

3.1 The right to development

If we're to successfully pursue an emergency program, our agenda must expand. A global climate regime with any promise of success must *explicitly embrace the right to sustainable human development*. This right must be declared and preserved, despite even the dire pressures of the climate crisis. Simply put, any emergency program that does not do so will flounder and fail.

To be clear, we don't mean that development must put economic growth above the protection of the climate. Just the opposite. We're referring specifically to *human development*, which we may perhaps define as the satisfaction of fundamental needs in a manner that frees people from the vulnerability and deprivation of poverty and makes possible a decent level of security and well-being. The challenge lies in ensuring that right in a manner that properly links it with an emergency program designed to rapidly decarbonize the entire global economy.

Incidentally, we're lucky that it's still possible to pursue such a vision of sustainable human development, in good faith and on a global scale. That the situation is not (yet) so dire or the scale of the needed response so overwhelming that we're forced to make genuinely draconian decisions. We're lucky that our world is a rich and resourceful one in which, despite the challenges of the climate crisis and even the larger environmental crisis, viable options still remain. We need only find a way to embrace those options, and if this means allocating a significant fraction of the gross world product (GWP) – one percent or even three – to enabling the low-carbon transition, then what of it? We can afford it. It's not actually a lot of money. Not compared to the alternative.

This was Nicholas Stern's point,[20] and it bears repeating. And it's just the beginning of the tale. For there's no fundamental axiom of economics that tells us that, having made the transition to a low-carbon path, we wouldn't find it to be at least as economically convivial as this one. There's no economic law that precludes rational public policies, or that demands that massive subsidies continue indefinitely, or insists that economic statistics continue to be warped and deformed by a nonsensical blindness to human and natural well being. There's no law, indeed, that mandates that even wealthy countries, having committed themselves to a climate transition that made real demands on them, would not discover that they benefited enormously from it, and this even if its cost meant a small slowing in the rate of conventionally measured economic growth.

The key point here, the one that must not be lost, is simply that, today, we waste far more in building, adapting to, and maintaining ill-conceived infrastructure than we would need to not only decarbonize the entire global economy, but to do so in a manner that simultaneously meets all basic human needs. Having stipulated this, we can return to our central claim, that an effective climate regime must preserve the right to human development.

There are two aspects to this claim. First, there's the political imperative to embrace human development. For even as we seek a path to a global emergency program, southern negotiators will insist − with strong ethical and political justification − that their real priority must be lifting up their poor, not mitigating greenhouse gas emissions. They will assert this, moreover, despite strong and accumulating evidence that even climate changes that are not globally catastrophic will still cause immense localized damages, undermining many of the development gains that poor communities have thus far managed to achieve. Not that this evidence is much at issue, or that southern negotiators deny it, but they nevertheless do not make mitigation a first tier priority. Perhaps they can't, not while their development needs are so great and so pressing, and certainly not while northern policies – certainly climate policies but also trade policies, and intellectual-

rights policies, and development policies in general – remain equivocal or even counter-productive.

In any case, some matters are clear. One is that the people of the developing world are unlikely to *prioritize* low-carbon development, not if it means paying a premium for energy services while so many among them have not even achieved basic levels of, say, food security. Another is that southern negotiators will remain focused on macro-economic growth as a route to poverty reduction for many (as well as, of course, riches for a few) and that any climate regime that even appears to threaten growth will be an extremely tough sell. This, moreover, will probably remain true even as the impacts of climate change worsen and become more obvious, for even in this case the opportunity costs of mitigation expenditures, which could otherwise be spent on social welfare programs, will be an issue.

Second, and even more importantly, there's a structural imperative to engage the problem of human development. Simply put, there are so many intrinsic connections between the climate and human development challenges that, as a practical matter, we can only hope to successfully engage the climate problem if the poor majority of our people are visibly progressing toward genuine human development. These connections, though manifold and complex, can be briefly outlined with respect to both mitigation and adaptation. In the former case, an emergency program would require dramatic technological transformation, amounting to a wholesale reinvention of the global energy infrastructure on the basis on low-emission technologies. In the South, this reinvention would require large-scale investment in training and education, as well as creating the institutional capacity to adopt, develop, and implement revolutionary solutions, all at the same time as meeting the growing needs of expanding populations and economies. An emergency program would also require far-reaching changes in agricultural and land-use practices, which currently account for as much as one-third of southern greenhouse-gas emissions. These changes are possible, but only if there's a real commitment to the grassroots empowerment and civil society governance that's essential if any truly positive future is to open to the poor communities that are now dependent on land-clearing for subsistence farming, fuel wood harvesting, grazing, and timber extraction.[21] The point is that this dependence must be broken, and that this cannot happen without a new focus on, and new investment in, human development. Indeed, such investment is fundamental to any rapid transition, which depends not only on next-generation energy technologies, but also on female literacy, not only on new agronomic technologies, but also on universal neonatal healthcare.

As far as adaptation is concerned, the importance of human development is even clearer. Adaptation to climate change clearly requires a level of resilience that is far beyond the grasp of the billions of people still living in poverty. And we know this despite being unable to anticipate the precise impacts that climate change will impose on the poor, let alone describe the exact defensive / adaptive mechanisms that would be necessary to counter-balance the incremental harm that they'll suffer from climate destabilization. Poor households and communities endure a range of stresses, many of which are being exacerbated by climate change, stresses that together create a syndrome of vulnerability. Thus, adaptation calls for investments that support resilience.

It requires improved access to finance and technology, but just as importantly it demands social capital and enfranchisement. In other words, building adaptive capacity means much more than narrow, climate-focused measures. It might help to provide an agricultural household a more drought-resistant variety of a staple crop, but weathering the next drought will require much, much more. That family has far better odds if it has a literate family member, if it can access investment capital through local financial institutions, if it's integrated into relatively intact social networks, if it can hold policymakers accountable. As Amartya Sen famously said, famines don't happen in democracies.

But here's an important proviso. Though these arguments − the political and the practical − echo a deep sense of ethical propriety, the Greenhouse Development Rights approach is not fundamentally an appeal to morality. Its justification, rather, is a realist one. The GDRs framework, or something like it, will be necessary if we're to break the global impasse and rise to the demands of the climate crisis, and this for two simple reasons. *The North can't stabilize the climate without the full commitment of the South, and the South can't make that commitment if doing so would threaten to undermine its development.* In practice, this means that a global alliance to stabilize the climate can only arise, and survive, on terms that honor the poor world's right to development. The wealthy countries must not only cut their own emissions, deeply and soon; they must also create *developmental space* for the poor, and help them to leapfrog to a low-emissions, high-adaptation future.

3.2 A development threshold

Greenhouse Development Rights suggests a framework for such an alliance. The key is to make the abstract notion of a right to development a reality. In our climate-constrained world, the right to development is not a right to growth, as such, in the quest for indefinitely expanding wealth. It is, rather, a right to a particular level of development, a modest but dignified level of well-being. We define this level by way of a *development threshold*. Below this threshold, individuals must be allowed to prioritize development. This means that they should not have to help bear the costs of dealing with the changing climate, on either the mitigation or the adaptation sides. Individuals above the threshold, on the other hand, must help to shoulder these costs, regardless of whether they happen to live in the North or in the South, in Annex 1 or in non-Annex 1. It is they, after all, who have the capacity to do so, as it is they who bear the overwhelming share of the responsibility for the threatened climate.

The actual level at which such a development threshold would best be set is a matter for debate, but the relevant principles are clear. The development threshold should differentiate the global poor, who have pressing and legitimate unmet needs and must be free to exercise their right to development, from the 'global middle class.' This group of people has reached a level of consumption that yields an appreciable contribution to the climate problem, and have similarly acquired enough capacity to help bear the costs of managing that problem, however high or low they ultimately turn out to be.

Defining this threshold in a concrete and quantitative sense is, not surprisingly, tricky. The most straightforward option is to define the development threshold in terms of income level, though this option of course suffers a number of obvious problems. Income is a simplistic and one-dimensional indicator that quite inaccurately reflects sustainable human development. It prioritizes a certain mode of development − economic growth − while diminishing the importance of progress in human rights, political enfranchisement, liberty, social capital, health, environmental and physical security, without which we cannot legitimately claim to have achieved a decent standard of human well-being. Nevertheless, we'll stick for now with this purely economic indicator, and we'll do so for three main reasons. First, it's highly correlated with important indicators of well-being, and this particularly at the income levels that span the low and middle income countries, where there's an indisputable correlation between income and basic indicators such as infant mortality, life expectancy, malnourishment, and educational attainment. Second, income does indeed reflect the capacity to pay for mitigation, especially once a country is wealthy enough for most basic needs to be largely met. Third, income is a helpful proxy for consumption, and hence for the distribution of carbon emissions within a country, and hence for responsibility.

How then, should we set the development threshold? Our claim will be that a 'dignified level of human development free from the privations of poverty' implies a line higher than a 'poverty line,' that indeed it implies something like 150 percent of a poverty-line income. This particular level is, of course, somewhat arbitrary, but its appropriateness is supported by the many other contexts in which it's taken to define the upper boundary of 'exempt' or 'lifeline' income. It's used as a starting point for income tax calculations, as an eligibility threshold for social services, and as a criterion for defining 'economically vulnerable' or 'near-poor' populations. It might be an underestimate, but we'll take it as a plausible and indicative figure, and as a starting point for discussion. In any event, the principle it's meant to illustrate is clear, and the latitude for meaningful negotiation is not extremely broad.

So, what is a sensible 'global poverty line?' If anything is certain, it's that it's not the typical figures of $1 per day or $2 per day. [22] Indeed, these figures obscure the real meaning of poverty, and the real nature of the poverty crisis. The $1 a day line, more precisely, is a '*destitution line,'* and the $2 a day line an '*extreme poverty line.'* Moreover, this is obvious. A person's income can grow much higher that $2 a day and they still face pervasive exposure to the plagues of poverty: malnutrition, high infant mortality, low educational attainment, high relative food expenditures. A defensible definition of a global poverty line, on the other hand, must reflect the income level at which these plagues begin to disappear, or at least become the exception rather than the rule. It must, certainly, exceed the point at which the Millennium Development Goals have been largely met. All of which is to raise empirical and statistical questions that we'll not dwell on here. In any case, as it unsurprisingly turns out, the evidence suggests that a global poverty line should be defined to be well above the extreme poverty line. It's more like $16 a day, or, equivalently, $6,000 a year.[23] (Note, since this $6,000 figure is in PPP terms, it converts to a lower income level in a local developing country currency than if it were converted at market exchange rates.)

Taking $6,000 a year as the global poverty line, we then have an indicative development threshold of $9,000 a year. This is well above the global median income (of about $3500 in 2005), and just slightly above the global average (of about $8500). It might reasonably be called a 'global middle class' income level (not to be confused with the significantly higher rich-world middle-class standard. We think that, based on the question that we actually face – *would it be fair for people poorer than this to pay for emissions reductions, in order for wealthier people to pay less?* – this line is in just about the right place.

This is not to say that poverty and hardship do not persist above an income level of $9,000 a year. Nor is it to say that a higher development threshold could not be quite strongly defended. But for the purposes of clarifying the principles that the development threshold is meant to embody, and enabling us to illustrate the implications of the GDRs framework for national climate obligations, we will take $9,000 a year as our indicative development threshold, as we will take those above it, be they middle-class or wealthy, as members of the global consuming class. (Note that the appendix contain a sensitivity analysis that demonstrates the implications of higher and lower figures.)

Crucially, we reckon the development threshold as an *individual*, not *national* average, threshold. Countries with per capita incomes below $9,000 a year always have subpopulations with higher incomes, and smaller subpopulations with *far* higher incomes and vice versa. The more unequal a country, the more this is the case. Thus, we stress that, by rights, it should be poor individuals, not poor nations, who are excused from their climate-related obligations. Individuals with incomes above the development threshold − even if they live in countries with average incomes below the threshold − should be accountable for their fair share of the climate burden. Similarly, the obligations of nations should be reckoned in accordance with the obligations of their individual in habitants. This, in a world of nations, is the only reasonable approach to the problem here.

Now this proposition – that the consuming class in developing countries has no greater claim on the remaining environmental space than do its peers in wealthy countries – will of course be controversial. Taken seriously, it necessarily challenges the conventional wisdom that there is a unified 'South,' composed in meaningful degree by nations and peoples with overwhelmingly common interests. Nevertheless, the facts here can no longer be denied, as was starkly illustrated in 'Worlds collide in India over global warming,' an article that appeared in the *Financial Times* during 2007's G8+5 meeting.[24] Its central point – indeed its central warning – was that Mukesh Ambani, the world's 14th richest man, is now busily building himself a 60-storey glass palace in Mumbai. The key statistic is that this 'home,' which sports a helipad, a pool, parking for 168 luxury cars and quarters for an army of staff, is estimated to cost half a billion US dollars. The key quote: 'Such self-indulgence should be a reminder that the G8 is dealing with not one India when it comes to climate change, but two: first-world India and third-world India.'

To be sure, Bill Gates[25] is three times richer than Mukesh Ambani. But the point is still clear. The developing world, despite its millions of desperately poor people, contains a substantial and growing class of people that are partaking in northern-style consumption − some of it quite

absurd in its conspicuousness. And, obviously, this wealthy class has both a non-negligible degree of responsibility for the climate problem and the capacity to help solve it.

More particularly, intranational inequality must be taken into explicit account if we want to meaningfully calculate, and compare, the capacities of wealthy countries such as the United States with those of emerging but still developing countries such as China and India. Indeed, attempts to do so without properly considering inequality – without exempting the incomes and emissions of people below the development threshold, and counting those of people above it – are logically and politically absurd. As if the small incomes of impoverished peasants should be taken to increase Chinese or Indian capacity to mitigate emissions in a global energy regime they in no way benefit from. As if Mr. Ambani's billions, for their part, could be ignored.

Not that all cases are as clear cut. The 'global middle class' holds a more ambiguous position than either Mukesh Ambani or Bill Gates, and the precise location of the development threshold may be quite fairly debated. But the main point is obvious enough. Recognizing inequality *within* countries is unavoidable, as unavoidable as recognizing inequality *between* countries. If, that is, our goal is a burden sharing system that actually makes ethical and political sense. There's just no way around it. Any burden sharing system that even implicitly asks poor or middle class people in wealthy countries to put their shoulders to the wheel, while at the same time exempting wealthy people in poor countries from the same effort doesn't have a chance. Nor, just as crucially, does any system that asks wealthy and middle class people in poor countries to bear a mitigation burden that is defined, by convenient fiction, as if their poor were part of the problem. They are not.

3.3 Burden sharing in the greenhouse

Fundamentally, the GDRs framework is a rich / poor burden sharing arrangement designed to support an emergency program while protecting the right to development. It does so by allocating the costs of that program among those above the development threshold – irrespective of whether they live in wealthy or developing countries – while allowing those below that threshold to attend to their development priorities.

The keys here are the two notions that lie at the core of most burden sharing discussions: capacity and responsibility. The idea that burden sharing should be based on a systematic treatment of responsibility and capacity is not new, as it is reflected in most if not all contemporary proposals. These tend to be 'multi-stage' proposals that, at a minimum, exempt poor countries from any quantified (or, more importantly, cost-bearing) obligations, and at a maximum divide countries into classes defined by measures of income and emissions.[26] Not only are these moves intuitively sensible, but they're consistent with the principle of 'common but differentiated responsibilities and respective capabilities' enshrined in the UNFCCC itself.

3.3.1 Defining capacity

Capacity reflects wealth. For our purposes, it reflects the portion of national wealth that can reasonably be tapped into to respond to the climate crisis. But all wealth is not equal. Its

definition must be reconciled with the right to development, which is to say that capacity must be calculated, and the climate burden shared, in a manner that takes proper account of intranational inequality.

To understand this, assume that the emergency program is to be funded through a global tax (and this, in a sense, is what a burden sharing system amounts to) on each country's capacity. Now consider a too-simple example, in which a country's capacity is defined as its total income (GDP). Thus, a country's share of the global mitigation and adaptation burdens is exactly equal to its share of total global income. Straightforwardly, if the total 'global bill' for the emergency program is one percent of the total global income (the GWP), this bill could be paid by charging every country one percent of its national income.

Of course this sort of 'flat tax,' when used within countries to raise domestic revenue, is almost uniformly rejected as unfair. The poor are generally seen as deserving lower tax rates because, the poorer you are, the more of your income you spend on 'necessities', and the richer you are, the more of your income you spend on 'luxuries.' So if a dollar in taxes has to be taken from someone, it's fairer to take it from someone who'll then have to reduce their luxury consumption than from someone who'd have to reduce their consumption of necessities. *In other words, the consumption of the poor has a greater moral priority than the consumption of the rich.* For this reason, tax systems are generally progressive. They exempt from taxation income below some specified minimum threshold. The tax rate on additional income above this threshold typically also increases as income rises, increasing the progressivity of the overall system. But the exemption alone is enough to ensure that the distribution of the tax burden is basically progressive.

One simple way to approximate the same progressive effect in a global burden sharing system would be to define national capacity as the amount by which a country's per capita income exceeds some minimal threshold. This threshold would be set to equal the development threshold, as defined above, to make this definition of capacity consistent with the right to development. The result would be to ensure that the portion of a country's GDP that fell below the development threshold would be exempt from being 'taxed' to pay for the global emergency program. And, after all, to the degree that a country's GDP lies below the development threshold, it's likely to be paying for necessities that contribute directly to development, rather than for luxuries.

The logic here is akin to that of the southern negotiators who have, in the past, been able to successfully argue that developing countries should be granted an exemption from any obligation to pay for climate mitigation. This argument, however, is fast losing its moral force, and for the entirely justifiably reason that it ignores the 'North within the South' − a rising consuming class in the developing world that has more in common with its brethren in the North than with the poor majorities within its own countries. In other words, by focusing on per capita income, this argument obscures income disparities *within* countries, which are fully as significant as income disparities *between* countries.

What to do? The solution we propose is to define capacity in a manner that accounts for intranational disparities in income. To define it, that is, as *individual income* in excess of the development threshold, summed across all the individuals in a country, from the poorest peasant to the wealthiest tycoon. Ultimately, since this is all toward the end of a global climate agreement between nations, capacity will be defined − and the climate burden allocated − on a national basis. But the real point here is that capacity must be calculated in a manner that accounts for intranational inequality. Unless it is, it will not meaningfully reflect the development status – the wealth and poverty – of nations.

3.3.2 Defining responsibility

Responsibility, of course, is the central concept behind the 'polluter pays principle.' And, like capacity, it has a strong common-sense resonance. The notion of national 'responsibility for greenhouse gas pollution' is intuitively – and correctly – understood in terms of the greenhouse gases they've emitted. As such, the basic definition of responsibility is cumulative emissions of greenhouse gases, though there are obviously complications in defining and measuring it unambiguously.

Some of these are serious. There are, for example, the disjoint but overlapping responsibilities of people and nations. When a man moves from country A to country B, does his past responsibility travel with him? What if a country splits in two, or three? What if it is pillaged, or overtaken by another? Do a country's citizens have responsibility for the actions of its leaders? What, and this is a pertinent case, if a country suffers (or suffered) from illegitimate leadership and a lack of effective democracy?

Then there's the matter of time. From what point should historical emissions count toward a nation's responsibility? The potential risks of global warming were first identified by Svente Arrhenius in 1896, were included in some university curricula in the 1940s, and were recognized in studies by the Johnson Administration in the US in the 1960s. It's commonplace to suggest that 'responsibility' for greenhouse pollution should start in 1990, when the first report of the IPCC made the risks widely and publicly evident, but as even this capsule history makes plain, *some people*, including advisers to the president of the United States, have known about the risks for a much longer time.

The greatest of these problems, however, is that of intention. Initially, our nations had a *default* policy of inaction, one that arose from simple ignorance and was entirely excusable. Over time, however, this ignorance was attenuated. Dangers were mooted, but in general they were brushed aside and we shifted to a policy of *active* inaction, of denial disguised as 'risk-management.' This policy was, of course, based on short-term and sectoral interests, and on the desire to continue emitting, profiting, and consuming as usual – until it became demonstrably certain that drastic emissions cuts were indeed inevitable. And once that shift had occurred, we were no longer innocent, but rather were making the sometimes explicit, sometime implicit decision to accept the consequences of delayed action. We would continue to enjoy our easy ways, or – as might be argued by the sympathetic neoclassical economist − we would delay the reckoning until

we were more technologically advanced, and richer, and the costs of action would be lower and more bearable.

More issues arise when we try to choose an appropriate metric of responsibility. Bear in mind that we're actually concerned with two different impacts of greenhouse gas pollution – first, the *exhaustion* of the available 'sinks,' which has reduced the future opportunities of others to use those sinks, and second, the *harm* caused by greenhouse gas pollution. We must in both cases deal with complex links between emissions and impacts, and of course multiple gases. Even if we were concerned only with CO_2 emissions, we could choose to measure them, alternatively, as cumulative emissions over time, as the fraction of historical emissions that remain in the atmosphere, as the fraction of realized temperature change attributable to those emissions, or as the long-term contribution to expected temperature change. There are many issues here, and some are controversial (the inclusion of CO_2 emissions from deforestation first among them[27]), and no doubt countries will tend to favor definitions that favor their particular interests.

The critical question, though, from a 'right to development' perspective, is *are all emissions created equal?* Should we count 'survival' and 'luxury' emissions in the same way?[28] Should CO_2 emissions from cooking and heating or methane emissions from subsistence rice agriculture be treated the same way as CO_2 from jet travel or CFCs from air conditioners? We argue that they should not be, that these different types of emissions are of fundamentally different natures, that survival emissions do not imply responsibility, whereas luxury emissions do. We argue, moreover, that the recognition of this difference is crucial in a burden sharing framework designed to protect the right to development.

We argue, specifically, that safeguarding the right to development means allowing people to strive toward a decent level of economic development − that level defined by the development threshold − without being encumbered by emissions constraints. This will translate, as we go on to calculate indicative levels of national responsibility, into excluding those emissions that derive from a level of consumption below the development threshold.

Finally, as we did with capacity, we argue that the vast disparities existing within nations imply that responsibility must be conceived in a manner that recognizes the right to development as a right of individuals, not a right of countries. Even poor countries with overall low per capita levels of consumption and emissions have some residents who are members of the high-emitting consuming class. These emissions must be counted toward the country's responsibility, and hence its obligations.

3.3.3 Allocating obligations

Obligations, for their part, must be defined in a manner that combines capacity and responsibility. However this is done (and one sensible option is presented in Chapter 4), the underlying principle is clear. No national obligations should arise from the economic activities of individuals at low levels of development, reckoned either in terms of wealth or emissions. Only when people cross the development threshold and enter the consuming class should their activities affect the obligations of the nation in which they live.

As it happens, most of consuming class lives in the industrialized countries. Given our assumption that a true emergency program may have relatively high costs, the GDRs framework thus allocates obligations to industrialized countries that significantly exceed any levels that might currently be considered 'realistic.' But please note that it also assigns obligations to developing countries, and even though it specifies these entirely by reference to the responsibility and capacity of their wealthier citizens, this assignment clearly violates a second principle of today's climate realism, that countries cannot be asked to incur any mitigation costs as long as they are 'developing.' So we hope that we've at least shown ourselves willing to be unrealistic on both sides of the great divide.[29]

4 Quantifying the GDRs framework

In the preceding sections we described the urgency of the climate crisis and its implications for an emergency emissions reduction trajectory, and we drew conclusions about the nature of the burden sharing system that would be needed in order to meet such a trajectory while preserving the right to development. In this section, we'll estimate, step by step and quantitatively, the implications of the Greenhouse Development Rights approach. So recall that we've claimed that it's a reference framework, in that it lays out the core elements that must inevitably be part of any viable climate regime. If this claim is true, this quantification is particularly useful, insofar as it implies some stark − and we would claim inescapable − conclusions about who will have to pay to resolve the climate crisis.

At the core of the GDRs framework is the right to development, from which we seek to derive a consistent burden sharing system that combines a measure of *responsibility* (historic contributions to greenhouse gas pollution) with a measure of *capacity* (broadly, the ability to pay for mitigation and adaptation). Crucially, these are both defined in a manner that is explicitly sensitive to inequality *within* countries. Which is to say that we treat nations as collections of economically unequal individuals, and by so doing calculate national shares of the global mitigation and adaptation burden in a manner that, we believe, is truly consistent with the UNFCCC's broad principle of 'common but differentiated responsibilities and respective capabilities.'

Our particular formulas necessarily bear elements of arbitrariness. All definitions that generate practical measures of ethically-based principles must do so, and thus be subject to challenge and alternative interpretation. We do not claim that the GDRs framework, as we've elaborated it, defines the only possible responsibility and capacity based burden-sharing system. However, we do claim that the specific numeric choices and assumptions that we've made here are consistent with the principles that they're intended to capture, that these choices are fundamentally reasonable and usefully indicative, and that they indicate the *scale* of defensible national obligations. We claim, in other words, that these calculations usefully illustrate the qualities necessary to a climate regime that safeguards the right to development.

4.1 Steps to a responsibility and capacity indicator

4.1.1 Calculating capacity

Quantifying capacity in a manner that accounts for the development threshold and the intranational disparities in income, as defined in section 3, is relatively straightforward. And the results can be quite illuminating. For example, Figure 3, below, is a 'Capacity/Development Need' chart that compares three key countries – India, China, and the United States – showing for each an estimated income distribution based on the national per capita income and Gini

coefficient (a measure of national income inequality).[30] At each point on the x-axis, this curve shows the income of the corresponding percentile (one percent) of the population, measured in US dollars per capita (PPP adjusted). Each chart shows the income rising from the poorest percentile to the wealthiest, and by so doing helpfully illustrates a few key concepts. (Note that the charts have been scaled so that the length of the x-axis is proportional to population, and thus the areas of the different sections – e.g., the green section representing capacity – can be directly compared in absolute terms.)

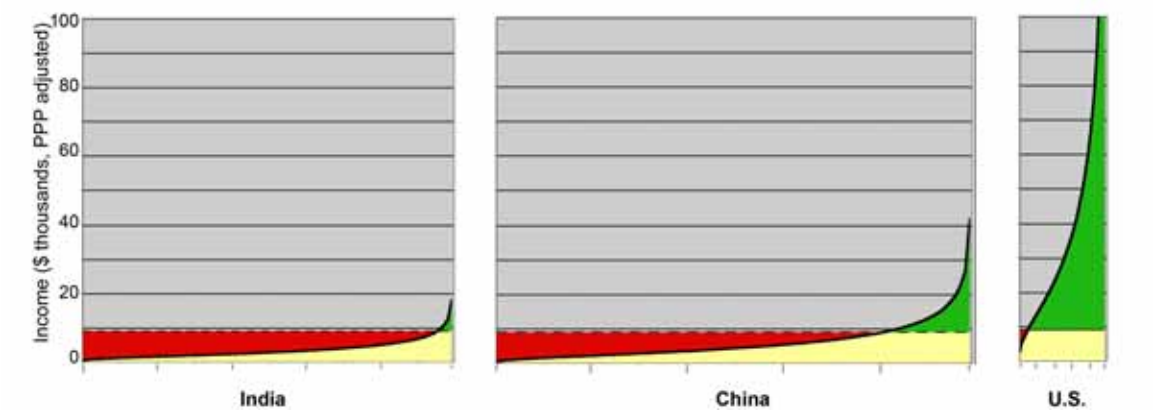

Figure 3. Capacity/Development Need chart for India, China and the US, with $9000 per capita (PPP) development threshold. See text.

One key concept illustrated here is the *development threshold*, which is the dashed horizontal line at $9,000 that crosses the income distribution line and splits the population into a poorer portion (to the left) and a wealthier portion (to the right). Obviously, the precise point where this line crosses that threshold depends on the wealth and income distribution of the country, but since all national populations include at least some people earning less than $9,000/year and some earning more, it always does. And since we're working with a global development threshold, this crossing makes it easy to compare both the heights of wealth and the depths of poverty in the three countries. For each, the income needed to raise the poorer part of the population to the development threshold is reflected in the red area on the left side of the charts, an area bounded below by the income distribution curve and above by the threshold. We term this area the *development need*. The charts also graphically convey each country's *capacity*, which we define as the income that the wealthier portion of the population has above the development threshold. This we depict as the green area bounded below by the threshold and above by the income distribution curve. All in all, this approximation of capacity is a somewhat crude but nonetheless defensible representation of the national income that could legitimately be taxed to help shoulder the climate burden.

Consider India, shown in the left panel. By our calculations, more than 95 percent of the Indian people have incomes below the $9000 development threshold. Plainly, in India as in similar countries, total national capacity – to pay for development, adaptation, or mitigation, or for that matter luxury consumption – is small compared to the national development need (though larger, it should be said, than the need that would be defined by a much lower 'destitution' line). Yet, just as plainly, India and other poor countries contain large (in absolute terms) middle classes and

even a subclass of truly rich people (though these latter are sufficiently few that they don't show up on these charts, given their low resolution).[31]

The center panel of the chart shows China. It has much more capacity than India, both in absolute terms and relative to its development need, but note as well that about 80 percent of the Chinese population is still below the $9000 threshold. Clearly, China is not a wealthy country, not taken as a whole, but at the same time, its national capacity is actually rather high, and the claim that shortages of investment capital (rather than consumption choices or institutional priorities) are limiting efforts at human development (and thus that few resources are available for climate mitigation) is not actually very credible.

Finally, on the right, we see the US. Here, graphically, is an image of wealth. The 'development need' of the small number of people with incomes under the threshold is entirely dwarfed by the 'capacity' of the rest, however you choose to name or categorize them. Which is not to say that this need is in any way irrelevant, or tangential to our concerns. Indeed, the continued existence of injustice and vulnerability – within the wealthy world (think of New Orleans) as well as within the developing world – is a key political challenge to any international burden sharing regime, in the sense that obligations must not come at the expense of the poor. In any case, the point is that the financial capacity of Americans with incomes above the development threshold – the only income that counts towards the calculation of capacity – is extremely large, absolutely and in relation to the national development need. Indeed, a good fraction of the US population has incomes so high that they're literally 'off the charts.'

These charts largely speak for themselves, but one point, at least, should be made explicit. Even though GDRs attributes capacity to both poor and wealthy countries, its implications are quite different − quantitative and politically − in these two different cases. Poor countries, as befits their small capacity, have small obligations, and these can be discharged entirely through domestic action. Wealthy countries will not generally have any such option, for as we'll show below, their obligations tend to be too great to be discharged with domestic action alone.

One consequence of this approach is that countries with the same population and average income do not necessarily have the same capacity, because a more *unequal* national distribution of income will raise it. Consider two countries, 'Fairland' and 'Unfairland,' both with a population of one million people. In both, the per capita income is $5000, but Fairland has a completely equal distribution of income (everyone makes $5000), while in Unfairland, 98 percent of the population has an income of $3,000 and the other two percent has an income of $103,000. Now, clearly, the wealthy two percent of Unfairland's population is more able to pay taxes than the poor 98 percent, for they can pay out of their luxury consumption. Indeed, they're more able to pay than any of the people of Fairland, where the people are equally, relatively poor. All of which is to say that the more rich people in a country the less sacrifice is required for a capacity based tax or levy to raise the same amount of revenue. [32]

Using the method described above, Table 1 below shows the capacity for three categories of countries – low income, middle income, and high income, per the World Bank's definitions[33] –

along with the share of global income, the share of global population, and the fraction of the population over the $9000 threshold in each group. Much can be read from this table, but one stark observation is that only 2.2% of the people in poor countries and 24% of the people in middle-income countries have incomes over the development threshold, and that the 'capacity' that of these countries – which together contain 85% of the global population – is *only 21% of the global total.*

	Low income	Middle income	High income	World
Income 2005 ($ trillion PPP)	US$6	US$22	US$33	US$61
Share of global Income (percent)	10%	37%	54%	100%
Share of population 2005 (percent)	37%	48%	16%	100%
Per capita income 2005 ($ thousands PPP)	US$2.5	US$7.3	US$33.1	US$9.5
Capacity ($ trillion PPP)	US$0.2	US$6	US$24	US$31
Share of global capacity (percent)	0.6%	20%	79%	100%
Percentage of population over $9000	2.2%	24%	93%	27%

Table 1. Characteristics of low-income, middle-income and high-income countries, including income, population, and 'capacity' as defined by $9000 development threshold.

4.1.2 Calculating responsibility

As noted above, there can be no uniquely 'correct' or even uncontroversial definition of responsibility. We suggest, however, that *cumulative per capita CO_2 emissions from fossil fuel consumption since 1990* is a reasonable one, largely because emissions made prior to this date were usually (though not always) made in ignorance rather than by deliberate policy.

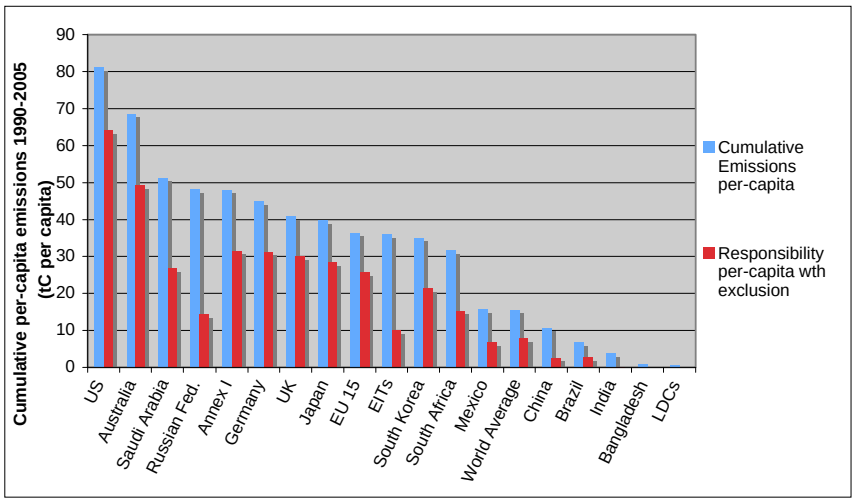

Figure 4. Cumulative per capita CO_2 emissions from fossil fuel combustion, 1990-2005 (in blue); 'responsibility' adjusted to account for the exclusion of emissions below the development threshold (in red). (See the appendix for data sources and calculation details.)

Figure 4 shows this measure of responsibility for selected countries and regions; the blue bar is the total national per capita figure (from 1990 to 2005), while the red bar adjusts to account for the exclusion of emissions below the development threshold. The adjustment is straightforward, based on our assumption that (within any given country) emissions are proportional to consumption, which is in turn proportional to income (see the appendix for details).

By this proxy, responsibility is, not surprisingly, higher in wealthy countries, and effectively zero in the poorest countries (including but not limited to the UN 'Least Developed Countries'). There are also important differences among countries with similar incomes. Some wealthy countries have much lower emissions than others (compare the UK or Japan with the US, for example), and some poor countries have much higher emissions than others (eg, Russia v. Mexico). This raises the question of how capacity and responsibility should be combined into a single obligation indicator, which can then drive the allocation of the global burden. We now turn to that question.

4.1.3 The responsibility and capacity indicator (RCI)

To review: The goal of this indicative calculation is to define and calculate a single indicator that properly combines responsibility and capacity and, by so doing, allows us to defensibly assign shares of the global mitigation and adaptation burdens to individual countries. Further, this responsibility and capacity indicator (RCI) must – following our claim that the right to development adheres to poor individuals and not poor nations – reflect the distribution of income and emissions within countries. When used to calculate national obligations, it should specifically exclude the responsibilities and capacities of individuals below the development threshold.

Again, there cannot be any uniquely correct way to do this, but there are more or less reasonable possibilities.[34] Plainly, the RCI must have the property that, among countries with the same capacities but different responsibilities, the country with greater responsibility has the greater obligation. Just as plainly, among countries with the same responsibility but different capacities, the one with the greater capacity must have the greater obligation.

There are many formulas which have this property. We use one which multiplies responsibility and capacity, in a way that allows different weights to be given to each:

$$RCI = R^{a} \bullet C^{b}$$

We specify that the exponents a and b sum to 1, which confers the property that, as the paired weights go from a=1 and b=0 towards a=0 and b=1, the RCI goes from being exactly equal to responsibility (*R*) to being exactly equal to capacity (*C*). Perhaps more importantly, the sum of the RCIs calculated for parts (say nations within a region) is equal to the RCI of the whole, which means that RCI calculation behave appropriately whether you're looking at countries, fractions of countries, or multi-country regions.

In our reference case we use a = 0.4 and b = 0.6, which weights capacity somewhat higher than responsibility. Again, this is just one of many possible choices, but our belief is that it is less fair to make a poor nation with high emissions pay more than it is to make a rich country with low emissions pay more. But we show a sensitivity analysis in the appendix, and we fully expect that some readers will prefer other formulas. A further explanation of how the calculation is done, taking account of income distribution, is given in the appendix.

By making the assumption that the national distribution of responsibility is the same as the national distribution of income (an over-simple assumption that is nevertheless reasonable for our purposes here) we can straightforwardly estimate the joint responsibility/capacity indicator for any portion of the population. By integrating, we can then estimate the country's total RCI, and compare it with the global total to calculate each country's share. The results of this calculation for selected countries and groups of countries are shown in Table 2.

	% Share of global population	% Share of global income	% Share of global capacity	% Share of cumulative emissions 1990-2005	% Share of global responsibility	% Share of global RCI
United States	4.6	20.3	32.1	24.0	38.1	35.0
EU (27)	8.9	22.6	29.7	18.5	23.4	27.2
UK	0.9	3.3	4.8	2.5	3.6	4.4
Germany	1.3	4.0	5.5	3.7	5.2	5.5
Russia	2.2	2.5	1.5	6.9	4.1	2.3
Brazil	2.9	2.6	2.1	1.3	1.0	1.6
China	20.4	14.5	6.8	14.1	6.7	6.9
India	17.1	6.2	0.4	4.1	0.3	0.4
South Africa	0.7	0.8	0.8	1.4	1.4	1.0
LDCs	8.4	1.4	0.1	0.4	0.0	0.0
All high income	15.5	53.9	79.0	51.8	76.7	78.4
All middle Income	47.8	36.5	20.4	41.3	22.9	21.1
All low Income	36.6	9.6	0.6	6.9	0.4	0.5

Table 2. Global percentage shares of population, income, capacity, cumulative emissions, responsibility, and RCI for selected countries and groups of countries.

When reviewing this table, keep three basic points in mind:

1) Because our measure of capacity excludes the income of the poor, a rich country's capacity will be larger in percentage terms than its share of global income, and a poor country's capacity will be lower.

2) Similarly, though less transparently, a wealthy country's responsibility will be larger than its share of cumulative emissions. (Fewer of its historical emissions will be excluded.)

3) An indicator that combines responsibility and capacity to derive an obligation indicator can be expected to yield a result that is between the calculated share of capacity on the one hand and the calculated share of responsibility on the other. (As we weight capacity slightly higher than responsibility, our result is closer to the capacity number than to the responsibility number.)

One notable feature of our results is that the US has the largest share of global capacity, the largest share of global responsibility, and the largest share of combined RCI. We'll translate this into per capita terms shortly, after following a few more steps. However, this result is extremely important, and deserves immediate notice: By any reasonable standard of 'common but differentiated responsibilities,' the United States would have to pay the largest share of the global climate 'bill.' But, despite the fact that the American people have come to accept the need for concerted action to stabilize the climate, that action is still conceived in almost entirely domestic terms. Indeed, when it comes to preparing the ground for US international obligations, the American climate movement has largely failed, having barely begun to even explain the necessities of emergency global action to its people. The same, moreover, is true in Europe, though perhaps to a slightly lesser degree.

This is a harsh charge, so allow us to reiterate: It won't be enough for the wealthy countries to embark on an aggressive program of domestic reductions, not even if it's an *extremely* aggressive one. Their 'bills' properly include much of the burden of accelerated *global* decarbonization, and of the robust adaptation program that will be needed if we're to maintain a workable measure of international solidarity and cooperation. But, thus far, the US and EU climate communities have generally failed to even raise these issues, let alone campaign on them. Obviously, this is a very serious problem.

Again, there's no single 'correct' way to define a responsibility and capacity indicator. But we're confident that our definition is reasonable, and especially confident that its built-in sensitivity to the distribution of income and emissions within countries is crucially important. It's this sensitivity that takes account of the primal facts of income inequality: In every country, some people have the responsibility for unsustainable levels of greenhouse gas pollution, and the proportionate capacity to pay for mitigation and adaptation from their luxury consumption; in every country, some people have no responsibility, and no capacity to pay.

Any climate regime that seeks to honor the right to development must acknowledge, and internalize, these facts.

4.1.4 Calculating national 'bills'

Having calculated RCIs for different countries, we can now use these RCIs to estimate the obligations that would fall to specific countries. How those would most properly be apportioned within countries is, of course, a different matter, though it would be contrary to the spirit of the GDRs system if, at the end of the day, the costs of climate mitigation were to devolve to those below the development threshold. The challenges here are great, but they're not in any way specific to Greenhouse Development Rights. Any climate regime must ensure that it does not

worsen either the overall fairness of the global economy or the overall well-being of the poor. If it does either, it's unlikely to survive.

In any case, the first task, when we use our RCIs to estimate national mitigation and adaptation costs, is to contrive reasonable estimates of the global costs that must be apportioned, and this despite a background of extreme uncertainty and confusion. (The UNFCCC has just reported it's own estimates, which are not wildly different.[35]) The most widely cited numbers are for stabilization between 500 and 550 ppm CO_2-equivalent, and estimate the cost to be about of 1 percent of GWP (65 trillion US dollars in 2005) annually, although exactly how this number is defined is often a bit unclear in the literature.[36] Expected costs vary with baseline levels of economic and population growth and with the efficiency with which policies are assumed to be implemented. And of course differences in basic definitions (what counts as a cost, and to whom?) and modeling assumptions produce different calculated costs, even with the same baseline and policy assumptions.

Our own view combines optimism and pessimism. That is to say, our understanding of the economic models leads us to conclude that the majority of them overstate costs relative to the mitigation objectives that they are actually modeling.[37] However, the scenario that we're advocating – an 'emergency program' – demands rates of emissions reductions that are outside the range typically modeled (the lowest stabilization levels reported by the Fourth Assessment Report's Working Group III are 445-550 ppm CO_2-equivalent, whereas our 'emergency pathway' aims to return to 400 ppm CO_2-e by 2100).

A more detailed discussion of mitigation costs would take us rather far afield, and in the end we'd still be forced to conclude that there is an enormous uncertainty, and little assurance of a reasonable upper bound to the costs of a true emergency program. Fortunately, for our purposes here, it's sufficient for us to use 'reasonable numbers,' and to stress that, *the larger the burden turns out to be, the more crucial it is that it be shared fairly*.

More important still is the fact that adaptation costs, which the burden-sharing literature rarely treats seriously, may turn out to be as large or even larger than mitigation costs. Estimates in the region of $100 billion per year are being reported, but there's little basis for confidence.[38] Discussion about what kinds of measures are possible and desirable are just beginning, and there has yet to be any coherent proposal as to what kind and degree of adaptation would be 'adequate,' or of how 'practical' proposals might be measured against such a standard. Even more importantly, discussions of adaptation have studiously avoided its inevitable relationship to liability and compensation. Yet lurking behind images of fresh new seawalls are increasingly clear understandings of the disaster relief and relocation costs that occur after a climate-change induced 'impact' has occurred. Considering these factors, and the impacts that will be visited on both developed and developing countries, it's hardly farfetched to imagine global adaptation and compensation costs reaching or exceeding one percent of GWP each year.

We will not attempt to resolve the uncertainties here, but will rather proceed by estimating national bills for *each* one percent of GWP that we finally accept as part of the total climate

burden. (Since our concern is to allocate that total burden − adaptation plus mitigation costs − we don't need to parse them out separately). This one percent estimate can stand for a case in which both adaptation and mitigation costs are 0.5 percent of GWP, or a case in which one is 0.9 percent and the other 0.1 percent.

	Total income (billion $ PPP adjusted, 2005)	Total capacity (billion $ PPP adjusted, 2005)	Percent of global RCI	Bill at 1% of GWP ($ billion PPP adjusted)	Average individual bill at 1% of GWP ($PPP/person)
United States	12,420	9,827	35.0	214	796
EU (27)	13,823	9,071	27.2	166	357
United Kingdom	2,001	1,464	4.4	27	461
Germany	2,430	1,693	5.5	34	420
Russia	1,552	464	2.3	14	190
Brazil	1,566	627	1.6	10	191
China	8,865	15	6.9	42	144
India	3,779	128	0.4	2.2	53
South Africa	502	241	1.0	6.2	383
LDCs	853	17	0.0	0.2	34
All High Income	32,941	24,146	78.4	479	517
All Mid. Income	22,271	6,250	21.1	129	172
All Low Income	5,873	169	0.5	2.9	56
World	61,091	30,570	100.0	611	353

Table 3. Total national income and national capacity (calculated with $9000 development threshold), along with national and individual 'bills' (calculated on the basis of the number of people above the $9000 development threshold) assuming a total global obligation (combining mitigation and adaptation) of 1% of GWP Note that the UK and Germany are included in the EU27 figures in addition to being shown separately. (All figures 2005 US dollars, PPP-adjusted)

In Table 3, we show national 'bills,' following the Greenhouse Development Rights approach and using this one percent of GWP cost estimate, for selected countries and regions. (This is done in terms of the 2005 GWP, 2005 being the last year for which national data is readily available. In general, the three significant digits of precisions here should not be taken too seriously.) In addition to showing the national obligation in billions of dollars, we also show an "average individual" bill: the amount that (on average) would have to be paid by each person whose income was over the $9,000 development threshold in order to discharge the full national obligation. (These individual bills would obviously be lower if they were "per capita" bills computed on the basis of total national population rather than only those above the development threshold, and this is especially true in poor countries.) The wide range of these individual bills reflects the widely different degrees of "per person" responsibility and capacity in different countries; indeed it varies across countries by more than an order of magnitude.

Keep in mind that these estimates of national obligation to pay (the last two columns) reflect our indicative calculation of RCI and assumes that total costs (both mitigation and adaptation) would be one percent of GWP.[39] The actual costs may in the end be quite a bit higher, and its also possible to tell stories in which costs would be even lower, but in any case it's easy to do the arithmetic. If you believe, for example, that the total cost of an emergency climate stabilization program would be more like two percent of GWP, just multiply the numbers in the last two columns by two. Similarly, if you think the total cost is likely to be 0.5 percent, divide it in half.

Note, too, that these figures make no assumptions about the fraction of any national obligation that could reasonably be discharged domestically, as opposed to internationally. Nor have we sought to prejudge the institutional, political and governance mechanisms that would be necessary were such obligations to be codified in international law, collected, and actually channeled toward mitigation and adaptation activities. That is, we've said next to nothing about how countries would actually pay their bills, or how their payments would be productively directed toward their targets. Certainly, one can imagine a great variety of mechanisms for generating the payments, such as various fees, levies, trade-related charges, carbon taxes and progressive income taxes. Similarly, one can imagine a great variety of mechanisms for directing them, such as funds, markets, incentives, and such. But a real discussion of these is far beyond the scope of this paper. Suffice it to say that that problem is inadequately understood and extremely daunting. It is also a problem universally shared by any climate regime that purports to actually do something about mitigation and adaptation. We acknowledge that it is vitally important, but do not attempt to solve it here.

Also, to move beyond the obvious point that this level of climate taxation is not 'realistic' it's useful to consider what they might appropriately be compared to. Military budgets in particular invite comparison. The US military budget, depending on what is included, is not less than $500 billion a year and, if estimated in a reasonable fashion, considerably more, as much as a third of the total US Federal budget.[40] All other military budgets are far smaller, but they still outweigh the climate costs assumed above. The UK's official military budget, for example, is about $51 billion a year, while China's is estimated at $188 billion and India's at $114 billion (all these figures are PPP). These are all conservatively estimated figures, and it's interesting to note that the military expenditures of the top 15 spenders amounts to just over two percent of GWP (PPP).[41] Given this, it's fair to say that an emergency program would entail a 'Keynesian' effort of about the same size as the global military enterprise, though one that, obviously, follows a radically different storyline.

Finally, it's important to put these figures in the context of continuing global economic growth. As has been pointed out by Christian Azar and Steve Schneider[42] among others, even costs that seem very large – two percent of GWP, for example, is well over a trillion dollars – can also be seen as implying a small – very small – delay in the rate at which we become richer. In a developed country growing at two percent a year, such a two percent national bill would only mean a one year delay in doubling current wealth − from 2042 to 2043. In a poor country

growing at five percent annually, a two percent national bill would amount to less than a six month delay in reaching such a milestone.

5 GDRs as a global allocation system

It might be useful, at this point, to recall the purposes of this entire exercise: pulling 'the right to development' down from the rhetorical skies and modeling an explicit burden sharing system with that right at its core. Now, having defined a framework that might just be able to support a true emergency program, one designed for both rapid mitigation and, to the extent that it's possible, adaptation to limit the suffering and dislocation that will be caused by climate change, we believe we have such a system in hand. We've even gone a step further, and combined this burden sharing system with reasonable − if merely indicative − estimates of the cost of mitigation and adaptation, and thus calculated implied national 'bills.' However, we've said precious little about implementation, about collecting those bills and actually carrying out an emergency program. In this section, we explore one option: the implementation of the mitigation side of GDRs within an international 'cap and allocate' trading system.[†]

This takes us, inevitably, into areas of bitter controversy. The institutions of modern economic life are so intimately bound up with the generation and globalization of inequality that even the suggestion that a fair global burden sharing system can be instituted is problematic. And if such a system is to be market-based, skepticism is particularly warranted. If we may be frank, carbon trading systems have had a rather inauspicious beginning. They have, in particular, shown themselves prone to 'capture' by corporations and private traders, which has legitimated the fear, now extremely widespread, that any global emissions trading system will function as a device by which wealthy countries, corporations, and individuals can 'buy their way out' of inconvenient emissions limitations.

Nevertheless, we think this exploration is warranted, for a number of reasons. First, the mitigation side of any global climate agreement is virtually guaranteed to involve market mechanisms, particularly in the critical years just ahead. [43] Such mechanisms, after all, have tremendous momentum and a large constituency − vested interests including carbon-intensive corporations, CDM project developers, the World Bank's Carbon Finance Unit, allowance-starved Annex 1 countries and finance-starved developing countries – that fully intend to move quickly into a next and grander phase of carbon trading. In this context, it seems to us vital to examine the potential for the most promising form of international trading – a global cap and allocate system that could, if well designed and effectively regulated, help to support an emergency framework.

[†] The term 'cap and allocate' is shorthand for 'cap and allocated and trade,' and refers to any principle-based allocation of tradable allowances *to countries*, under a global cap. It is distinct from the (all too familiar) 'cap and grandfather' systems, and there are many, that continue patterns of historical inequity by formalizing rights to something (close to) historical emissions. Think of phase 1 of the EU's ETS.

Second, such a system would provide something of immense value to any true emergency program: It would make it possible to achieve reductions *cost-effectively* by carrying them out wherever they were least expensive. Come what may, such cost effectiveness will be absolutely essential to the success of any true emergency program. Indeed, as the desperateness of our situation comes to be fully appreciated, we'll be casting frenetically about for the most affordable ways to keep within the 2ºC trajectory. And the lower the costs, the better the odds are that we'll keep our resolve.

Third, and even more importantly, a workable 'cap and allocate' system would make it possible to establish national mitigation obligations without regard to the volume of reductions that are physically (and economically) available within any given country. Trading, in other words, offers a way to implement a global burden sharing system in which countries with high capacity and responsibility are obligated to carry out strenuous reductions at home *and also* to help pay for decarbonization in poorer countries. This is a key point, and we must underscore it, though we gladly add that, in principle, alternatives based on taxes, public funds, and other financing mechanism could do the same. In any case, most of this section is devoted to the implications of such a burden sharing system, which, trading based or not, is our central concern.

5.1 Cap and allocate (and trade)

How then would we use GDR's Responsibility and Capacity Indicator to distribute permits under a cap-and-allocate system? The means is fairly straightforward, and requires only three steps:

First, we estimate the *global mitigation requirement*. This is the difference between a global baseline path (constructed as a bottom-up aggregation of national baseline paths) and the emergency 2ºC trajectory. Graphically, the 'gap' or 'wedge' between those two curves reflects the amount of mitigation work that needs to be done globally.

Second, this global mitigation requirement is divided into *national mitigation obligations*. Each country – however rich or poor it may be – is allocated a portion of the global mitigation requirement, in proportion to its aggregate national RCI.

Third, each country is assigned a *national emission budget* equal to its national baseline trajectory minus its national mitigation obligation. This determines each country's share of the (rapidly declining) global emissions budget, and makes it possible to assign each country an appropriate permit allocation (equal to its national emission budget).

Conceptually, this is akin to the original Brazilian proposal, which was intended to divide the global reduction requirement (relative to 1990 levels) among Annex I countries. In the rest of this section, we'll follow the above steps in order to calculate future allocations for selected countries. But first note this all-important point: Depending on the relationship between its baseline trajectory and its mitigation obligation, a country might have 1) an allocation allowing some emissions growth over time, 2) an allocation requiring a rate of emission reductions that could easily be met domestically, 3) an allocation requiring substantial domestic reductions *as*

well as the purchase of permits from abroad. We will show examples illustrating the first and last cases.

One key clarification about national baseline paths is needed. In Figure 5 below, we show global emissions projections based on two hypothetical trajectories. The first (the top of the green wedge) is a 'Business-as-Usual' trajectory, which extrapolates the historical approach to energy conservation, renewables, fossil fuel subsidies, pollution controls, etc.[44] The second (the top of the red wedge) is a so-called 'No-Regrets' trajectory, a projection of the global emissions pathway as it would be if all negative- and zero-cost emissions reduction options were successfully captured.[45] The green wedge, in other words, represents free and profitable reductions, which are large, though not by any means large enough to bring emissions all the way down to the global emergency 2ºC trajectory (the top of blue area).

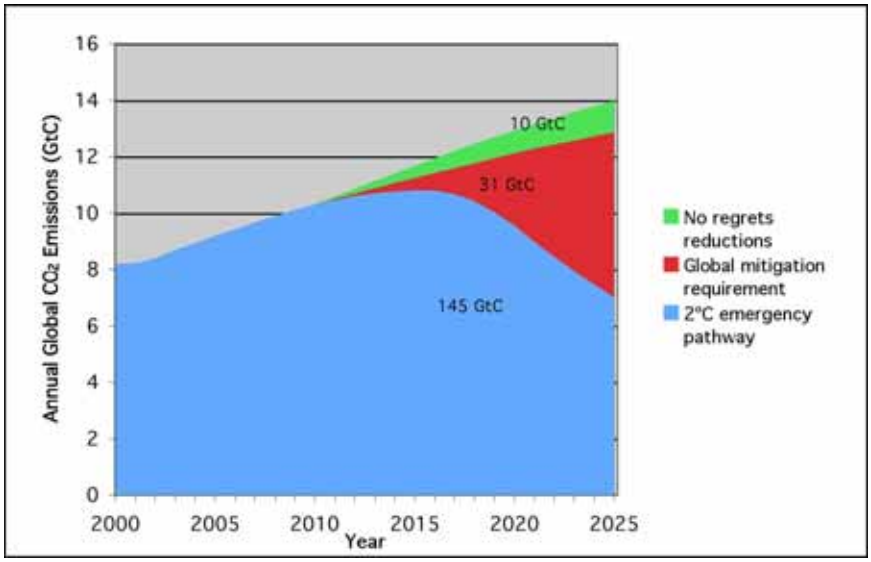

Figure 5. The 'mitigation gap' (red wedge) between a 'No-Regrets' baseline (border of red and green) and the 2°C emergency pathway' (border of red and blue). See text.

We argue that a country's no-regrets trajectory should be adopted as its national baseline. That is to say that each nation should be responsible for capturing all of its own no-regrets reductions, and that only further reductions – those that actually cost something to realize – should count toward discharging a national mitigation obligation.

Baselines are of course notoriously difficult to define and impossible to accurately forecast. Thus, the negotiations would see plenty of gaming over such national baseline trajectories. But this, please note, is an inevitable feature of essentially all international burden sharing proposals. In the face of any proposed commitment, negotiators carefully consider the levels of effort implied by their own prospects and those of other countries. Either explicitly or implicitly, they assess any effort relative to the 'effortless' case. This will not change. But explicitly requiring each country to put forward a national no-regrets trajectory, and subjecting it to the scrutiny of international negotiations, would add transparency to a process that has to this point allowed

discussions of national baselines, levels of effort, and underlying principles to occur as a tangled, indecipherable mess.

Taking this 'No-Regrets' definition of the baseline trajectory, Figure 5 shows the global mitigation requirement associated with the emergency program as the red wedge. Its width, growing through time, reflects the additional annual emissions reductions required by our emergency program to hold the 2ºC line, relative to a world in which countries diligently work to capture the benefits of all no-regrets opportunities. Based on the baseline projections used here and our emergency pathway, the global mitigation burden would amount to 31 GtC of emissions reductions over the period 2011-2025. This burden is then allocated to each nation in proportion to its share of the of the global RCI, as shown in Table 3 above.

Graphically, the global mitigation burden can be divided into wedges, as in Figure 6. These wedges are analogous to the technology-based wedges defined by Pacala and Socolow[46], but instead of showing technologies and the gigatons of reductions that they're projected to deliver, they show countries and the gigatons of reductions that they're obligated to pay for. Thus the US's wedge is 35% of 31 GtC, or about 11 GtC, while the EU's wedge (including the British and German shares, which are here shown separately) is 27%, a bit below 8 GtC. Russia, a middle-income country, gets 2.3%, or 0.7 GtC, and China, another, gets 6.9%, or 2.1 GtC.

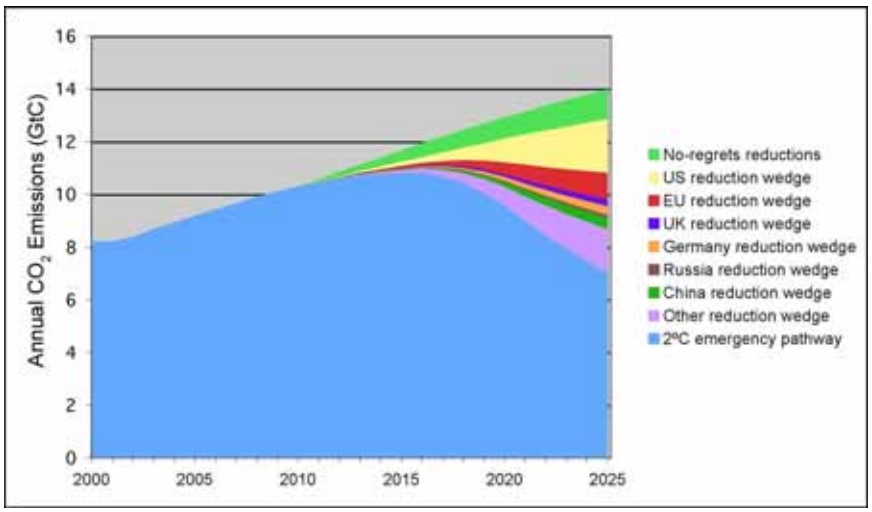

Figure 6. Mitigation requirement, divided into 'obligation wedges' that reflect national / regional shares of RCI. (The UK and Germany are of course part of the EU, but are shown separately here; total EU obligation is thus shown as a three-color wedge).

This gives the big picture, in a useful way that allows us to talk, quantitatively, about individual national situations. We can 'zoom in' on each country to look at its national mitigation obligation wedge – its share of necessary global reductions in gigatons – and compare it to its own national no-regrets trajectory. And, for each country, we can examine the relationship between its plausible rates of *domestic emissions reductions* and the scale of its total mitigation obligation, and hence the *international reductions* it would need to somehow pay for to fulfill its mitigation obligation.

Such an examination is quite striking, for it plainly shows that that wealthier countries with high RCIs are obligated to generate reductions far larger that even the ambitious 90% by 2050 targets now being discussed (at least by Al Gore and a few others) for Annex 1 countries. Indeed, for key wealthy countries, *reduction obligations exceed even total baseline emissions. So that even if these countries were to reduce their emissions to zero, they'd still be obligated to pay for emissions reductions elsewhere.*

This result, though striking, is not at all surprising. In fact, it exists by design. It is the intended outcome of the fact – for it is a fact – that any framework that actually preserves the right to development must obligate the wealthy nations to rapidly reduce their own emissions at the same time as they pay to accelerate the decarbonization of the developing world. And it follows, equally implacably, from an allocation of reduction obligations on the basis of responsibility and capacity. It is the reason that Greenhouse Development Rights works, the way it drives global decarbonization, the means by which it creates the atmospheric space needed by those who are still 'under-developed.'

The example of the United Kingdom is given below in Figure 7.

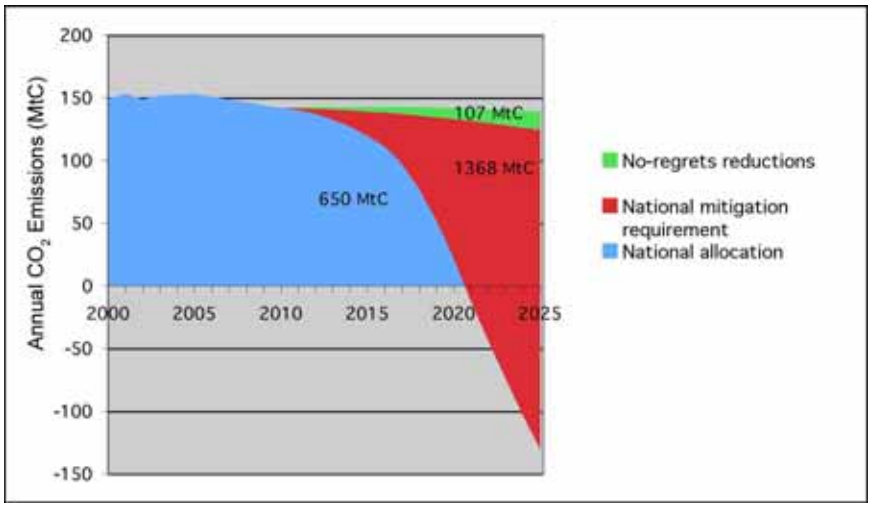

Figure 7. 'Mitigation Obligation' chart for the UK for the period 2010-2025. See text.

The top line, at the top of the green wedge, represents the 'Business-as-Usual' case (emissions growth as per the IPCC's A1B scenario), while the lower border of the green wedge shows the UK's no-regrets trajectory, calculated on the basis of the IPCC B1 scenario's growth rate for OECD countries. The green wedge, in other words, is an estimate of the UK's no-regrets reductions opportunities between 2010-2025, which here amounts to 107 MtC, all of which it is the responsibility of the UK to aggressively exploit. The striking bit is the red wedge. It is the UK's share of the global mitigation requirement, its national reduction obligation, which amounts, under our indicative assumptions, to 1368 MtC. The lower border of the red wedge shows the UK's effective allocation, once its national mitigation obligation has been subtracted from its no-regrets trajectory. (The allocation is shown as a pathway in time, although in practice

it might be better assigned as a cumulative allocation over the 15 year (2011 to 2025) 'commitment period' shown.)

Although this chart looks quite different from the above global chart (Figure 6,) this is entirely due to the scale of the axes; both show the UK's same 1368 MtC mitigation obligation 'wedge.' The difference is that, this time, it's in the spotlight, and its significance is more obvious because it's shown relative to the UK's emissions rather than relative to global emissions. And given this, the way that the 'allocation' line drops below zero around 2021 is pretty hard to miss, as is the political fact that this drop implies: The UK's national mitigation obligation is not limited by the magnitude of its current emissions!

It's notable, in this context, that the GDRs framework makes no intrinsic assumptions about the combination of *domestic reductions* and *international reductions* that a country will choose in order to fulfill its mitigation obligations. All else being equal, with international purchases managed via a global cap and allocate system, a country would, at least in theory, be free to make any portion of its reductions domestically, and the remainder internationally, based on any nationally salient economic or political considerations. In practice, however, some restrictions are likely to be necessary, a point to which we'll return below.

For the meantime, consider a scenario in which the UK's rate of domestic reductions mirrors the global reductions demanded by the emergency 2ºC pathway, which increase gradually after the 2015 global emissions peak and reach a maximum of about 6% per year. The implications of this are illustrated below in Figure 8, wherein a yellow wedge, representing domestic reductions accelerating to 6% a year, is carved out of the UK's mitigation obligation. This yellow wedge represents 424 MtC of domestic physical reductions, and leaves the UK with a need to purchase or otherwise fund an additional 945 MtC of reductions internationally (the red wedge).

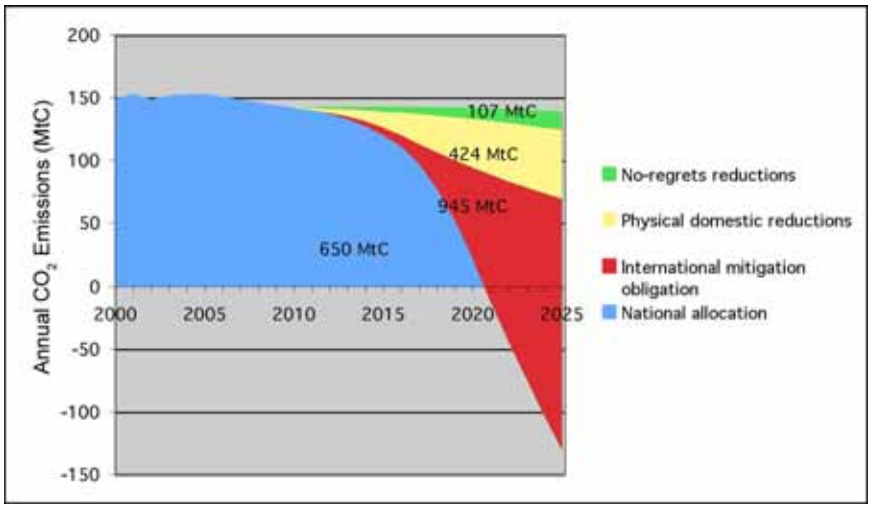

Figure 8. Hypothetical UK emissions reductions allocated between domestic reductions reaching a 6% annual rate of decline (yellow wedge), and international reduction obligations (red wedge) under the GDRs framework.

A greater rate of domestic reductions would of course reduce the UK's need to purchase offshore reductions. And, conversely, the UK could, at least in theory, refuse to make any reductions domestically, and to choose instead to purchase all its required reductions internationally. This latter approach, however, would be implausible, or irrational, or both, given that domestic reduction opportunities would accumulate unused while the national expenditure on internationally purchased reductions grew more and more taxing. Still, the possibility is worth considering, for it raises the specter that the UK − or any other wealthy nation − could 'buy its way out' of the need to make inconvenient domestic accommodations to the climate crisis. Such a choice would be both ethically problematic and politically dangerous, issues we'll return to at the end of this section.

What this scenario illustrates – and indeed doing so is a major point of this entire exercise – is that even very steep domestic reductions would only discharge a fraction of the mitigation obligations that, under a reasonable responsibility/capacity framework, would properly fall upon the wealthy countries. This, again, is striking but not surprising. The underlying premise of the Greenhouse Development Rights framework is that the right to development must be safeguarded, and that doing so requires the wealthier population of the world to both free up sufficient space for the poorer nations and subsidize their rapid transition to low-carbon economies. The need for wealthy countries like the UK to make steep domestic reductions and still pay for major reductions internationally is the direct result of this foundational premise.

5.2 The example of the United States

In Figure 9 we show a similar calculation for the United States. But instead of showing a domestic reduction wedge that thickens to 6% per year (reflecting the global rate in the emergency 2ºC trajectory) we show an even more ambitious domestic reduction trajectory – call it Gore's trajectory – that reduces national emissions to 90% below 1990 levels in 2050.

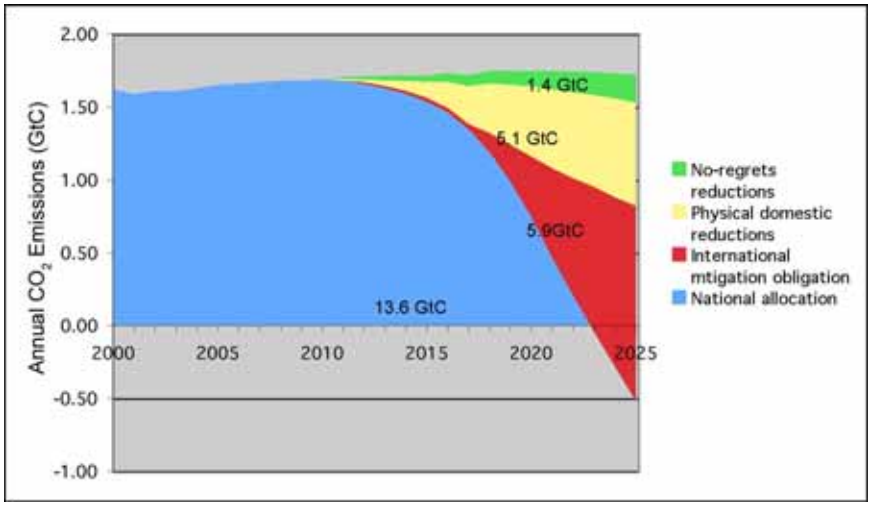

Figure 9. US allocation under GDRs reference case, with domestic physical reductions (yellow wedge) defined to (following Gore) to reduce US emissions by 90% by 2050. See text.

In this '90% by 2050' trajectory, the rate of domestic emissions reductions reaches 6.7% annually by 2025, and leads to about five GtC of domestic reductions over the period of 2011 to 2025. This reduction rate is greater than those mandated by even the strictest of the bills now in play in the US Congress: the House of Representative's *Safe Climate Act* and the Senate's *Global Warming Pollution Reduction Act.* And, again, even this ambitious '90% by 2050' trajectory would only satisfy a portion of the US's total obligation, the rest of which would have to be satisfied by funding international reductions.

Which is a fine opportunity to note that GDRs would substantially reframe the 'international offsets' debate. Today, that debate turns on the limits that should, or should not, be placed on the ability of wealthy countries to purchase offshore reductions. GDRs, however, implies that rich nations have reduction obligations that are quite properly *larger* than their plausible domestic reductions. The implication is that it's inevitable, and even desirable, for wealthy nations to pay for international reductions, and that the debate should focus not on limiting such payments but rather on ensuring that they're made in as fair and effective a manner as possible.

5.3 The example of Germany

The German case is also interesting. The top of the green wedge, again, represents a 'business as usual' trajectory, while the lower border of the green wedge shows Germany's no-regrets trajectory, calculated on the basis of the IPCC B1 scenario's growth rate for OECD countries. Here, as in the UK case above, the rate of domestic reductions mirrors the global reductions demanded by the emergency 2ºC pathway, which increase gradually after 2015's global emissions peak and reach a maximum of about 6% per year). The implications of this are illustrated below in Figure 10**,** wherein a yellow wedge, representing the domestic reductions as they rise to 6% a year, is carved out of Germany's mitigation obligation. This yellow wedge represents 690 MtC of domestic reductions, and leaves Germany with a need to purchase or otherwise fund an additional 1032 MtC of reductions internationally (the red wedge).

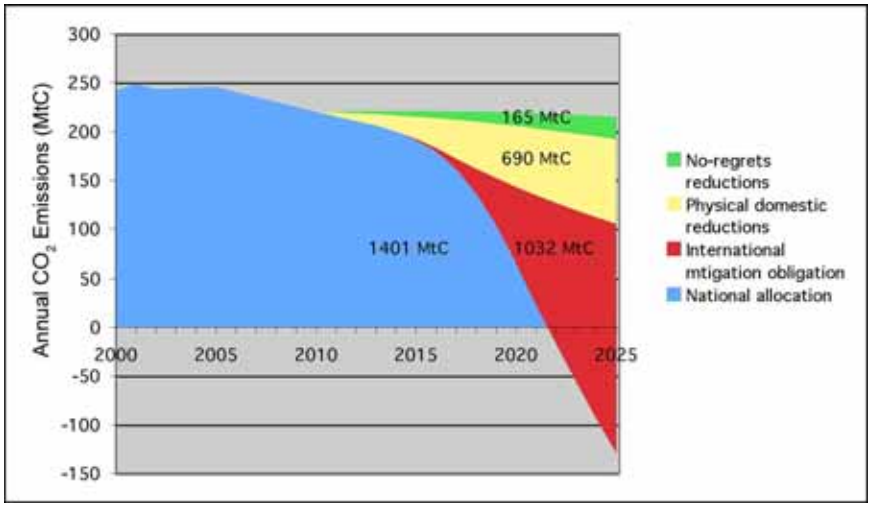

Figure 10. Hypothetical German emissions reductions allocated between domestic reductions reaching a 6% annual rate of decline (yellow

wedge), and international reduction obligations (red wedge) under the GDRs framework.

5.4 The example of China

The complement to the situations illustrated above is the one in the developing world, where national mitigation obligations are *smaller* than the 6% per annum reductions required globally by the emergency 2ºC trajectory. This situation is well illustrated by the case of China.

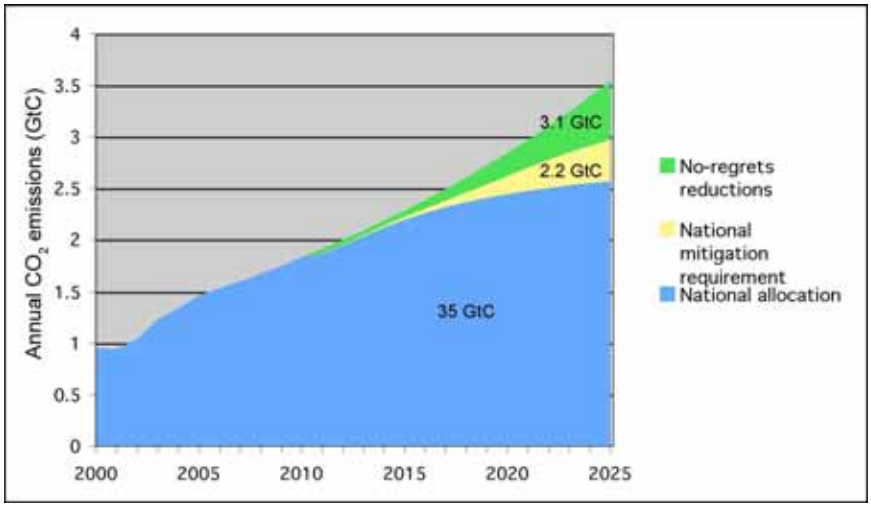

Figure 11. Allocation under GDRs framework reference case for China.

Here, again, the green wedge represents no-regrets reductions. The 'Business-as-Usual' trajectory (the top of the green wedge) is taken as an extrapolation of China's historical emissions growth, a choice that seems appropriate given its atypical rate and recent momentum, though the bottom of China's no-regrets wedge, and thus its area, is still based upon the B1 emissions trajectory. But note that China's (yellow) mitigation obligation, calculated as it is on the basis of China's RCI, is not particularly large, despite the projected continuation of China's unusually rapid economic growth.[47]

Finally, in Figure 12, below, we see the point of this whole story – a hypothetical instance in which a large amount of additional emissions reductions (the red wedge) are made within China, but financed by wealthy countries in need of offsets. These reductions are absolutely necessary, for China's emissions are large, and making full use of its mitigation potential is essential if we're to keep within the emergency 2ºC trajectory. Fortunately, under the GDRs framework, there's a strong incentive for China to reduce beyond its national obligation by, in effect, selling mitigation potential to wealthy and middle-income countries like the UK and US that need it to fulfill their mitigation obligations. Or, to put it another way, in a cap and allocate system, China would in principle be able to sell reductions at an international price that's greater than its marginal cost, and by so doing earn the revenue needed to finance its own required reductions, at least partially and perhaps wholly.

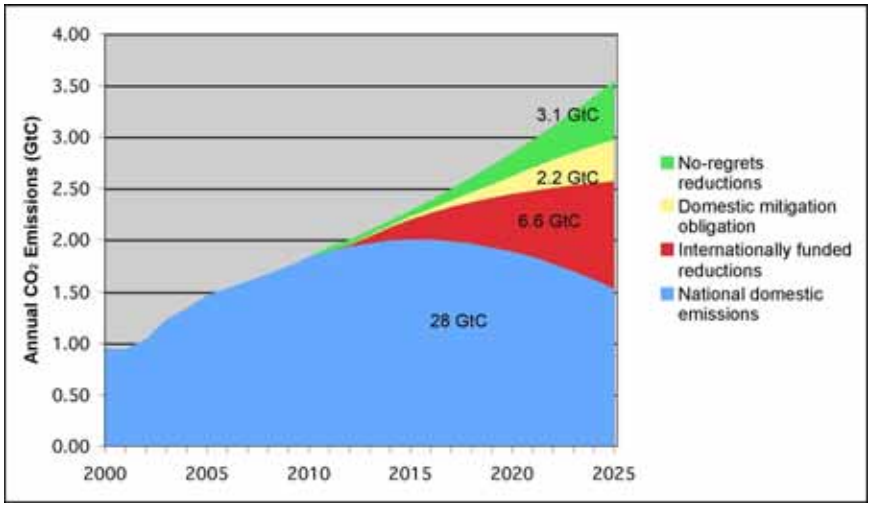

Figure 12. Plausible emissions trajectory for China under GDRs reference case if international purchases lead to 6% annual rate of reduction. See text.

5.5 The trouble with carbon markets

The prospect of international carbon trading is controversial, and even divisive.[48] But as we suggested above, it may well be that some kind of trading is inevitable, and that, in the proper framework, it is even desirable. Having said this, however, caveats are immediately necessary. Trading must be well designed, well implemented, and well regulated. And a serious, sustained effort must be made to ensure that, at the end of the day, carbon trading delivers on its promise of generating reductions – *real* reductions – cost-effectively. Cheap but illusory offsets (many of which are being provided by the Clean Development Mechanism) are not a viable substitute. And it's not just the CDM that's a problem. The EU's Emissions Trading System is badly hobbled by grandfathering and over-generous allocations, and the private carbon markets are a veritable Wild West of unsubstantiated reductions. All things considered, carbon trading hasn't been going well, and, at this point the onus is on the policy makers to prove that they're capable of designing and implementing trading systems that can be widely accepted as being both legitimate and useful.

Also, effective and broadly participatory social and environmental safeguards must be built into the trading system. However, the need here is not limited to carbon markets or crediting systems. Any mechanisms that serve to channel large financial flows will be difficult to get right, and however they're structured, a great deal civil society and governmental involvement and oversight will be necessary s if they're to be both fair and effective. So whatever institutions we finally choose to mediate and manage the considerable international financial transfers that must, inevitably, be associated with a viable emergency program – whether these mechanisms are fund-based or tax-based or trading-based, whether they're public or private, whether they're tied to existing institutions like the World Bank or to the new institutions that the climate regime will inevitably call into existence – they'll carry real risks. In every case, questions must be asked: about how the mechanisms work; about how transparent and accountable they are; about what

strings are attached to them, and who's pulling them; about social and environmental safeguards; about governance. About who's hurt, who benefits, and who decides.

All this is critical because, whatever we do, some people will be negatively affected by the greenhouse transition. Mitigation and even adaptation will have their winners and losers, and the damage to the losers cannot be blithely ignored in the interests of a larger good. Indeed, any claims to the larger good must, finally, be judged in terms of affected peoples, and whether they have real opportunities to assert their interests, and to decide how these interests are understood and acted upon.

5.5.1 Setting limits

One key justification for emissions trading is that it allows nations to choose how much of their mitigation obligation to discharge domestically, and how much internationally. Indeed, the fact that countries may have obligations greater than their plausible rates of physical reductions – and possibly even greater than their total emissions – is central to the GDRs framework. It's by exercising their option to meet these obligations by paying for international reductions that wealthy countries help poorer countries to decarbonize.

But can this option be abused? What if wealthy countries try to 'buy their way out' of the climate problem, by purchasing all or even most of their reductions internationally? To some degree, the emergency program contains a built in corrective to this problem, since reductions in the wealthy countries would become more and more difficult to pass up as the pressures of the 2ºC trajectory bear down and reductions in the South become more costly. But what if this isn't enough? After all, a true emergency program would inevitably, at some point, require serious structural adjustments (on top of major technological changes), and wouldn't wealthy northerners be willing to pay quite a premium to avoid such adjustments and preserve their high-carbon lifestyles?

There are several problems here. The first has to do with the path dependency of the carbon transition itself, which require deep infrastructural change to start early and unfold over a long period of time (e.g., more compact urban forms to reduce transport requirements). Such changes will not be universally popular, and wealthy countries might well seek to dodge the resulting discord by avoiding domestic reductions in favor of purchased international reductions. Such a strategy could, however, be extremely short-sighted. Internationally purchased permits would only rise in price, and at some point might simply become too scarce to be affordable. At that point, we might well find that the wealthy, having failed to take the necessary early, incremental actions, simply default on their obligations under the climate regime. And at that point the regime, and the emergency program, would be in deep trouble.

A second problem arises from the reality of markets in an unequal world. The idealized view of carbon markets assumes that the sellers of permits are acting voluntarily, and perhaps even reaping a handsome profit. But in fact markets of all sorts engage actors with widely disparate levels of power. In this context, it's not always easy to ensure that the permits being sold by the South, or rather the mitigation these permits correspond to, arises from the implementation of

low-carbon energy services, rather than from the involuntary sacrifice of energy services (and hence welfare) by politically weak communities that are not being sufficiently compensated, or not compensated at all.

Finally, politics matters. Under the rigors of an emergency program, international cooperation will be essential, and it's extremely unlikely that such cooperation can be sustained if developed countries are seen to be buying environmental space in order to prolong high-emitting lifestyles. Further, it's unlikely that technological changes alone will be able to deliver the needed rates of emissions reductions. Thus, the historically wealthy and high-emitting countries will have to help pioneer new kinds of low-impact lifestyles, of a kind that would scale, and be at least potentially adoptable by the growing global population. There's no way around it; this is not a story in which legitimacy and perceived justice are mere expendable ingredients.

These various arguments suggest that it might be justified to compel northern countries to make domestic reductions of at least the same scale as those required globally. That is, that it might be justified, under an emergency program, to compel nations with large national reduction obligations to make domestic reductions of at least 6% annually. Such a 'supplementarity' rule would, to be sure, offend the economists, but this does not seem, on balance, to be a decisive argument against it. And given the inauspicious experience with carbon markets so far, the case for such a 'regulatory backstop' is strong.

In any event, any climate regime that safeguards the right to development will have to provide a way for large amounts of resources to flow from the wealthy countries to the poor. This is the only way that the required mitigation can become a reality. Perhaps there are better ways than trading to achieve this objective. We shall see. In the meanwhile, we're compelled to admit that such international transfers will be difficult to achieve. And that, nevertheless, we must at all costs achieve them. Any climate regime that functions as just another brick in the wall of economic stratification will simply be rejected, and justly so.

6 Politics and Greenhouse Development Rights

The real world of course follows a more complex and varied path than can be represented by this sort of top-down analysis. There's a big world, and a lot happening. Some developments, however, are directly relevant to our argument, and among these we would count sharpening disagreements within both Annex 1 and the G77/China; the emergence of the 'Accession' or '+5' group (as in the 'G8+5') of high emitting developing countries (China, India, Brazil, South Africa, and Mexico), and of course China's rising emissions. The United States, too, deserves special mention, particularly because, now in the late days of the Bush administration, the air is charged with the expectation of change. We all feel it, as we all, inevitably, hope for the best.

This hope, alas, could be easily dashed. The United States, after all, scores uncomfortably high, and indeed leads, in any reasonable obligation indicator, with implications that will not be welcomed even in a Democratically controlled Washington, or indeed within the average American household. So, yes, much will change when the Democrats take office, but it's not obvious that they'll change enough to bring the US into the new 'leadership' position that so many people are hoping for. At this point, frankly, such leadership can only flow from an acceptance of national obligations, and from the promotion of approaches that take proper account of not only the scale and severity of the climate threat, but also the realities of unequal development.

The situation is changing fast. But even with 'aspirational targets' such as '90 percent by 2050' on the rhetorical table, the imperatives of the short term are still the main drivers of climate policy. One way to put this is that there's no obvious way to be 'policy relevant' while calling for an international framework designed to support a true emergency program. Soon, perhaps, this will change, but until then, anything like Greenhouse Development Rights can only be, at best, a reference framework. As such, the tests of its utility is simple enough: does it help us see where we actually are? And does it also point beyond the short-comings of existing climate policy?

We of course hope that, by outlining a burden sharing system appropriate to a divided world, the Greenhouse Development Rights framework can serve as a useful benchmark against which other proposals can be assessed. At the very least, it can help to call attention to the real divide – that between rich and poor – and particularly the way in which it manifests itself *within* the large developing countries. This, we're confident, is an important move, for the problem is not simply that these countries are large – as if China, and India, and Brazil, despite their relative poverty, were the culpable ones – but rather that, by their very size and dynamism, they stand between the rich world and the poor, and at the edge of an impossible future. The core of the impasse? Simply that there's very little atmospheric space left, far too little for the poor to 'develop' along anything like the business-as-usual path, not at least if we're to avoid a catastrophe. And that,

despite this and despite all else, the emerging powers of the South have no intention of trading away their right to development.

6.1 The showdown

Recall the June 2007 meeting of the G8+5. And remember that the battle there was one of targets and timetables. The drama was high but the plot, alas, was all too familiar. It was Angela Merkel's progressive Europe v. George Bush's self-interested America, and each came brandishing its favorite standards. Merkel spoke for a global emissions target of 50 percent reductions by 2050, which she presented as if it was unambiguously consistent with the 2°C temperature target. And of course the Bush administration replied, as everyone knew it would, with high-sounding refusal and its usual twisted replies: What about China? What about India? What about the developing world?

These, unfortunately, are good questions. Just as unfortunately, they're dangerous questions that the European Union, for all its many attempts to move the agenda forward, has never really satisfactorily answered. Which brings us to the point of this section – that from the GDRs perspective, the key lesson of 2007's G8+5 was not that the EU couldn't move the Americans, but rather that, even in the face of extreme provocation by the Americans, it couldn't even move the +5 countries. It was that China, India, and the others did so little to support the Europeans. That, even as the EU led a critical battle against an extremely unpopular American administration, the +5 countries barely left the sidelines.

So, why not?

Is it that southern negotiators don't believe the science? That they don't know how horrifically climate change will strike their nations, their lands, their vulnerable poor? Perhaps this is part of the story, but it doesn't really explain the singular reticence of the South's negotiators. Far better, we feel, to presume that they indeed understand the urgency of the climate crisis, but that they also understand its defining political reality. Which is simply that the urgency is now on the table, along with calls for rapid, stringent global reductions, but without any correspondingly serious protections for the South's developmental equity. That, in particular, there's a pervasive and critical absence of concrete proposals for a burden sharing architecture that's capable of supporting rapid emissions reductions without radically circumscribing the prospects of the South's nations and populations. In fact, we believe that the South's negotiators – many of them at least – have consciously judged the situation, and, for better or for worse, have reached the conclusion that, absent substantive movement towards a defensibly fair global burden sharing system, they have more to lose than to gain by admitting the severity of the crisis.

Such an interpretation will not, perhaps, be particularly controversial within the climate community. But it seems to us that neither its implications nor its explanatory power have been followed though. And this despite its ability to explain why the developing countries have been so consistent in not only rejecting the need for hard global targets, but also in resisting official recognition of the science (as for example China did during the drafting of the IPCC's recent Working Group I *Summary for Policymakers*) and, more generally, denying that humanity as a

whole now faces an emergency situation. An emergency, after all, is by definition a situation that requires an extraordinary response, and southern decision makers can be forgiven if, surveying the state of the real geo-political world and the lessons of the recent past, they conclude that a politics of global climate emergency would likely play out in a manner that constrains their development aspirations.

Nor is it obvious that they are wrong to do so.

It's helpful to illustrate the situation with one more set of graphs. Recall first Figure 2, from Section 3 above, which showed that developing country emissions alone will soon send us all hurtling across the 2°C emissions line (even if the world follows the relatively benign BAU pathway defined by the IPCC's B1 scenario family[49]). Indeed, defining that line in terms of our emergency pathway (the one that drops to 80 percent below 1990 levels in 2050 and has the highest probability of holding the 2°C line), developing country emissions cross it in only about 15 years. And even the least stringent of our pathways would be crossed within 25 years.

Thus, even such a 'relatively benign' BAU pathway would likely wreak havoc. And if we're to have a significant chance of holding the 2°C line, the developing world's emissions must instead, and exactly as its negotiators fear, drop extremely quickly. How quickly? Well, what if, just hypothetically, the Annex 1 countries were to commit to our emergency pathway, and what if, to prove their earnestness, they were to commit as well to the challenge of the day, making 90 percent reductions from the 1990 baseline by 2050? How much space would then remain for the development of the Non-Annex 1 countries?

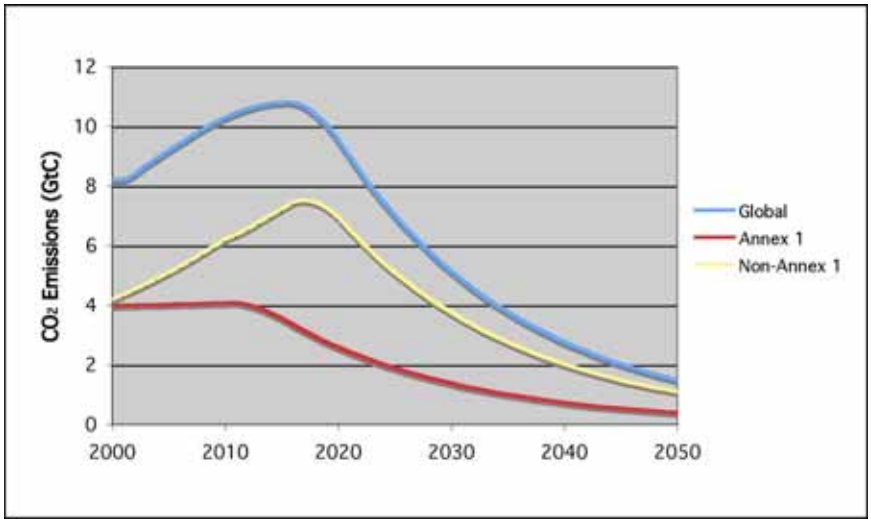

Figure 13. Global emissions scenario with peak CO_2 emissions in 2015, falling to 80% below 1990 levels in 2050. Annex 1 emissions decline to 90% below 1990 levels in 2050.

The math, alas, is implacable. In fact, as Figure 13 clearly shows, non-Annex 1 must itself be on an emergency path if we're to hold to the global emergency path. Indeed, despite the rapid and deep cuts in Annex 1, non-Annex 1 emissions would have to peak *before* 2020, and be dropping at six percent annually within a few years.

With only a small amount of emissions space left, there are few degrees of freedom available to allow a more relaxed southern trajectory. The non-Annex 1 peak could be postponed, but only by committing to an even steeper subsequent decline. And, conversely, the decline could be less steep, but only if the peak is lower and comes sooner. Neither of these alternatives is significantly more forgiving than the non-Annex 1 path shown in Figure 13. The other option, in theory, is that the North would make more space available. But this is already a scenario of extremely aggressive northern reductions, with 2050 emissions being cut by 90 percent. And even 100 percent wouldn't open a great deal more space for the developing world. The possibility of emissions from the North going radically negative is in principle an option, but as discussed earlier, it is a distant option on which we choose not to base our hopes for the survival of the planet.

The same trajectories are shown in per capita terms in Figure 14, which illustrates a different aspect of this same situation. Here we see that Annex I per capita emissions would decline dramatically in meeting this '90 percent by 2050' trajectory, but that even this would leave little space for Non-Annex I to develop. In fact, Non-Annex 1 per capita emissions would still have to drop sharply within the next few years, and do so even though they were a mere half of the northern average. That average would also drop of course, but it would remain far higher than that in the South, and continue to reflect a far higher level of consumption. Consider, for example, India. Even assuming a steady five percent rate of annual growth (the average over the last 10 years), its per capita income would still be under $8000 (PPP) in 2020. [50]

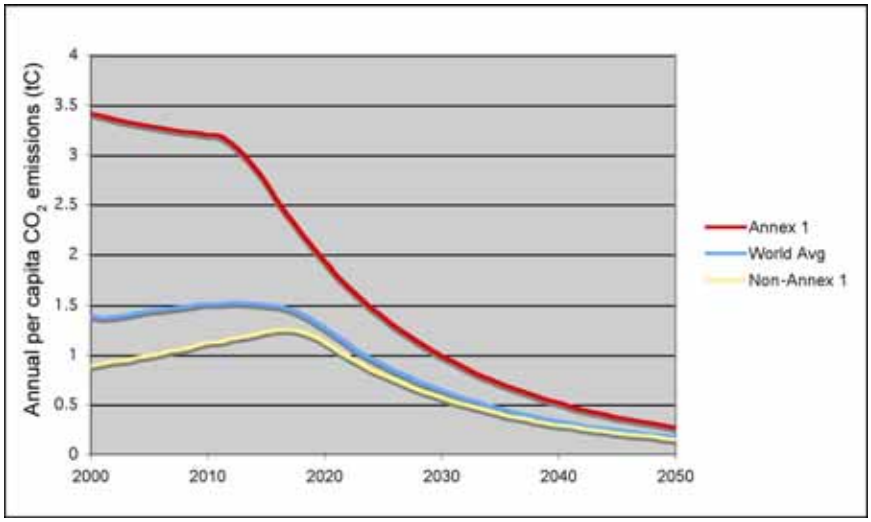

Figure 14. Per capita emissions (from fossil fuel combustion) in the emergency scenario with Annex 1 emissions declining to 90% below 1990 levels in 2050.

Much more could be said along these lines, but the point should be clear enough, and sufficient to illustrate why developing countries are so hesitant to commit to the 2ºC target. Because if we're to have a real chance of keeping to it, southern emissions simply *must* peak by around 2020, and then begin dropping by something like six percent a year. All else being equal, all it seems to leave them is a stifling 'Contraction and Convergence' style future in which their efforts to

modestly expand energy services knock quickly against inexorable limits, even while the world's wealthy continue to enjoy luxury levels of consumption and emissions. And what this promises the South, or seems to, is a future in which developmental equity remains forever out of reach.

And yet, there are in fact two possibilities. The first, of course, is one in which the climate crisis threatens to lock the South into a position of long-term underdevelopment, but it should be obvious by now that such a prospect can only harden the impasse and draw us further toward catastrophe. The other is one in which the threat of long-term underdevelopment is taken off the table, in which the wealthy commit to a future in which global development no longer depends on rising emissions and then do whatever it takes to make that future real, in which developmental justice is understood not as a matter of equalizing per capita emissions but as a matter of extremely rapid global decarbonization. Such a program would have to be conceived, *and announced*, as one in which the poor – most of whom live in the South – are not obliged to pay.

This is the only way, and just the problem. Because right now such a global program simply isn't on the agenda, and chances are pretty good that it's going to be hard to get it there. Which means that the developing countries, were they to commit to an emergency global emissions pathway, would be opening themselves to an entanglement that was likely to compromise their development.

None of which is to say that the long battle to establish the 2°C target was a mistake. In fact, it was essential; the 2°C target is a proxy for the science as a whole, and expresses the emergency in a manner as clear as it is bracing. Nor is it correct to insist that a comprehensive, structurally appropriate burden sharing regime (something like the GDRs framework) can now find real international traction. Clearly, we're not there yet. But, on the other hand, it is fair to say that we, all of us, including southern negotiators, have got to become a great deal more honest about the political logic of this extremely difficult situation, in which an emergency target is on the table, but without any matching burden-sharing architecture. It's absence, indeed, is a decisive one, and given it, we shouldn't be surprised if vague talk about 'no-lose' targets isn't enough to move the +5 countries off the sidelines and into the ranks of the climate protection coalition.

Not to excuse the inaction in the North, but we're compelled to add that the southern negotiators are clearly part of the problem. For while emergency action really is impossible without a burden-sharing system that protects the right to development, *the South has passed up numerous opportunities to put such a system onto the table*. This must be recognized, because if any single move has a real chance of breaking the impasse, it would be *a southern proposal for an emergency architecture that the large developing countries could actually agree to*. So though it might seem dangerous to engage with this almost impossible problem, it's time, past time really, for the South to step forward with just such a proposal.

6.2 Beyond the annexes

Whatever happens, an emergency program must come soon. In the meanwhile, we believe that the GDRs framework usefully clarifies the structure of the climate problem, and even that it suggests bridges to the future. We believe, in fact, that it suggests a helpful approach to the key

problem of the second commitment period: the expansion of Kyoto's Annex 1, and the establishment of a rule-based rather than ad hoc means of burden sharing within that expanded annex.

The underlying problem is that the annexes, as currently defined, are, at best, unhelpful. By necessity, they are lists of countries that have something – but not everything – in common. They only vaguely hint at the appropriate role for each country, and they leave a great deal unsaid. Which is why, back in 1997, when it came time to allocate emission reduction targets within Annex 1, it wasn't clear if decisions were being made on the basis of measurable indicators of national circumstance, on the basis of political history (like those shared by the former Soviet states) or on the basis of negotiating power and acumen. It's no accident that whenever the origin of Kyoto's burden sharing rules is at issue, discussions invariably come around to the politics of 'hot air' (read 'bribery') and 'horse trading.'

Equally confounding is the fact that today's climate negotiations take place within and between annexes as they were classified in the late 20th century, even though it's quite evident that these lists, frozen snapshots of the past, will no longer do. The climate regime must push beyond today's Annex 1 to take account of new realities in which, for example, 'newly industrialized' countries (e.g., Singapore and South Korea) are far richer than many of the nations within Annex 1 (e.g., the countries of eastern European and the former Soviet Union). Nor is this challenge of defining and updating annex membership just a near-term problem of Singapore and South Korea. It's a perennial challenge as countries develop and then 'graduate' to assume more rigorous obligations. The problem, particularly, is that if graduation is defined as moving from one imprecisely defined annex to another, the 'triggers' that signal graduation are necessarily ambiguous. And since, in almost every case, it's in the short-term interests of a country to resist graduation, this is a recipe for dysfunction. After all, if newly industrialized countries are to graduate into Annex 1, then which ones and when? And, as they say in Washington, what about China?

In Kyoto, the shortcomings of Annex I were tolerable. 'Strategic ambiguity' − the watchword of the day − was good enough, and perhaps it was even necessary. It was fine to leave "common but differentiated" at the abstract level of preambular text. But these problems will have to be faced, or at least finessed, in the post-2012 negotiations. As the climate problem bears down, as action becomes urgent and costs real, the stakes will only grow higher. Agreements and procedures designed to smooth and rationalize the process are needed, but, unless they're transparent, unambiguous, and based on jointly accepted principles, they'll be fraught and contentious. Possibly fatally so.[51]

The most rational scheme would eliminate annexes altogether and replace them with a differentiation scheme based on a transparent, quantifiable, and defensible definition of national obligation. But since such a step doesn't seem to be on the table, at least not yet, the question is whether Annex 1 − in the interim − can at least be rationalized. Whether its membership and burden sharing arrangements are at least be made internally consistent, and brought closer to the principles of responsibility and capacity underlying the UNFCCC. This is, in essence, what the

international Climate Action Network, in its June 2007 AWG submission,[52] suggests, though only by means of a brief reference to a national 'Capacity and Responsibility Indicator' that is, perhaps, too simple.[53]

Consider that problem concretely, while examining Table 4. It lists today's Annex 1 countries (in red), embedded within a larger list of the top 76 countries in the world, ranked by their average individual RCI. That is to say, it ranks countries by their total national RCI divided by the number of people contributing to that RCI. It does so because, as we've argued, capacity and responsibility are most appropriately attributed to individuals – rich countries are not rich because of their total income, but because of their high per capita income.

Average individual RCIs would obviously be lower – especially in developing countries – if they were calculated in per capita terms – dividing the national RCI by the total population rather than by the smaller number of people above the development threshold. But this would make no sense, because the people below the development threshold made no contribution to the national RCI in the first place. The key point is that the RCI is an indicator of national obligation, and national obligation should, by rights, be shared only among those above the development threshold, by those, that is, within the consuming class.

In the Table 4 rankings, then, we get a sense of the relative obligations that could reasonably be assigned to a typical member of each country's consuming class. Two points are worth noting. First, this per person obligation varies dramatically across countries. By the time we've worked our way down to the last country on the list (Belarus), it's dropped to less than one thirtieth of that in Luxemburg, the first country on the list. Second, while today's Annex 1 countries cluster toward the top of the list, roughly a quarter of them don't even fall in the top half, while many non-Annex 1 countries do. All in all, it's plain to see that, if the current Annex 1/Non-annex 1 distinction is going to be maintained, some countries should be added to Annex 1, and some, perhaps, should be dropped.

Table 4 also shows aggregate national RCIs, as shares of the global RCI, and cumulative RCI, as the share of the total global RCI that has been included at any point in the ranking. So we can see that, if the size of Annex 1 were to hold steady at 40 members, dropping current members with low per-person RCI in favor of countries (now non-Annex 1 countries) with higher per person RCI, the new Annex 1 would capture close to 80 percent of total global RCI. And if the membership were brought to 76 (so as to include all the countries now in Annex 1 plus any that fall between them) Annex 1 would capture almost the entire global RCI.

Rank	Country	Average Individual RCI	Percent of Global RCI	Cumulative Global RCI
1	Luxembourg	3845	0.1%	0.1%
2	Qatar	2809	0.1%	0.2%
3	United States	2723	35.2%	35.4%
4	Canada	2042	2.9%	38.2%
5	Australia	1959	1.7%	40.0%
6	Norway	1907	0.4%	40.4%
7	Ireland	1867	0.3%	40.7%
8	Singapore	1847	0.4%	41.0%
9	Kuwait	1823	0.2%	41.2%
10	Denmark	1793	0.4%	41.7%
11	United Arab Emirates	1790	0.4%	42.0%
12	Netherlands	1766	1.3%	43.3%
13	Belgium	1744	0.8%	44.1%
14	Finland	1725	0.4%	44.5%
15	Iceland	1680	0.02%	44.5%
16	United Kingdom	1668	4.4%	48.9%
17	Bahrain	1580	0.05%	48.9%
18	Austria	1573	0.6%	49.5%
19	Japan	1552	8.7%	58.1%
20	Germany	1534	5.5%	63.6%
21	Switzerland	1472	0.5%	64.1%
22	Sweden	1363	0.5%	64.7%
23	Italy	1296	3.2%	67.9%
24	France	1293	3.4%	71.3%
25	Israel	1215	0.4%	71.7%
26	Spain	1172	2.2%	73.9%
27	New Zealand	1146	0.2%	74.1%
28	Greece	1076	0.5%	74.6%
29	Czech Republic	1057	0.5%	75.1%
30	Cyprus	1041	0.04%	75.1%
31	Korea, Rep.	1021	2.1%	77.3%
32	Slovenia	973	0.1%	77.4%
33	Trinidad and Tobago	928	0.05%	77.4%
34	Saudi Arabia	828	0.9%	78.3%
35	Estonia	790	0.05%	78.4%
36	Portugal	787	0.4%	78.7%
37	Oman	681	0.1%	78.8%
38	Hungary	659	0.3%	79.1%
39	Malta	614	0.01%	79.1%

Rank	Country	Average Individual RCI	Percent of Global RCI	Cumulative Global RCI
40	Slovak Republic	602	0.1%	79.2%
41	Tajikistan	592	0.2%	79.4%
42	Libya	556	0.1%	79.5%
43	Poland	552	0.9%	80.5%
44	South Africa	513	1.0%	81.5%
45	Argentina	462	0.8%	82.2%
46	Lithuania	443	0.1%	82.3%
47	Latvia	393	0.04%	82.4%
48	Chile	386	0.3%	82.6%
49	Russian Federation	371	2.3%	84.9%
50	Malaysia	367	0.4%	85.3%
51	Croatia	355	0.1%	85.4%
52	Botswana	335	0.03%	85.4%
53	Mexico	334	1.5%	86.9%
54	Mauritius	280	0.02%	87.0%
55	Turkmenistan	271	0.1%	87.0%
56	Bulgaria	214	0.1%	87.1%
57	Kazakhstan	212	0.1%	87.2%
58	Romania	211	0.2%	87.4%
59	Iran, Islamic Rep.	199	0.6%	88.0%
60	Brazil	195	1.6%	89.6%
61	Panama	193	0.03%	89.6%
62	Uruguay	190	0.03%	89.7%
63	Namibia	190	0.02%	89.7%
64	Costa Rica	187	0.04%	89.7%
65	Thailand	181	0.5%	90.2%
66	Turkey	180	0.6%	90.8%
67	Dominican Republic	174	0.1%	90.8%
68	Gabon	164	0.01%	90.9%
69	Venezuela, RB	159	0.2%	91.0%
70	Colombia	149	0.3%	91.3%
71	Tunisia	137	0.1%	91.4%
72	Macedonia, FYR	122	0.01%	91.4%
73	China	121	6.9%	98.3%
74	Ukraine	118	0.2%	98.6%
75	Jamaica	116	0.01%	98.6%
76	Belarus	102	0.04%	98.6%

Table 4. Top 76 countries, as ranked by average individual RCI (see text). Note that this includes all current Annex 1 countries (in red).

Unsurprisingly, and particularly if the intent is to group countries deserving of immediate commitments, there's no correct place to draw the Annex 1 line. Any given partitioning would entail a good measure of arbitrariness. Still, if we're indeed fated to carry the Annex 1/Non-annex 1 distinction forward into the second commitment period, something like the above ranking can at least allow us to move forward into rule-based rather than ad hoc means of defining Annex 1 membership.

It can also help us to define the burden sharing within Annex 1. A nation's portion of global RCI (column 4) is a direct indication of the portion of the global effort that it can reasonably be expected to bear, assuming, that is, that the burden sharing arrangement aims to base obligations on responsibility and capacity. And if it doesn't, then this sort of ranking can tell us how far off the mark it is.

We don't, by the way, presume that this particular RCI, built up as it is from the assumptions that we happen to believe are most defensible, is the last word. But for the moment, the key thing is simply to put the right pieces on the table. Which is why the RCI we've presented seeks to be consistent with a defensible definition of the right to development. Why it's designed to measure both historical responsibility and capacity to pay, and to do so in a manner that makes sense even in when comparing wealthy, middle income, and poor countries, all of which have skewed, and perhaps highly skewed, income structures. Why it's robust enough to compare the obligations of the United States, China, and Sierra Leone and produce meaningful results. These are the qualities that it must have if it's to make the point, that a principle based indicator need not just be a policy abstraction, and that a proper variant, fully vetted and debated, could well provide some impetus to nudge the Kyoto Protocol away from the burden sharing system we have today, in which countries are assigned semi-arbitrary obligations within semi-arbitrary annexes, to one that is transparently based on agreed principles. And as such, we believe, it illuminates the road ahead. In any case, as Al Gore put it in a recent editorial, 'countries will be asked to meet different requirements based upon their historical share or contribution to the problem and their relative ability to carry the burden of change. This precedent is well established in international law, and there is no other way to do it.' [54]

6.3 Last words

It's time now to act in good faith. Many years have passed since ignorance of the climate problem could honestly be cited as an excuse for inaction. The climate *problem* is now a climate *crisis*, and it's time – past time really – to admit it. Prudence no longer means modest, measured, and gradual action. Indeed, the only prudent course left to us is an emergency program − one that begins immediately and takes in the whole world.

It's also time to stop pretending that the climate crisis can be solved on its own, and that the development crisis is another matter. Only a regime that structurally encompasses the right to development has a real hope of catalyzing the necessary emergency program. And hard though it may be to admit it, meaningfully recognizing the right to development inevitably means taking account of inequality within nations as well as inequality between them.

Such inequality is still a taboo subject, at least when it comes to climate policy as usual. But the longer we fear this taboo, the greater our risk of not only continued impasse, but incoherence and irrelevance as well. This is clear not only in the 'What about China?' gambit that's now so popular in Washington, a gambit that presents Shanghai's affluent enclaves as if they were the whole of the Chinese nation, and thus allows the American rich to hide behind the Chinese rich. And it's clear as well in the rhetoric now popular in New Delhi, in which official climate spokesmen can confabulate India's 'very, very large number of poor people' with its goal of 'maintaining our current rates of GDP growth and poverty alleviation programs,' and by so doing argue that, as long as India's per capita emissions remain below those of the North, its citizens (including its complement of high-emitting consumers) are in full moral compliance with their mitigation responsibilities.[55] Let us then be clear: with words like this, India matches the US gambit with another, even better one, in which India's rich hide not only behind the North's rich, but behind India's poor as well.

The way out of this macabre dance, as we have argued, is to recognize that the right to development adheres not to nations, but to people, and that the wealthy – whether they happen to live in Washington, or Shanghai, or New Delhi – have no further claim to it at all. The alternative to this realization, and to its operationalization within a global climate regime, is to sit helplessly by as our endless negotiations, designed for a world of idealized and monolithic nations, come finally to failure, delegitimation, and despair.

Which – this too must be said – is not to claim that it's the job of the climate regime to solve all the problems of the world. Inequality preceded the climate crisis, and there's little doubt that it will survive past the coming peak in global greenhouse gas emissions. But in a world as bitterly divided as ours, a viable climate regime must at least do no harm, and this means that it must not erect further barriers to the progress of the poor. The key virtue of the Greenhouse Development Rights approach is that it does not do so; indeed it's because it doesn't that we can claim that the GDRs approach is in fact realistic. And if the cost of meeting this condition is that, in the end, both mitigation and adaptation must be financed via a (fairly modest) tax on the luxury consumption of the relatively wealthy – for this is, finally, what GDRs proposes – well what is this but realism about our actual conditions of life?

In the meanwhile, no one should confuse the expediency of the currently possible with the realism demanded by a true emergency program. Because if we manage to avoid a global climate catastrophe, it's not going to be by much. And the sooner the architecture of the climate regime is aligned to the real structure of the problem the better our chances are going to be.

7 Technical Appendices

7.1 Appendix A: The GDRs database

The database used in the Greenhouse Development Rights paper (hereafter 'the GDRs database') has been assembled from a variety of publicly available data sources, with some missing elements (e.g., estimated 2005 per capita CO2 emissions for a few countries) calculated on the basis of other elements, and some missing elements (e.g., Gini coefficients for some countries) filled in with educated guesses.

The GDRs database includes 158 countries accounting for about 99.7 percent of the world population in 2005, according to the World Bank's World Development Indicators (WDI). Most of the excluded countries are small island states, including some which are members of the UNFCCC.

The key elements in the GDRs database, from which all the calculations are derived, are the following:

- Population in 2005
- Per capita income (PPP adjusted) in 2005
- Gini coefficient
- Cumulative per capita CO_2 emissions from fossil fuels, 1990-2005

7.1.1 Data sources

Population

The population data for 2005 is taken from the World Bank's *World Development Indicators* online (hereafter WDI), with the exception of three countries: Afghanistan, Iraq and Taiwan. For those three, 2007 population estimates were taken from the CIA World Factbook, and back-dated to 2005 by subtracting two years of population growth at the estimated 2007 population growth rate.

Per capita income

Income data (per capita income for 2005, purchasing power parity adjusted, current (2005) international dollars) is taken from the WDI, except for 18 countries (see Table A1), for which data was taken from the CIA Factbook and adjusted to 2005 by forward or backward extrapolation with estimated growth rates.

Gini coefficient

Gini coefficients were taken from the World Income Inequality Database (WIID v. 2.0b, http://www.wider.unu.edu/wiid/wiid.htm) for all but about 30 countries. The national values were selected by first filtering to ensure that only data were used that covered the entire geographic extent of a country and all of its population, then selecting the most suitable based on the date of the data (with the most recent year preferred) and the quality of the data as reported in the WIID data. In a few of the other cases, where Gini coefficients were not in the WIID database, published Gini coefficients were available from other sources (e.g., the EU's Europa database for Malta and Cyprus). For the remainder, Ginis were estimated on the basis of comparable countries. These countries include only about six percent of the global population and are generally (though not exclusively) smaller and poorer countries, so any disagreement between the estimated and true values should not greatly affect the calculated global RCI and thus the national RCIs for countries which have published Gini coefficients. Note also that the measurement of Gini coefficients is in general only approximate, and in countries undergoing rapid economic changes they can change significantly over even a fairly small number of years. Though they are a useful and widely cited indicator of income distribution, refinements are an important subject for further research.

Cumulative per capita emissions from fossil fuels, 1990-2005

The emissions component of the GDRs database was compiled from four primary sources: The World Resources Institute Climate Analysis Indicators Tool (CAIT), version 4.0; the World Bank's World Development Indicators (WDI) online; the US Department of Energy's Energy Information Administration (EIA); and the Netherlands Environmental Assessment Agency (MNP). The data were combined as follows:

Three different time series were available for CO_2 emissions for most countries for the period 1990-2003, from the WDI, CAIT and EIA sources. These were taken as national aggregate data (not per capita figures). The average across these three data sets was used for both cumulative emissions through 2003 and annual emissions in 2003. Estimates of 2004 and 2005 emissions were calculated for all countries using their 2003 emissions and reported emissions growth rates for all countries for 2004 from the EIA database, and for countries based on representative regions for 2005 from the Netherlands database. On this basis cumulative emissions 1990-2005 were calculated for all countries, and then divided by 2005 population to estimate cumulative per capita figures for all countries.

CO_2 emissions from land use change and international bunker fuels were excluded. Land-use emissions were excluded because they are much more uncertain than fossil fuel emissions, and the choice to include them would require addressing the implications of the deforestation of the northern hemisphere in the 19th century or before. Bunker fuels were excluded because they are small relative to other fossil fuel emissions, and two of the three sources we considered did not include them.

7.1.2 Master data table

The four primary variables used in the GDRs calculations are shown below for all 158 countries, along with their classification as Annex I, EITs, LDCs, and 'European Union Era.' This latter is coded as 1 for EU15, 2 for EU25, 3 for EU 27, and 4 for (future) EU 29. Aggregated data for the EU include the EU 27, unless specified otherwise. For a machine readable copy of this data, please contact GDRs@ecoequity.org or visit gdrs.sourceforge.net.

Table A1. Master data table. ***Country names in italics are those for which income data came from the CIA Factbook rather than the World Bank, per above.***

Country	Per capita income 2005 ($ PPP)	Pop 2005	Gini latest	Cumulative per capita CO_2 1990-2005	Annex 1	EIT	LDC	EU Era	Income class
Afghanistan	800	31,000,000	50	0.2	0	0	1	0	Low
Albania	5,316	3,129,678	28	4.4	0	1	0	0	Lower Middle
Algeria	7,062	32,853,798	35	13.0	0	0	0	0	Lower Middle
Angola	2,335	15,941,392	50	2.3	0	0	1	0	Lower Middle
Argentina	14,280	38,747,148	53	14.1	0	0	0	0	Upper Middle
Armenia	4,945	3,016,312	34	7.5	0	1	0	0	Lower Middle
Australia	31,794	20,320,904	35	68.6	1	0	0	0	High
Austria	33,700	8,211,359	29	34.4	1	0	0	1	High
Azerbaijan	5,016	8,388,402	37	18.8	0	1	0	0	Lower Middle
Bahrain	21,482	726,617	50	97.1	0	0	0	0	High
Bangladesh	2,053	141,822,272	32	0.8	0	0	1	0	Low
Belarus	7,918	9,775,591	30	29.3	1	1	0	0	Lower Middle
Belgium	32,119	10,470,738	33	50.2	1	0	0	1	High
Benin	1,141	8,438,853	36	0.7	0	0	1	0	Low
Bolivia	2,819	9,182,015	60	4.2	0	0	0	0	Lower Middle
Bosnia and Herzegovina	7,643	3,907,074	26	13.5	0	1	0	0	Lower Middle
Botswana	12,387	1,764,926	54	8.7	0	0	0	0	Upper Middle
Brazil	8,402	186,404,912	58	6.8	0	0	0	0	Lower Middle
Bulgaria	9,032	7,740,928	29	29.8	1	1	0	3	Lower Middle
Burkina Faso	1,213	13,227,835	40	0.3	0	0	1	0	Low
Burundi	699	7,547,515	42	0.2	0	0	1	0	Low
Cambodia	2,727	14,071,014	40	0.2	0	0	1	0	Low
Cameroon	2,299	16,321,863	45	1.4	0	0	0	0	Lower Middle
Canada	33,375	32,270,508	33	67.6	1	0	0	0	High
Central African Republic	1,224	4,037,747	61	0.3	0	0	1	0	Low
Chad	1,616	9,748,931	50	0.1	0	0	1	0	Low
Chile	12,027	16,295,102	58	13.2	0	0	0	0	Upper Middle

Country	Per capita income 2005 ($ PPP)	Pop 2005	Gini latest	Cumulative per capita CO_2 1990-2005	Annex 1	EIT	LDC	EU Era	Income class
China	6,757	1,311,903,730	45	10.8	0	0	0	0	Lower Middle
Colombia	7,304	45,600,244	59	5.7	0	0	0	0	Lower Middle
Congo, Dem. Rep.	714	57,548,744	50	0.2	0	0	0	0	Low
Congo, Rep.	1,262	3,998,904	50	2.5	0	0	0	0	Lower Middle
Costa Rica	10,180	4,327,228	50	4.9	0	0	0	0	Upper Middle
Cote d'Ivoire	1,648	18,153,868	45	1.3	0	0	0	0	Low
Croatia	13,042	4,444,451	31	19.1	1	1	0	4	Upper Middle
Cuba	3,920	11,269,400	25	10.9	0	0	0	0	Lower Middle
Cyprus	22,400	835,307	50	37.1	0	0	0	2	High
Czech Republic	20,538	10,196,360	26	51.7	1	1	0	2	Upper Middle
Denmark	33,973	5,418,313	25	46.9	1	0	0	1	High
Dominican Republic	8,217	8,894,907	52	7.8	0	0	0	0	Lower Middle
Ecuador	4,341	13,228,423	54	6.8	0	0	0	0	Lower Middle
Egypt, Arab Rep.	4,337	74,032,880	34	6.7	0	0	0	0	Lower Middle
El Salvador	5,255	6,880,951	52	3.3	0	0	0	0	Lower Middle
Eritrea	1,109	4,401,357	50	0.6	0	0	0	0	Low
Estonia	15,478	1,345,005	36	59.1	1	1	0	2	Upper Middle
Ethiopia	1,055	71,256,000	33	0.2	0	0	0	0	Low
Finland	32,153	5,245,071	27	48.7	1	0	0	1	High
France	30,386	60,742,612	33	27.2	1	0	0	1	High
Gabon	6,954	1,383,841	50	13.4	0	0	0	0	Upper Middle
Gambia, The	1,921	1,517,079	50	0.7	0	0	0	0	Low
Georgia	3,365	4,474,404	40	6.2	0	1	0	0	Lower Middle
Germany	29,461	82,485,352	28	45.0	1	0	0	1	High
Ghana	2,480	22,112,804	40	1.1	0	0	0	0	Low
Greece	23,381	11,089,185	34	34.6	1	0	0	1	High
Guatemala	4,568	12,599,059	55	2.7	0	0	0	0	Lower Middle
Guinea	2,316	9,402,098	40	0.6	0	0	0	0	Low
Guinea-Bissau	827	1,586,344	47	0.8	0	0	0	0	Low
Guyana	4,508	751,218	43	8.2	0	0	0	0	Lower Middle
Haiti	1,663	8,527,777	59	0.6	0	0	0	0	Low
Honduras	3,430	7,204,723	54	2.7	0	0	0	0	Lower Middle
Hungary	17,887	10,087,914	27	25.6	1	1	0	2	Upper Middle
Iceland	36,510	295,112	30	33.6	1	0	0	0	High
India	3,452	1,094,583,040	38	3.8	0	0	0	0	Low
Indonesia	3,843	220,558,000	34	5.0	0	0	0	0	Lower Middle
Iran, Islamic Rep.	7,968	67,699,896	44	19.0	0	0	0	0	Lower Middle
Iraq	2,016	26,800,000	45	11.8	0	0	0	0	Lower Middle

Country	Per capita income 2005 ($ PPP)	Pop 2005	Gini latest	Cumulative per capita CO_2 1990-2005	Annex 1	EIT	LDC	EU Era	Income class
Ireland	38,505	4,150,566	34	38.7	1	0	0	1	High
Israel	25,864	6,909,000	39	34.6	0	0	0	0	High
Italy	28,529	57,471,000	36	32.0	1	0	0	1	High
Jamaica	4,291	2,657,223	39	16.0	0	0	0	0	Lower Middle
Japan	31,267	127,956,008	25	39.9	1	0	0	0	High
Jordan	5,530	5,411,151	39	11.4	0	0	0	0	Lower Middle
Kazakhstan	7,857	15,146,081	34	46.3	0	1	0	0	Lower Middle
Kenya	1,240	34,255,720	45	1.0	0	0	0	0	Low
Korea, Dem. Rep.	1,904	22,487,660	40	21.2	0	0	0	0	Low
Korea, Rep.	22,029	48,294,144	32	35.1	0	0	0	0	High
Kuwait	26,321	2,535,446	45	86.9	0	0	0	0	High
Kyrgyz Republic	1,927	5,156,000	30	5.5	0	1	0	0	Low
Lao PDR	2,039	5,924,145	35	0.5	0	0	0	0	Low
Latvia	13,646	2,300,027	38	16.5	1	1	0	2	Upper Middle
Lebanon	5,584	3,576,818	45	17.3	0	0	0	0	Upper Middle
Lesotho	3,335	1,794,769	63	0.3	0	0	0	0	Lower Middle
Liberia	1,008	3,283,267	50	0.5	0	0	0	0	Low
Libya	13,216	5,853,452	45	33.2	0	0	0	0	Upper Middle
Lithuania	14,494	3,415,046	36	19.2	1	1	0	2	Upper Middle
Luxembourg	60,228	456,710	31	93.0	1	0	0	0	High
Macedonia, FYR	7,200	2,034,060	39	20.6	0	1	0	0	Lower Middle
Madagascar	923	18,605,922	47	0.4	0	0	0	0	Low
Malawi	667	12,883,935	50	0.3	0	0	0	0	Low
Malaysia	10,882	25,347,368	49	19.1	0	0	0	0	Upper Middle
Mali	1,033	13,518,416	51	0.2	0	0	0	0	Low
Malta	17,479	404,107	30	22.2	0	0	0	2	High
Mauritania	2,234	3,068,742	39	4.0	0	0	1	0	Low
Mauritius	12,715	1,248,000	50	9.0	0	0	0	0	Upper Middle
Mexico	10,751	103,089,136	50	15.7	0	0	0	0	Upper Middle
Moldova	2,100	4,205,747	33	10.3	0	1	0	0	Lower Middle
Mongolia	2,107	2,554,000	30	14.6	0	0	0	0	Low
Morocco	4,555	30,168,082	39	4.5	0	0	0	0	Lower Middle
Mozambique	1,242	19,792,296	40	0.3	0	0	1	0	Low
Myanmar	1,904	50,519,492	50	0.7	0	0	1	0	Low
Namibia	7,586	2,031,252	74	3.6	0	0	0	0	Lower Middle
Nepal	1,550	27,132,628	47	0.4	0	0	1	0	Low
Netherlands	32,684	16,329,302	31	49.6	1	0	0	1	High
New Zealand	24,996	4,110,000	36	33.3	1	0	0	0	High

Country	Per capita income 2005 ($ PPP)	Pop 2005	Gini latest	Cumulative per capita CO_2 1990-2005	Annex 1	EIT	LDC	EU Era	Income class
Nicaragua	3,674	5,486,685	43	2.7	0	0	0	0	Lower Middle
Niger	781	13,956,977	51	0.4	0	0	1	0	Low
Nigeria	1,128	131,529,672	44	2.5	0	0	0	0	Low
Norway	41,420	4,618,450	26	34.8	1	0	0	1	High
Oman	15,120	2,566,981	45	35.5	0	0	0	0	Upper Middle
Pakistan	2,370	155,772,000	31	2.6	0	0	0	0	Low
Panama	7,605	3,231,502	56	10.3	0	0	0	0	Upper Middle
Papua New Guinea	2,563	5,887,138	51	1.9	0	0	0	0	Low
Paraguay	4,642	6,158,259	58	2.5	0	0	0	0	Lower Middle
Peru	6,039	27,968,244	55	3.9	0	0	0	0	Lower Middle
Philippines	5,137	83,054,480	46	3.4	0	0	0	0	Lower Middle
Poland	13,847	38,165,404	34	37.1	1	1	0	2	Upper Middle
Portugal	20,410	10,556,707	38	22.7	1	0	0	1	High
Qatar	31,696	812,842	50	159.1	0	0	0	0	High
Romania	9,060	21,632,148	31	22.8	1	1	0	3	Upper Middle
Russian Federation	10,845	143,151,280	40	48.1	1	1	0	0	Upper Middle
Rwanda	1,206	9,037,690	29	0.3	0	0	1	0	Low
Saudi Arabia	15,711	24,573,100	45	51.3	0	0	0	0	High
Senegal	1,792	11,658,172	41	1.4	0	0	1	0	Low
Serbia and Montenegro	4,928	8,168,414	30	25.9	0	1	0	0	Lower Middle
Sierra Leone	806	5,525,478	63	0.5	0	0	1	0	Low
Singapore	29,663	4,351,400	42	65.8	0	0	0	0	High
Slovak Republic	15,871	5,387,152	26	32.6	1	1	0	2	Upper Middle
Slovenia	22,273	1,998,200	28	32.3	1	1	0	2	High
Somalia	672	8,227,826	50	0.2	0	0	1	0	Low
South Africa	11,110	45,192,000	58	31.8	0	0	0	0	Upper Middle
Spain	27,169	43,388,588	35	28.4	1	0	0	1	High
Sri Lanka	4,595	19,582,214	40	1.9	0	0	0	0	Lower Middle
St. Lucia	6,386	165,500	43	7.1	0	0	0	0	Upper Middle
Sudan	2,083	36,232,944	50	0.7	0	0	1	0	Low
Swaziland	4,824	1,131,000	61	2.9	0	0	0	0	Lower Middle
Sweden	32,525	9,024,040	25	26.3	1	0	0	1	High
Switzerland	35,633	7,440,711	25	25.6	1	0	0	0	High
Syrian Arab Republic	3,808	19,043,382	45	10.4	0	0	0	0	Lower Middle
Taiwan	27,600	22,900,000	40	4.9	0	0	0	0	High
Tajikistan	1,356	6,506,980	33	39.5	0	1	0	0	Low
Tanzania	744	38,328,808	39	0.3	0	0	1	0	Low

Country	Per capita income 2005 ($ PPP)	Pop 2005	Gini latest	Cumulative per capita CO_2 1990-2005	Annex 1	EIT	LDC	EU Era	Income class
Thailand	8,677	64,232,760	42	11.4	0	0	0	0	Lower Middle
Togo	1,506	6,145,004	50	0.9	0	0	1	0	Low
Trinidad and Tobago	14,603	1,305,236	40	76.9	0	0	0	0	Upper Middle
Tunisia	8,371	10,021,900	41	7.7	0	0	0	0	Lower Middle
Turkey	8,407	72,636,000	44	11.1	1	0	0	4	Upper Middle
Turkmenistan	8,848	4,833,266	41	29.7	0	1	0	0	Lower Middle
Uganda	1,454	28,816,228	43	0.2	0	0	1	0	Low
Ukraine	6,848	47,110,920	28	35.4	1	1	0	0	Lower Middle
United Arab Emirates	25,514	4,533,145	45	89.9	0	0	0	0	High
United Kingdom	33,238	60,202,604	36	40.9	1	0	0	1	High
United States	41,890	296,496,640	46.9	81.1	1	0	0	0	High
Uruguay	9,962	3,463,197	45	6.4	0	0	0	0	Upper Middle
Uzbekistan	2,063	26,593,124	27	18.9	0	1	0	0	Low
Venezuela, RB	6,632	26,577,000	44	22.3	0	0	0	0	Upper Middle
Vietnam	3,071	82,966,000	38	2.3	0	0	0	0	Low
Yemen, Rep.	930	20,974,656	33	2.5	0	0	1	0	Low
Zambia	1,023	11,668,457	42	0.8	0	0	1	0	Low
Zimbabwe	2,038	13,009,534	50	4.9	0	0	0	0	Low

7.2 Appendix B: GDRs calculations

7.2.1 Overview of GDRs calculations architecture

The heart of the GDRs analysis is the estimation of the capacity and responsibility of each country, and thus the Responsibility/Capacity Indicator (RCI), as per the definitions in the main text. This calculation requires four data elements for each country (population, per capita income, per capita cumulative emissions, and Gini coefficient). The definitions and sources we use for these data elements are given in Appendix A.

In addition to data for each country, the RCI calculation depends on the specification of a development threshold, above which a person's income contributes to the calculation of capacity, and which is also used to calculate the portion of a person's emissions that contributes to the calculation of responsibility. The development threshold used was $9000, PPP adjusted; the justification for this figure is given in Section 3 of the main text. This calculation also requires an assumption about distribution of income and emissions within a country, for which we describe our approximation below.

The GDRs database is maintained in Excel, while the calculation of the RCI is done by a script written in the Tcl/Tk language using a data file created from the Excel database. Output from the script was imported back into Excel to produce the various tables and graphs. Additional calculations of emissions, population and income projections (used in Section 5) are done in a model built in the Stella modeling language. The software and data are available at http://gdrs.sourceforge.net.

7.2.2 Calculation formulas

Conceptually, the calculation of responsibility and capacity is based on the assumption that the distribution of income across individuals in a country can be approximated by a log-normal income distribution. We also assume that within a given country, the distribution of emissions is proportional to consumption, which is in turn proportional to income. With these two assumptions, it is possible to use relatively simple analytical formulas and functions to calculate the RCI for each country by aggregating RCI across individuals by means of a simple integration across the full income range (done numerically in Tcl/Tk programming language).

The log-normal model of income distribution

The calculations used in this paper are based on the approximation that income distribution can be modeled reasonably well as a continuous log-normal distribution, which requires the specification of only two parameters: the country's per capita income, and its Gini coefficient, a well-known measure of inequality.

A graph of the log-normal distribution is shown in Figure A1 below, for two hypothetical countries with the same per capita income ($15,000 per capita) and Gini coefficients of 0.3

(dotted line) and 0.5 (solid line). The measure on the y-axis is a metric called the 'probability density,' which shows the relative number of people at each income level.

The log-normal distribution is defined as a distribution that is normal (the classic, symmetrical bell-curve shape) in the natural logarithm[‡] of the variable of interest. There are, in this case, two important features of the log-normal distribution: first, none of it is below zero (essential for a measure of income distribution); and second, it has a very long 'tail' on the right. As a model of income distribution, this means that most of the population will have incomes near the modal (most common) value (the peak), which is slightly lower than the mean (average) per capita income, but that a significant fraction will have higher incomes, and a small fraction will have incomes many times the mean per capita income.

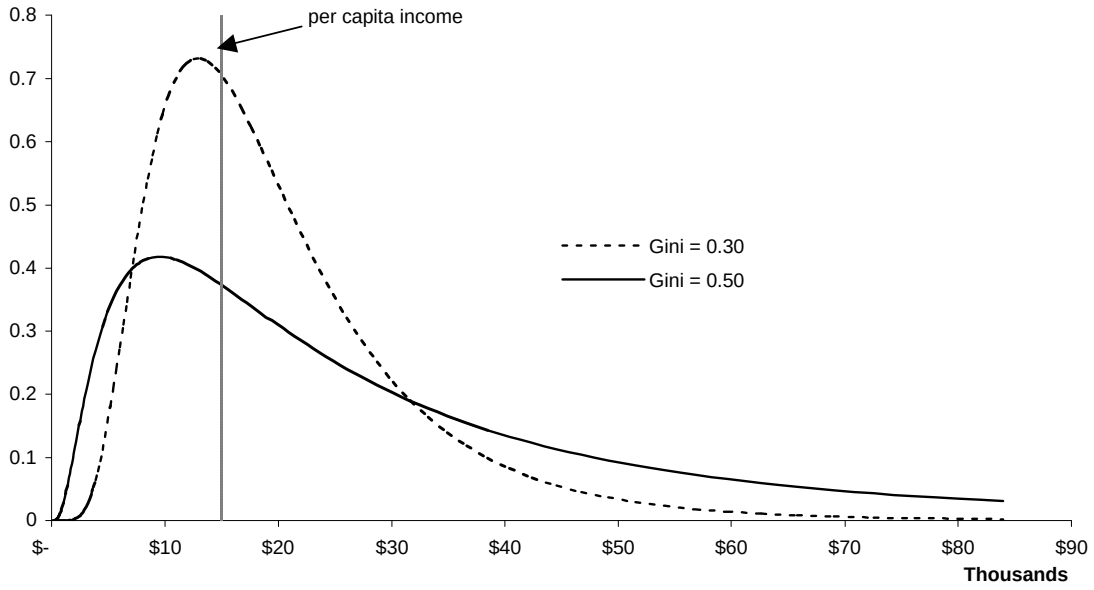

Figure A1. The log-normal distribution as a model of income distribution for two hypothetical countries with per capita income of $15,000, with Gini coefficients of 0.30 and 0.50 respectively.

The log-normal distribution has been proposed as an adequate model of income distribution since at least the work of Cowell (1995). A detailed discussion of the justification and some alternatives is available in Kemp-Benedict (2001). A more recent defense, based on a new statistical analysis, was offered by Humberto Lopez and Servén (2006) of the World Bank.

Using the log-normal distribution to calculate the RCI

[‡] You do not need to understand logarithms to follow the calculations. However, if you're not familiar with logarithms and want to learn more about them, there are several web-based tutorials available, such as "What on Earth is a Logarithm," by Peter Alfeld of the University of Utah (www.math.utah.edu/~pa/math/log.html).

As noted above, the RCI is calculated using scripts written in the Tcl/Tk language. The scripts and a Windows executable 'RCI calculator' based on them are available from http://gdrs.sourceforge.net/. Because of the assumption that both income distribution and the distribution of emissions can be modeled by the log-normal distribution, analytical solutions exist for the calculations of R, C, and the RCI, that are at the core of calculation. These are presented immediately below. Those not interested in the derivation of these integral solutions might choose to skip this section, going instead to the following section, which presents a more graphically intuitive explanation of the calculations.

Integral solutions for R, C, and RCI

For national capacity, we have by definition

$$C = P \int_{y_{DT}}^{\infty} dy \ \ (y - y_{DT})\, f(y, \bar{y}, G) \tag{1}$$

where, P is the population, y_{DT} is the development threshold, $\bar{y}$ is the per capita income, G is the Gini coefficient, and the lognormal income distribution $f(y, \bar{y}, G)$ is given by

$$f\ (y, \bar{y}, G) = \frac{1}{\sqrt{2\pi\sigma^2(G)}} \exp\left[-\frac{1}{2\sigma^2(G)} \left(\ln\frac{y}{\bar{y}} + \frac{\sigma^2(G)}{2} \right)^2 \right] \tag{2a}$$

where the dependence on the Gini coefficient is fully contained in the variance

$$\sigma^2(G) = 2\left[N^{-1}\left(\frac{1+G}{2} \right) \right]^2 \tag{2b}$$

and N^{1} is the inverse of the cumulative normal distribution.

For national responsibility, we have

$$R = P \int_{y_{DT}}^{\infty} dy \left(e(y) - e_{DT} \right) f(y, \bar{y}, G)\,, \tag{3a}$$

where e is emissions at a given level of income, and e_{DT} is equal to the emissions of a person whose income is precisely equal to the development threshold. The quantity e_{DT} behaves analogously to the development threshold, as the "emission threshold," such that only emissions above this threshold contribute to R. The assumption that emissions are proportional to income allows us to reexpress equation (3a) using the proportionality constant $\left(E / \bar{y} \right)$, where E is the average per capita historical emissions. Expressing e_{DT} as $\left(E/\bar{y} \right) \cdot y_{DT}$, we have

$$R = P \int_{y_{DT}}^{\infty} dy \, \frac{E}{\bar{y}} (y - y_{DT})\, f(y, \bar{y}, G)\,. \tag{3b}$$

Since $f(y, \bar{y}, G)$ is the lognormal distribution, both R and C can now be calculated (making use of the known expression for the first moment of the cumulative lognormal distribution) as

$$C = P \times \left\{ \bar{y} \left\{ 1 - N\left[\frac{1}{\sigma(G)} \left(\ln \frac{y_{DT}}{\bar{y}} - \frac{\sigma^2(G)}{2} \right) \right] \right\} - y_{DT} \left\{ 1 - N\left[\frac{1}{\sigma(G)} \left(\ln \frac{y_{DT}}{\bar{y}} + \frac{\sigma^2(G)}{2} \right) \right] \right\} \right\}$$

(4a)

and

$$R = P \frac{E}{\bar{y}} \times \left\{ \bar{y} \left\{ 1 - N\left[\frac{1}{\sigma(G)} \left(\ln \frac{y_{DT}}{\bar{y}} - \frac{\sigma^2(G)}{2} \right) \right] \right\} - y_{DT} \left\{ 1 - N\left[\frac{1}{\sigma(G)} \left(\ln \frac{y_{DT}}{\bar{y}} + \frac{\sigma^2(G)}{2} \right) \right] \right\} \right\}$$

(4b)

To calculate national RCI, we start with the definition, RCI = $R^a C^b$ for each individual and we integrate over the entire income distribution

$$\text{RCI} = \int_{y_{DT}}^{\infty} dy \; R(y)^a \; C(y)^b \; f(y, \bar{y}, G) \tag{5a}$$

and, thus

$$\text{RCI} = \int_{y_{DT}}^{\infty} dy \; (y - y_{DT})^a \left[\frac{E}{\bar{y}} (y - y_{DT}) \right]^b f(y, \bar{y}, G) \, . \tag{5b}$$

This can be rearranged to give

$$\text{RCI} = \left(\frac{E}{\bar{y}} \right)^b \int_{y_{DT}}^{\infty} dy \; (y - y_{DT})^{a+b} f(y, \bar{y}, G) \, . \tag{5c}$$

Since a and b are weightings, they satisfy $a+b = 1$ by definition. This ensures that the definition RCI = $R^a C^b$ adheres to the intuitive property that a 1% increase in R will raise RCI by a %, a 1% increase in R will raise RCI by b %, and a 1% increase in both R and C will raise RCI by 1%. Equation (5c) thus becomes

$$\text{RCI} = \left(\frac{E}{\bar{y}} \right)^b \int_{y_{DT}}^{\infty} dy \; (y - y_{DT}) f(y, \bar{y}, G) \, . \tag{5d}$$

Again because $a + b = 1$, this can be written

$$\mathrm{RCI} = \left[\int_{y_{DT}}^{\infty} dy\,(y - y_{DT}) f(y, \bar{y}, G) \right]^{a} \left[\left(\frac{E}{\bar{y}} \right) \int_{y_{DT}}^{\infty} dy\,(y - y_{DT}) f(y, \bar{y}, G) \right]^{b}. \tag{5d}$$

The two integrals in square brackets are precisely the definitions of the national capacity, *C*, and national responsibility, *R*, so we have

$$\mathrm{RCI} = C^{a}\ R^{b} \tag{5e}$$

at the national level as well as the individual level, allowing us to calculate the national RCI from the national R and C calculated as per equations (4a) and (4b).

Graphical explanations for R, C, and RCI

The same calculation can be described in more graphical terms, referring to Figure A1. (Keep in mind that the shape of the curve will be different for countries with different per capita incomes and different Gini coefficients.)

The x-axis, which measures income, can be divided into arbitrarily small sections – call them 'bins' – for example, exactly one dollar wide. For a country with a given population, there will be a specific number of people in each bin, proportional to the height of the income distribution curve on the y-axis at the particular income value on the x-axis.

Given our assumption that emissions in a given country are distributed proportionally to income, we can also calculate the emissions associated with the people in each bin. Straightforwardly, since a person with the average (per capita) income also has the average (per capita) emissions, the emissions for a person at any other income value is simply equal to the average per capita emissions times the ratio of that person's income to the average per capita income, which is expressed above as $\left(E / \bar{y}\right)$. The assumption that emissions are proportional to income implies that the Gini coefficient affects the distribution of emissions in precisely the same manner as income.

To calculate the RCI, given the values for income and emissions in each bin, we need first to calculate the portion of each exceeding the development threshold and the associated 'emissions threshold.' That is, capacity *C* of a person in this bin is given by $C = y\text{-}y_{DT}$, where as before *y* is income and y_{DT} is the development threshold, and so, for persons with income of \$15,000 and our development threshold of \$9,000, then *C* = \$6,000. Similarly, $R = e - e_{DT}$, where *e* equals emissions, and e_{DT} serves as an emissions threshold (as above), given by the emissions of someone whose income is precisely equal to the development threshold; say, hypothetically, 9 tC cumulatively between 1990 and 2005. Then for a person with an income of \$15,000, their responsibility *R* would be (15,000/9,000) × 9 – 9 = 6. Then using the definition of the RCI, which is $C^{a} R^{b}$, with $a = 0.4$ and $b = 0.6$, we get for this typical individual in the bin $\mathrm{RCI}=6{,}000^{0.6} \times 6^{0.4} = 379$. By comparison, for a person with an income of \$20,000, their contribution to their country's RCI would be $(20{,}0000 - 9{,}000)^{0.6}$ $((20{,}000/6{,}000) * 9 - 9)^{0.4} = 694$. The resulting

number is measured in units of dollars^{a} ·tonnes^{b}, and can be compared across countries. Note, relative RCI (e.g. national RCI as a fraction of global RCI) can be compared for different values of the weightings *a* and *b*, but absolute values cannot since they are measured in different units.

Finally, to calculate the national RCI, multiply the RCI for a typical person in each bin by the number of people in that bin, then sum the values for each bin, up to an income level sufficiently high to capture the entire population. Thus, given specific choice of development threshold and the weighting exponents, every person, and thus every country, has a well defined RCI, and their share of the global total can be calculated.

7.2.3 Output table for all countries

The central calculation made for each country is a single responsibility/capacity indicator (we call it an indicator rather than an index because it measures a 'quantity,' rather than being a comparison of one country to another). In principle the RCI for two hypothetical individuals in different countries who have the same income and historical emissions contribute the same amount to their country's (and thus the world's) RCI; thus countries with the same per capita income, cumulative per capita emissions and Gini coefficient but with different populations would have different national RCIs, exactly proportional to their populations, but identical per capita RCIs and thus identical per capita obligations. (Note that in the context of a cap-and-allocate model (per chapter 5), countries could have different allocations if they had different no-regrets baselines.)

Table A2 below shows the RCI calculations for the 158 countries in our primary database and 11 aggregated regions, using our default assumptions [i.e., a development threshold of $9000 PPP adjusted, cumulative per capita CO_2 emissions from fossil fuel consumption 1990-2005, per capita income in 2005 (PPP adjusted) and capacity weighted slightly more than responsibility (see above)]. The table shows for each country its share of global population, its calculated capacity as a percentage of GDP, its national share of the total global RCI, the fraction of the population above the development threshold, the RCI per capita for the fraction of the population above the development threshold, and its rank in order of average individual RCI. (See the discussion in the main text regarding the average individual RCI).

Table A2. RCI calculations for all countries and country groups.

Country or region	Share of global population (%)	Percentage of population above the cutoff	Capacity (% of GDP)	Share of global RCI (%)	Average individual RCI	Rank by average individual RCI
Afghanistan	0.48	0.1	0.5	0	0.15	146
Albania	0.05	9.9	5.1	0	15.67	101
Algeria	0.51	24.3	17.2	0.14	97.55	78
Angola	0.25	2.9	6.1	0.01	9.01	106
Argentina	0.6	50.3	51.5	0.78	461.54	45
Armenia	0.05	13.2	17.3	0.01	63.76	84

Country or region	Share of global population (%)	Percentage of population above the cutoff	Capacity (% of GDP)	Share of global RCI (%)	Average individual RCI	Rank by average individual RCI
Australia	0.32	98.3	71.8	1.73	1958.85	5
Austria	0.13	99.5	73.3	0.56	1572.53	18
Azerbaijan	0.13	11.6	9.8	0.02	52.43	87
Bahrain	0.01	66.8	63.8	0.05	1580.26	17
Bangladesh	2.21	0.2	0.2	0	0.17	144
Belarus	0.15	30.4	12.1	0.04	101.53	76
Belgium	0.16	99.3	72.0	0.79	1744.07	13
Benin	0.13	0.0	0.0	0	0.03	153
Bolivia	0.14	5.8	16.7	0.01	34.78	94
Bosnia and Herzegovina	0.06	28.0	12.5	0.01	75.66	82
Botswana	0.03	41.6	49.3	0.03	334.95	52
Brazil	2.9	26.9	40.0	1.57	194.51	60
Bulgaria	0.12	38.7	23.3	0.07	213.58	56
Burkina Faso	0.21	1.3	6.9	0	3.1	120
Burundi	0.12	0.0	0.0	0	0.01	154
Cambodia	0.22	3.2	4.9	0	2.73	122
Cameroon	0.25	1.9	3.1	0	3.66	116
Canada	0.5	98.3	73.1	2.86	2041.66	4
Central African Republic	0.06	1.5	8.7	0	3.77	115
Chad	0.15	1.1	2.9	0	0.99	132
Chile	0.25	39.9	49.0	0.27	385.87	48
China	20.44	22.3	23.5	6.89	121.02	73
Colombia	0.71	23.0	35.7	0.29	148.65	70
Congo, Dem. Rep.	0.9	0.1	0.4	0	0.1	147
Congo, Rep.	0.06	0.6	1.7	0	1.76	129
Costa Rica	0.07	37.5	39.1	0.04	187.4	64
Cote d Ivoire	0.28	0.7	1.4	0	1.36	130
Croatia	0.07	67.1	37.1	0.07	355.37	51
Cuba	0.18	1.9	0.9	0	3.18	118
Cyprus	0.01	94.8	60.2	0.04	1040.83	30
Czech Republic	0.16	96.5	56.4	0.47	1057.39	29
Denmark	0.08	99.8	73.5	0.42	1793.44	10
Dominican Republic	0.14	28.2	34.3	0.07	174.4	67
Ecuador	0.21	11.3	24.6	0.05	80.57	81
Egypt, Arab Rep.	1.15	8.1	7.4	0.08	23.9	98
El Salvador	0.11	14.8	19.6	0.02	53.91	85
Eritrea	0.07	0.4	1.2	0	0.68	135

Country or region	Share of global population (%)	Percentage of population above the cutoff	Capacity (% of GDP)	Share of global RCI (%)	Average individual RCI	Rank by average individual RCI
Estonia	0.02	69.4	47.3	0.05	789.97	35
Ethiopia	1.11	0.0	0.0	0	0	156
Finland	0.08	99.5	72.0	0.39	1725.28	14
France	0.95	98.4	70.5	3.41	1292.63	24
Gabon	0.02	22.7	28.8	0.01	163.77	68
Gambia, The	0.02	1.5	3.0	0	2.45	126
Georgia	0.07	3.7	3.4	0	9.32	105
Germany	1.29	96.5	69.7	5.49	1533.59	20
Ghana	0.34	1.9	2.5	0	2.74	121
Greece	0.17	90.0	62.4	0.52	1075.92	28
Guatemala	0.2	11.7	17.1	0.02	40.16	92
Guinea	0.15	3.6	9.3	0	7.91	107
Guinea-Bissau	0.02	0.1	0.2	0	0.08	148
Guyana	0.01	10.6	12.6	0	45.42	91
Haiti	0.13	1.3	3.5	0	2.5	123
Honduras	0.11	7.5	15.4	0.01	30.39	96
Hungary	0.16	90.0	50.6	0.29	659.07	38
Iceland	0	98.9	75.4	0.02	1679.67	15
India	17.05	3.8	3.4	0.36	7.63	108
Indonesia	3.44	4.6	3.6	0.09	9.58	104
Iran, Islamic Rep.	1.05	28.8	27.9	0.58	198.83	59
Iraq	0.42	1.0	1.5	0	3.99	114
Ireland	0.06	98.6	76.7	0.34	1867.29	7
Israel	0.11	88.5	66.2	0.36	1214.81	25
Italy	0.9	94.7	68.8	3.23	1296.04	23
Jamaica	0.04	11.2	25.3	0.01	116.07	75
Japan	1.99	96.8	71.4	8.62	1552.2	19
Jordan	0.08	14.4	11.3	0.01	52.57	86
Kazakhstan	0.24	29.6	21.0	0.14	211.67	57
Kenya	0.53	0.9	3.5	0	2.5	124
Korea, Dem. Rep.	0.35	0.7	1.0	0	3.16	119
Korea, Rep.	0.75	83.6	61.0	2.14	1021.02	31
Kuwait	0.04	80.1	68.1	0.2	1822.8	9
Kyrgyz Republic	0.08	0.3	0.4	0	0.7	134
Lao PDR	0.09	0.5	0.6	0	0.48	139
Latvia	0.04	61.9	42.4	0.04	393.49	47
Lebanon	0.06	16.2	18.3	0.02	101.36	77

Country or region	Share of global population (%)	Percentage of population above the cutoff	Capacity (% of GDP)	Share of global RCI (%)	Average individual RCI	Rank by average individual RCI
Lesotho	0.03	7.7	19.9	0	16.48	100
Liberia	0.05	0.3	1.0	0	0.48	140
Libya	0.09	51.3	46.1	0.14	555.59	42
Lithuania	0.05	69.5	43.3	0.07	442.92	46
Luxembourg	0.01	100.0	85.1	0.08	3845.4	1
Macedonia, FYR	0.03	25.2	17.6	0.01	122.01	72
Madagascar	0.29	0.1	0.5	0	0.19	143
Malawi	0.2	0.1	0.3	0	0.08	149
Malaysia	0.39	39.1	42.7	0.4	367.02	50
Mali	0.21	0.5	1.9	0	0.61	136
Malta	0.01	82.8	50.6	0.01	613.69	39
Mauritania	0.05	1.1	1.4	0	2.49	125
Mauritius	0.02	56.5	40.2	0.02	280.28	54
Mexico	1.61	38.6	42.3	1.5	334.37	53
Moldova	0.07	1.4	2.4	0	5.89	110
Mongolia	0.04	1.5	2.5	0	7.25	109
Morocco	0.47	9.6	9.0	0.03	25.68	97
Mozambique	0.31	0.1	0.2	0	0.08	150
Myanmar	0.79	1.8	4.1	0.01	3.24	117
Namibia	0.03	18.3	53.6	0.02	190.16	63
Nepal	0.42	0.7	1.7	0	0.93	133
Netherlands	0.25	99.2	72.5	1.25	1766.23	12
New Zealand	0.06	90.7	64.8	0.2	1145.52	27
Nicaragua	0.09	8.4	16.7	0.01	34.37	95
Niger	0.22	0.1	0.6	0	0.2	142
Nigeria	2.05	0.4	1.3	0.01	1.3	131
Norway	0.07	99.9	78.3	0.38	1907.46	6
Oman	0.04	57.6	50.7	0.08	681.07	37
Pakistan	2.43	0.4	0.3	0	0.5	138
Panama	0.05	24.5	35.6	0.03	193.02	61
Papua New Guinea	0.09	3.7	7.5	0	10.88	103
Paraguay	0.1	12.4	22.7	0.01	52.04	88
Peru	0.44	18.4	26.5	0.1	84.42	80
Philippines	1.29	14.2	18.6	0.18	50.91	89
Poland	0.59	63.5	42.6	0.91	552.42	43
Portugal	0.16	79.3	58.6	0.36	787.07	36
Qatar	0.01	80.0	73.7	0.1	2808.53	2

Country or region	Share of global population (%)	Percentage of population above the cutoff	Capacity (% of GDP)	Share of global RCI (%)	Average individual RCI	Rank by average individual RCI
Romania	0.34	37.7	25.6	0.2	211.27	58
Russian Federation	2.23	51.9	29.9	2.31	371.17	49
Rwanda	0.14	0.3	0.7	0	0.3	141
Saudi Arabia	0.38	59.3	52.0	0.88	828.21	34
Senegal	0.18	0.1	0.0	0	0.04	151
Serbia and Montenegro	0.13	7.5	3.9	0.01	23.51	99
Sierra Leone	0.09	0.0	0.0	0	0.01	155
Singapore	0.07	80.3	71.8	0.35	1847.28	8
Slovak Republic	0.08	84.2	45.1	0.14	602.19	40
Slovenia	0.03	98.2	59.7	0.08	972.67	32
Somalia	0.13	0.0	0.2	0	0.04	152
South Africa	0.7	35.9	48.1	1.01	512.7	44
Spain	0.68	95.3	67.2	2.21	1172.38	26
Sri Lanka	0.31	5.5	2.8	0	5.69	111
St. Lucia	0	20.4	20.3	0	85.29	79
Sudan	0.56	2.2	5.0	0.01	4.27	113
Swaziland	0.02	13.2	27.5	0	68.55	83
Sweden	0.14	99.8	72.3	0.53	1362.88	22
Switzerland	0.12	98.4	74.8	0.48	1472.47	21
Syrian Arab Republic	0.3	7.5	9.9	0.03	35.59	93
Tajikistan	0.1	0.0	0.1	0	0.16	145
Taiwan	0.36	94.5	67.8	0.59	592.42	41
Tanzania	0.6	0.0	0.0	0	0	157
Thailand	1	32.8	29.7	0.51	181.31	65
Togo	0.1	0.9	2.5	0	1.92	127
Trinidad and Tobago	0.02	51.9	51.8	0.05	927.84	33
Tunisia	0.16	31.8	26.9	0.06	137.41	71
Turkey	1.13	30.7	30.5	0.57	180.39	66
Turkmenistan	0.08	33.9	29.9	0.06	271.15	55
Uganda	0.45	0.6	1.5	0	0.61	137
Ukraine	0.73	22.5	14.1	0.24	117.77	74
United Arab Emirates	0.07	79.1	67.2	0.35	1790.17	11
United Kingdom	0.94	95.7	73.2	4.36	1667.61	16
United States	4.62	90.6	79.1	35.04	2723.45	3
Uruguay	0.05	38.1	36.2	0.03	190.41	62
Uzbekistan	0.41	1.9	4.0	0.01	12.49	102
Venezuela, RB	0.41	21.6	23.4	0.18	159.13	69

Country or region	Share of global population (%)	Percentage of population above the cutoff	Capacity (% of GDP)	Share of global RCI (%)	Average individual RCI	Rank by average individual RCI
Vietnam	1.29	2.7	2.7	0.02	4.59	112
Yemen, Rep.	0.33	0.0	0.0	0	0	158
Zambia	0.18	0.6	3.0	0	1.8	128
Zimbabwe	0.2	4.2	25.2	0.03	46.14	90
High Income	15.54	92.9	73.3	78.42	1811.55	
Upper Middle Income	9.3	45.1	39.4	9.67	373.29	
Lower Middle Income	38.53	19.5	23.2	11.44	106.66	
Low Income	36.63	2.2	2.9	0.47	4.64	
Annex I	19.6	80.2	69.4	78.8	1443.5	
EITs	6.27	41.6	31.4	5.25	300.75	
LDCs	8.37	0.7	2.0	0.03	1.28	
EU 15	6.07	96.1	70.3	24.24	1434.61	
EU +12	2.81	50.9	39.5	3	383.22	
EU 27	8.88	81.8	65.6	27.24	1101.5	
World	100	26.9	50.0	100	359.08	

7.3 Appendix C: Sensitivity analysis

As we emphasized in the text, any effort to quantify ethical concepts like capacity and responsibility is necessarily subjective, and there can be no 'correct' definitions, only more or less reasonable ones. We have attempted to justify our choices, but discussion about alternatives to these parameters is welcome and important. Accordingly, we show in what follows a sensitivity analysis that repeats key output tables with slightly higher or lower values of the key parameters, in particular the development threshold, and the exponents which assign relative weights to responsibility and capacity in the calculation of the RCI.

In Table A3, which is modified from Table 3, we recalculate capacity using a development threshold that is 33 percent lower ($6000) and 33 percent higher ($12,000) than our reference value of $9000. Lowering the development threshold excludes fewer people and less income, and thus increases the calculated capacity of low and middle income countries relative to high income countries, while raising the development threshold does the opposite. Even with the lower development threshold, however, the low income countries, which have 37 percent of global population, still have only 1.3 percent of global capacity; the share of the middle income countries (48 percent of global population) increases from 20 percent to 25 percent, and the share of the high-income countries decreases from 79 to 74 percent. For an increase in the development threshold, the changes are roughly the same magnitude in the opposite direction.

	Low income			Middle income			High income			World		
Global income 2005 ($trillion PPP)	6			22			33			61		
Share of global income (percent)	10			36			54			100		
Share of population 2005 (percent)	37			48			16			100		
Per capita income 2005 ($ thousands PPP)	2.5			7.3			33.0			9.5		
CAPACITY THRESHOLD	6000	9000	12000	6000	9000	12000	6000	9000	12000	6000	9000	12000
Capacity ($ billion PPP)	0.5	0.2	0.1	9	6	4	27	24	21	37	31	26
Share of global capacity(percent)	1.3	0.6	0.3	25	20	17	74	79	83	100	100	100
Percentage of population over capacity threshold	7.1	2.2	0.8	41	24	16	97	93	86	37	27	21

Table A3. Comparison of capacity, share of global capacity and percentage of population over development threshold for development threshold of $6000, $9000 (reference case), and $12000.

In Table A4, we show for the same alternative values of the development threshold the share of global RCI, the national bill based on a total mitigation and adaptation expense of one percent of GWP, and the average individual bill (based on the share of the population over the development threshold). The countries and country groups shown are the same as in Table 3. The changes have a larger impact in percentage terms on low income countries, but a larger impact in absolute terms on high income countries. For instance, changing the development threshold from $9000 to $6000 increases the bill to India by roughly 150 percent, though the increase is only $3 billion

annually, while it decreases the bill to the US by only ten percent, which is about $20 billion annually. The average individual bills vary by a smaller amount in percentage terms, since changing the development threshold changes the number of people over the threshold who are presumed to share the bill. (Recall of course that, while obligations are calculated on a national basis, the average individual bill calculation is presented as well as it reflects the notion that costs should be allocated only among those above the development threshold..)

	Percent of global RCI			Bill at 1% of GWP ($ billion PPP adjusted)			Average individual bill at 1% of GWP ($)		
Capacity threshold	**6000**	**9000**	**12000**	**6000**	**9000**	**12000**	**6000**	**9000**	**12000**
United States	31.7	35.0	38.0	193	214	232	678	796	933
EU (27)	26.5	27.2	27.3	162	166	167	317	357	399
United Kingdom	4.1	4.4	4.5	25	27	28	416	461	512
Germany	5.2	5.5	5.6	32	34	34	388	420	456
Russia	3.1	2.3	1.7	19	14	10	168	190	221
Brazil	1.7	1.6	1.5	10	10	9	139	191	255
China	9.0	6.9	5.4	55	42	33	107	144	188
India	0.9	0.4	0.2	5	2	1	39	53	71
South Africa	1.0	1.0	1.0	6	6	6	282	383	499
LDCs	0.1	0.0	0.0	0	0	0	19	34	65
All high income	73	78	82	446	479	503	459	517	584
All middle income	26	21	18	159	129	107	128	172	224
All low income	1.1	0.5	0.2	6	2.9	1	39	56	79
World	100.0	100.0	100.0	611	611	611	257	353	450

Table A4. Comparison of share of global RCI, national bill at 1% of GWP, and per capita bill at 1% of GWP (based on fraction of population over development threshold) for development threshold of $6000, $9000 (reference case), and $12000.

We have chosen an intuitively reasonable expression, $R^a C^b$, for combining *R* and *C* into an RCI. It allows for choosing different weighting of R and C. It is familiar to economists (where it is known as Cobb-Douglas production function). It satisfies the critical condition that RCIs are consistent defined whether you're looking at countries, fractions of countries, or individuals, since the sum of the RCIs calculated for parts (say nations within a region) is equal to the RCI of the whole. And, it is a simple and analytically straightforward form. Still, there are other formulas that could conceivably be used to combine *R* and *C* into an RCI. However, we suspect that ultimately the choice of weightings for responsibility and capacity captures most of the meaningful variation in possible function forms. So, in the final table (Table A5), we explore alternative values for the weightings. We show the same output as in Table A4 (share of global RCI, national and per capita bills), but this time with three possible weightings *a* and *b*.

In our reference case, capacity was weighted higher than responsibility, with exponents of 0.6 and 0.4 respectively; in the sensitivity analysis we show a case with greater weighting of capacity (0.8, vs. 0.2 for responsibility), and a case with a greater weighting on responsibility (0.4 for capacity vs. 0.6 for responsibility).

	Percent of Global RCI			Bill at 1% of GWP ($ Billion PPP adjusted)			Average Individual bill at 1% of GWP ($)		
Capacity weighting	**0.8**	**0.6**	**0.4**	**0.8**	**0.6**	**0.4**	**0.8**	**0.6**	**0.4**
Responsibility weighting	**0.2**	**0.4**	**0.6**	**0.2**	**0.4**	**0.6**	**0.2**	**0.4**	**0.6**
United States	33.7	35.0	36.2	206	214	221	765	796	824
EU (27)	28.5	27.2	26.0	174	166	159	373	357	340
United Kingdom	4.6	4.4	4.1	28	27	25	485	461	436
Germany	5.5	5.5	5.4	34	34	33	423	420	414
Russia	1.9	2.3	2.8	11	14	17	154	190	231
Brazil	1.8	1.6	1.4	11	10	8	220	191	166
China	6.9	6.9	6.9	42	42	42	144	144	143
India	0.39	0.36	0.33	2.4	2.2	2.0	58	53	49
South Africa	0.89	1.01	1.12	5.4	6.2	6.8	337	383	424
LDCs	0.04	0.03	0.02	0.2	0.2	0.1	45	34	23
All high income	78.8	78.4	78.0	481	479	476	519	517	514
All middle income	20.7	21.1	21.6	127	129	132	169	172	175
All low income	0.5	0.5	0.4	3.1	2.9	2.7	61	56	53
World	100.0	100.0	100.0	611	611	611	353	353	353

Table A5. Comparison of share of global RCI, national bill at 1% of GWP, and average individual bill at 1% of GWP (based on fraction of population over development threshold) for capacity/responsibility weighting of 0.8/0.2, 0.6/0.4 (reference case), and 0.4/0.6.

The results show that in general, these changes in the weighting of responsibility and capacity make substantially less difference than the changes in the development threshold. The notable exception is Russia, which, because it has very low capacity relative to its responsibility, is relatively sensitive to the parameter choice. This is an important example of the general case, which is that the weighting of responsibility vs. capacity matters only to countries that are much higher on one than the other.

7.4 Appendix D: Emissions trajectories and risk analysis

The risk calculations shown in Section 2 are based on the Monte Carlo Climate Model (MC^2) built by Paul Baer and Michael Mastrandrea, and used in the 2006 report 'High Stakes: Designing Emissions Trajectories to Reduce the Risk of Dangerous Climate Change' published by the Institute for Public Policy Research in the UK. It contains a far more detailed discussion of both the model and the results than this appendix.

7.4.1 About Monte Carlo models

Monte Carlo models are so-called because their results, rather than being a single number, are reported as a probability distribution - like the expected results of a game of, say, roulette. Briefly, each uncertain variable in the model is input as a probability distribution, and a computer's random-number generator is used to select a value from that distribution each time the model is run. When the model is run repeatedly (typically hundreds or thousands of times), the output value or values will sometimes be higher than the mean result and sometimes lower, depending on which input values were selected on each run by the random number generator. The full set of output values form a probability distribution, which can be interpreted as representing the likelihood that the 'real world' outcome will actually be a particular value. Thus we can say, for a hypothetical emissions scenario, that if 50 percent of the model runs resulted in a temperature increase over 2ºC, then the 'risk' of exceeding 2ºC that is associated with that scenario is 50 percent.

Such results need to be interpreted with great caution. Crucially, the uncertainty in the input variables in a model like the simple climate model do not reflect only the stochastic (random) processes in the climate system, but also (and in fact primarily) ignorance about the climate system. The uncertainty in, say, the climate sensitivity (the equilibrium warming expected in response to a doubling of CO_2 concentration), is not like the uncertainty of a gambling result. When we say that there is (for example) a 10 percent likelihood that the climate sensitivity is more than 4.5ºC, we do not mean that, if we doubled the CO_2 concentration 100 times, it would be over 4.5ºC ten of those times; or that if we doubled the CO_2 on 100 earthlike planets, it would be over 4.5ºC ten of those times. Rather, the estimate is a "subjective probability": an estimate, made by a human (or a group of humans) that, based on all the evidence, it is about as likely that the climate sensitivity is more than 4.5ºC that (for example) you would draw a black ball from an urn for which we have various forms of evidence suggesting it contains ten black and 90 white balls.

For properties of complex systems like the climate, the various forms of evidence about the climate sensitivity (or the response of the carbon cycle to warming, or the radiative forcing of aerosols) do not very strongly constrain the likely values. (To continue the ball-and-urn metaphor, some experts might interpret the evidence to say the urn has 10 black balls, but some conclude a few more, and some a few less). That is, different experts can quite reasonably hold different beliefs about the probability distributions of the critical variables. Thus there is not and cannot be a 'correct' probability distribution, since it is a measure of our remaining ignorance

about the climate system, rather than a well known property of the climate system itself. As a consequence, it is appropriate to report the output of probabilistic models such as MC^2 as a range that accounts for the spread in the interpretations of the evidence. For this reason, we report the 'likelihood of exceeding 2ºC' of our emissions pathways as a range (e.g., between 17 and 36 percent for our most stringent trajectory) that reasonably, if approximately, captures the range of reasonable scientific opinion.

A further discussion of the implications of this 'multi-dimensional uncertainty' is beyond our scope. The critical point is that, while different models using different assumptions will produce different likelihoods, there is a *reasonable* overlap, which gives guidance about broad risk estimates for exceeding 2ºC. Ultimately, decisions then need to be based on ethical judgments about risk aversion (including consideration of the distribution of risk), not on an appeal to science as such.

7.4.2 The structure of the MC2 model

MC^2 is a simple parameterized climate model which calculates the annual change in global mean temperature based on the difference between the current temperature and the 'implied equilibrium temperature' – that is, the temperature that would be reached at equilibrium if radiative forcing were held constant from that point out. Radiative forcing in turn is calculated as the sum of forcing from CO_2, the offsetting forcing from aerosols, and a single specified forcing from 'other non-CO_2 gases'. The emissions trajectory for CO_2 is specified by the user, and the change in CO_2 concentrations is determined by the difference between emissions and the uptake of carbon by the global carbon sink.

The behavior of the model is governed by five variables which are treated as uncertain, for which a different value is randomly drawn from a specified probability distribution in each run of the model. The five uncertain variables are the climate sensitivity, the effective thermal inertia of the ocean, the initial value of land use emissions (which also defines the initial carbon sink), the rate of change of the carbon sink, and the initial value of aerosol forcing. In the default configuration of the model, normal distributions are used for each of the uncertain variables except the climate sensitivity; the input probability for the climate sensitivity can be chosen from a set of six that have been published in the scientific literature. (There are other even more 'extreme' probability distributions published, but we believe these six span most of the range of the estimates that would be considered reasonable by experts.) And while the model is built from simple equations for temperature and the carbon cycle, it produces a reasonable reproduction of the range of results from the most complex coupled global general circulation models.

For a given configuration of input probability distributions, the model is then run several hundred times for the period from 2000 to 2100, generating a distribution of output results for the peak temperature over that time period. As noted above, if (say) 20 of 200 runs result in a peak temperature over 2ºC, we report that the specified scenario has a ten percent risk of exceeding the 2ºC threshold. The variation reported in our results – e.g., a 17 to 36 percent risk for the lowest emissions scenario – is based on a run where the probability distribution for the climate

sensitivity is fixed at either the most 'optimistic' of the six (the lognormal distribution of Wigley and Raper 2001) or the most 'pessimistic' (the distribution of Murphy et al. 2005, based on their own Monte Carlo analysis using the Hadley Centre's GCM).

For further information see Baer and Mastrandrea (2006), or contact Paul Baer (pbaer@ecoquity.org).

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[1] By 'aggressive realist scenarios' we mean for example the recommendations of the Scientific Expert Group (2007) or the Stern Review (2006), both of which put 450 ppm CO_2-equivalent as their lowest recommended stabilization target. Yet both acknowledge (following for example Meinshausen 2006) that 450 ppm CO_2-equivalent has at best even odds of keeping below 2ºC warming, and something like a 20% likelihood of exceeding 3ºC warming. And as James Hansen and colleagues (2006, 2007) among others have warned, the destabilization of the Greenland Ice Sheet is possible even before global mean warming reaches the 2ºC level, potentially causing up to seven meters of sea level rise, over centuries or, perhaps, much more quickly. Although there are many other potential impacts that would count as regionally or even globally catastrophic, the threat of destabilizing the ice sheets seems for obvious reasons to be a critical justification for urgent precaution.

[2] See Meinshausen 2006, or Baer and Mastrandrea 2006.

[3] As we discuss later, even if Annex 1 countries reached 80 percent below 1990 levels by 2050 through exclusively *domestic* reductions and, at the same time, non-Annex 1 emissions converged to equal them (in per capita terms), global emissions would still be inconsistent with a high likelihood of staying below 2ºC. Worse, in most 'realist' proposals, steep Annex 1 reductions are not assumed to be exclusively domestic, but rather to be met, in large part, with purchased offsets.

[4] This must be done, of course, even as the impacts of the now inevitable warming intensify the development burden and undercut efforts to alleviate poverty. The disproportionate impact of climate change on poor people and developing countries due to both specific climatic impacts and greater vulnerability is well documented in the report of Working Group II of the IPCC's Fourth Assessment Report. A more political view of the topic, and in particular its likely impacts on development progress and poverty alleviation, can be found in, for example, 'Up In Smoke' (Simms et al., 2004) from the New Economics Foundation (www.neweconomics.org).

[5] See for example, Barclay Capital's 'Equity Gilt Study 2007,' which argues for the optimistic case with these words: 'If ever the time were ripe for such an energy revolution, it is now. And like all historical adoptions of general purpose technologies, the process should prove immensely stimulative to economic growth. Oddly, the climate change policy debate is couched in terms of the cost to GDP growth. Even the proponents of policy shifts tend to assume a negative effect on growth. This stance is underselling the actual impact of an energy revolution. All of the historical changes in energy supply – from dung to wood to coal to oil – were stimulative for the economy concerned. Every major technological change was accompanied or followed by faster economic growth.' We accept this argument, but believe that it tells far less than the whole story.

[6] Per capita approaches are strongly identified with the 'Contraction and Convergence' approach. This is as it should be, for C&C was the first real 'equity reference framework,' and as such it has done a great deal to publicly establish the need for just global burden sharing as an essential aspect of an emergency climate stabilization program. It has acquired, and deserves, a great deal of respect and support. (We used to be C&C supporters ourselves). But the simplicity that is one of its great virtues is also one of its greatest weaknesses. More particularly, in its focus on equality of emissions rights, it loses sight of the *end* to which emissions rights can only be a *means* – sustainable human development for all, even in this a world that is profoundly not constrained by the prior overuse of the now-scarce atmospheric commons. Our analysis has convinced us that, under stringent mitigation targets, C&C cannot deliver this essential *developmental equity*, and it is to respond to this requirement that we have been elaborating the GDRs framework.

C&C fails to deliver developmental equity for two fundamental reasons. First, it fails to account for the historical advantage acquired by the developed countries, who had decades of unrestrained emissions. Second, it fails to account for the wide range of variation in national circumstances, particularly among

developing countries but also among high emitting 'industrialized' countries, many of which (like Russia) are now quite poor.

Supporters of C&C have variously argued that these drawbacks are sufficiently minor that they can be ignored, or that modifications can be made to C&C's basic allocation scheme to improve its 'performance' on these issues. We considered these arguments carefully and over a long period of time, and concluded that it would be far better to take the South at its word, and to begin the search for a viable global climate stabilization framework with 'the right to development' rather than the 'equal per capita emissions rights' that C&C (implicitly) posits as its proxy. Our argument, in a nutshell, is that this 'developmental equity,' and not instead of emissions equity, must be the organizing principle of a viable climate framework.

We have elaborated these criticisms in a framework comparison for the Heinrich Böll Foundation (Baer and Athanasiou 2007), and hope to eventually publish a more detailed analysis of C&C and per capita approaches more generally.

[7] The UNFCCC famously notes in its preamble that 'the global nature of climate change calls for the widest possible cooperation by all countries and their participation in an effective and appropriate international response, in accordance with their common but differentiated responsibilities and respective capabilities and their social and economic conditions.'

[8] The three scenarios are based on CO_2 emissions only, including both fossil fuel emissions and land use emissions. All three scenarios begin with historical fossil fuel emissions through 2005 and estimated land use emissions of 1.5 GtC/yr. Emissions after 2005 are projected to rise at 2.5 percent a year until 2010, 2009 and 2007 respectively, at which point the rate of increase starts to decline. All three trajectories peak in 2015, before declining by 2050 to 50, 65, and 80 percent below 1990 levels (estimated at 7.5 GtC including land use emissions). The annual rate of emissions reductions reach a peak rate of 3.4, 4.4, and 6.0 percent respectively. Non CO_2 emissions are assumed to fall such that the radiative forcing from non CO_2 GHGs declines by 50 percent between 2010 and 2050 (from 1 Wm^{-2} to 0.5 Wm^{-2}).

	Reductions start	Emissions peak	2050 CO_2 emissions relative to 1990	Maximum rate of reductions	Chance of exceeding 2ºC	Peak concentration ppm ($Co_2/CO_{2\text{-}eq}$)
Trajectory 1 (least stringent)	2010	2015	50% below	3.4%/yr	26-55%	445/500
Trajectory 2	2009	2015	65% below	4.4%/yr	21-46%	435/485
Trajectory 3 (most stringent)	2007	2015	80% below	6.0%/yr	17-36%	425/470

[9] These calculations are based on the model used in Baer and Mastrandrea 2006, cited in Note 2. Because the probability distributions for key parameters such as the climate sensitivity and the behavior of the carbon cycle are not well defined, the probabilistic methodology takes as an input subjective expert opinion about the uncertainty of various parameters. This method accounts for the fact that a range of reasonable assumptions can be made about key parameters by reporting the calculated risk as a range (in which the upper and lower bounds reflect the spread in the scientific opinion.) For a discussion of the issues and the model used in these calculations, see the appendix, or Baer and Mastrandrea (2006).

[10] There is no universal definition of 'CO_2-equivalent levels'. The Stern Review recently established the precedent of referring to the equivalent concentration levels of the Kyoto gases only, and the 470 ppm CO_2-equivalent figure given for this trajectory is calculated on this basis for the purpose of comparison. However, more precisely CO_2-equivalent levels should include all radiative forcings, positive and negative, as that is what produces the overall impact on the climate system. The largest additional forcing is the

negative forcing from aerosols. In our model, aerosol forcings reduce the net radiative forcing to about 435 ppm CO_2-e at the peak.

[11] Perhaps there are even more radical trajectories, in which global emissions actually go negative. These might be possible with "negative emission" mitigation options, such as biomass-based power coupled with carbon capture and sequestration (Azar et al, 2006), which extract carbon dioxide from the atmosphere. (Coal-based power coupled with sequestration could be close to zero emission, but not negative.) This could open the door to trajectories with higher probabilities of preserving the 2ºC line than the most stringent of our emergency trajectories. In theory, it could also open the door to trajectories that slightly delay the necessary emissions peak. In practice, however, such trajectories would require us to bank on debatable assumptions: that we would eventually find these unproven technologies to be feasible, that we would implement them at a sufficiently large scale to reverse our earlier delay, that we would deploy them rapidly enough to avoid a climate catastrophe in the meantime. It's one thing to *hope* that these will prove true, and thus improve our chances of keeping within 2ºC. It's quite another to *assume* that they'll prove true, and then use that assumption to justify a sluggish response now. For this reason, we choose to take these options off the table for the purposes of our discussion.

[12] Hansen, James., 2006. 'Climate Change: On the Edge.' (*The Independent*, 17 February, 2006). The details of Hansen's analysis can be found in James Hansen, Makiko Sato, et. al., 2006.

[13] Climate Action Network International, 2007.

[14] Scientific Experts Group, 2007.

[15] Note, however, that the Stern Review focused on stabilization scenarios, while our scenarios are projected to *reduce* concentrations after their peak. In practice our ability to reduce after peaking will depend not only on our resolve and technical capability but also on carbon cycle feedbacks beyond our control.

[16] See the IPCC's Fourth Assessment Report, Summary for Policy Makers of the report of Working Group III, Table SPM-4.

[17] The SRES B1 scenario is characterized by relatively low population growth, 'reductions in material intensity, and the introduction of clean and resource-efficient technologies' (IPCC, 2000) at aggressive rates that exceed historic precedent. And like all the SRES reference scenarios, it includes by definition no explicit climate policy.

[18] The reader may notice that this way of presenting the problem is actually quite optimistic, in that it implicitly posits that northern emissions magically and entirely disappear by 2020, making the entire precautionary emissions budget available to the South. Without this assumption, southern emissions would have to start their precipitous decline even earlier − well before 2020.

[19] The SRES B1 scenario has southern per capita income rising at a rate of around 4.5 percent per year. Using this rate, per capita income in the South would thus have not quite doubled from the 2005 average of around $4800 (PPP adjusted) to around $9400 in 2020.

[20] Stern argued, more precisely, that spending 1% of GWP would save us damages equivalent to between five and 20 percent. This cost estimate, however, was associated with a concentration target in the range of 500 to 550 CO_2 equivalent, which is far more likely to yield 3°C than 2°C of warming, as Stern himself admits.

[21] This is not to imply that poor people are responsible for all or even most land clearing, as opposed to national or international elites; only that land-use emissions must be dramatically reduced, whatever their purpose.

[22] All dollar figures in this paper are given using 2005 US dollars, converted on a purchasing power parity (PPP) basis.

[23] According to Pritchett (2003) the use of this line 'is justifiable, more consistent with international fairness, and is a better foundation for the World Bank's organizational mission of poverty reduction.' See also Pritchett (2006).

[24] Jo Johnson, 'Worlds collide in India over global warming,' Financial Times, June 7, 2007.

[25] Bill Gates is still listed as the world's richest man in the March 2007 Forbes list of billionaires.) However, that title is now held by telecom tycoon Carlos Slim. A Mexican, Slim is a citizen of a country that is not even in the top fifty in terms of per capita national income. ("Mexican tycoon overtakes Bill Gates as world's richest man," by Fiona Walsh, *London Guardian*, 3 July, 2007).

[26] And of course the Brazilian proposal famously allocated obligations, albeit only within Annex I, on the basis of responsibility for global temperature change.

[27] Plainly deforestation causes a large fraction of the emissions from tropical countries today. Yet most northern countries were largely deforested centuries ago for the same reasons – for timber, fuel-wood, and agriculture. By one calculation that we've done, per capita emissions from land use change in the US reached 10 tons of carbon (not CO_2!) per capita in the mid-19th century. But these forests are now regrowing, perhaps fertilized by increased CO_2 concentrations, and even being claimed as carbon-sinks. Clearly a fair treatment of land-use emissions will require consideration of these issues.

[28] This distinction between luxury and subsistence emissions has been popularized by Anil Agarwal and Sunita Narain (1991, see also Agarwal, Narain and Sharma 1999) of India's Centre for Science and the Environment, and by the philosopher Henry Shue (1993).

[29] Benito Müller, (2002) is quite good, and equally brief.

[30] We use here the so-called 'lognormal distribution' as a model of the income distribution with two country-specific parameters: the mean per capita income and the Gini coefficient. For an explanation, see the technical appendix. For a justification of the use of lognormals for income distributions, see for example Lopez, (2006).

[31] Note that the fact that the chart appears to reach a maximum income level at about $20,000 does not mean that there are not people in India with higher incomes. It's rather that the average income of the highest one percent is still fairly low.

[32] This observation might seem counter-intuitive to readers who note that Unfairland has not only more capacity than Fairland, but also more development need. Actually, this fact merely underscores the importance of sharing the national burden equitably among citizens; that is, sharing it among the wealthy citizens who have the capacity to pay it. The capacity-based tax won't be a burden on the poor of Unfairland so long as it is not passed down to them, but rather absorbed by the wealthy of Unfairland, on whose capacity it is based.

[33] The World Bank defines countries by income class using per capita income in market exchange rate, not purchasing power parity, terms. The official classes (in 2005 dollars) are low income (below $875), lower-middle ($876-$3465), upper middle ($3,466-$10,725), and high (over $10,725). We combine lower middle and upper middle income groups. In PPP terms, the borders are on the order of $2000, $7000, and $15000. For a list of countries, see the Appendix.

[34] For an approach that is similar to ours in spirit, but significantly different in details, see Oxfam (2007).

[35] The UNFCCC secretariat's background paper (UNFCCC secretariat, 2007) argues that that 'global additional investment and financial flows of USD 200-210 billion will be necessary in 2030 to return GHG emissions to current levels,' and that this amount 'is large compared with the funding currently available under the Convention and its Kyoto Protocol, but small in relation to estimated global gross domestic product (GDP) (0.3-0.5 percent) and global investment (1.1-1.7 percent) in 2030.'

[36] Some models simply calculate the reduction in GWP v. a baseline in (say) 2050; others estimate a marginal and average cost of emissions reductions and a total amount of reductions to calculate a total cost.

[37] For example, many economic models assume that as energy prices rise with carbon prices, central banks will respond with anti-inflationary measures, causing significant losses in GDP. There are many reasons to think such measures would be inappropriate. For further discussion, see, for example, *Economic Models of Climate Change: A Critique* by Stephen J. DeCanio (2003).

[38] The global adaptation need will be even more challenging to calculate than a global mitigation shortfall, for the scope of adaptations reflect choices that are fundamentally social and not economic in nature. But this challenge is by no means unique to the GDRs approach. Any approach that takes the notion of 'polluter pays' seriously requires a cost assessment. To a first order, this assessment can be envisioned as an evolution and generalization of the process that is already underway to develop National Adaptation Plans of Action. See also section 5 of (UNFCCC secretariat, 2007).

[39] Because each country's share of global RCI is not the same as its share of GWP, a practical proposal to raise one percent (or some other specific fraction) of GWP in taxes paid to an international fund would require appropriate scaling. We thank Kate Raworth of Oxfam for pointing this out.

[40] See for example 'Bush's New Defense Budget,' by Robert Higgs, 14 February, 2005: "The Pentagon's own budget—for fiscal year 2006, the widely reported amount of $419 billion in discretionary budget authority—does not include the costs of nuclear warheads, which the Department of Energy produces; the defense-related activities of the Department of State, including 'foreign military financing'; the past military services being compensated currently by benefits provided through the Department of Veterans Affairs; the defense-related activities of the Homeland Security Department, such as the Coast Guard's defense activities; various defense-related activities of several other federal departments; or the current interest costs of previous, debt-financed military activities. Applying my rule of thumb, I estimate that the government's total military-related outlays in fiscal year 2006 will be in the neighborhood of $840 billion—or, approximately a third of the total budget, as opposed to the 16 percent that one calculates by comparing the Pentagon's $419 billion request to the administration's total request, $2.57 trillion." Posted at www.independent.org/newsroom/article.asp?id=1464

[41] GWP is $46 trillion and military expenditures are $1.2 trillion in 2006 (or approximately 2.5 percent). See www.sipri.org/contents/milap/milex/mex_trends.html and en.wikipedia.org/wiki/World_economy.

[42] Christian Azar and Steve Schneider (2002) among others have pointed out that in a world of continuing economic growth at two or three percent annually, even a five percent decrease in GWP in 2050 implies only a delay of two years or so in becoming twice as wealthy. Presumably, most people, if asked whether they would go without raises for two years in order to preserve the planet for their grandchildren, would not hesitate.

[43] Adaptation is, at its core, a problem of resilience and adaptive capacity, and thus a development challenge that cannot plausibly be addressed by market-based institutions. So while modeling the mitigation side of a global climate regime makes good sense, and while market institutions are certain to play a role in the mitigation regime, adaptation investments must, for fundamental reasons, be implemented through democratically controlled funds that rely heavily on the involvement of civil society.

[44] Based on the global growth rates for CO_2 emissions specified in the IPCC's SRES A1B scenario.

[45] Our No-Regrets trajectory uses growth rates in per capita emissions from the SRES B1 scenario as a plausible guess. The result – 1.3 GtC of no regrets reductions below the A1B scenario in 2025 – is very close to the estimate based on bottom-up calculations in the IPCC's AR4 Working Group III Summary for Policymakers, which reports about 1.5-2 GtC of no regrets reductions below A1B in 2030. We suspect that the actual opportunity may be much larger, particularly if policies are designed intelligently and as technological advances bring costs down, but it will still only be a modest part of the necessary 'emergency program.'

[46] Pacala and Socolow (2004).

[47] Note that China's reduction obligation for the whole 2011-2025 period is proportional to its share of global RCI based on 2005 figures. If its RCI were recalculated in an intermediate year its share would presumably be somewhat larger.

[48] See, most exhaustively, Lohmann et. al, (2007).

[49] Given that, in recent years, global emissions have exceeded those projected in all SRES scenarios, it is benign indeed.

[50] Based on World Bank data (per capita growth rates and per capita income through 2006).

[51] Baer and Athanasiou, (2007). See, in particular, the discussion of the South-North Dialogue's 'Equity in the Greenhouse' Proposal.

[52] Climate Action Network International, (2007).

[53] 'Participation thresholds are based on a Capability–Responsibility index (e.g., Criqui and Kouvaritakis, 2000), and is defined as the sum of per capita GDP income (in PPP €1000 per capita), which relates to the capability to act, and of per capita CO_2-equivalent emissions (in tCO_2 per capita), reflecting the responsibility in climate change.' Den Elzen and Meinshausen, (2005), cited in Climate Action Network International (2007).

[54] Al Gore, 'Moving Beyond Kyoto,' *The New York Times*, 1 July, 2007.

[55] Quoted in Peter Foster, 'India snubs West on climate change,' UK Telegraph, 6 December, 2006.