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Executive summary

International action against climate change has reached a critical juncture in 2014. The Fifth Assessment Report of the Intergovernmental Panel on Climate Change re-emphasised the scientific consensus about the risks posed by rising atmospheric concentrations of greenhouse gases, and has highlighted impacts that are already occurring. At the same time, many national leaders have been more focused on recovering from the global economic crisis than on tackling climate change. Ongoing economic troubles are also causing policy-makers to focus more on the costs of the transition to a low-carbon economy rather than on the potential benefits.

Countries are now seeking to reach a new international agreement on climate change, to be signed in Paris in December 2015. A key element of the international negotiations since the Kyoto Protocol, has been equity, but discussions have focused on narrow and unsatisfactory approaches based on 'burden-sharing' and 'atmospheric rights'. These approaches mainly revolve around the assignment of the ‘right to emit’ or, as it is alternatively framed, the ‘costs and burdens’ of climate change action. Various proposals have been put forward that differ in terms of the principles and formulas applied in determining how the costs and burdens should be shared between countries. These range from historical cumulative emissions to relative capabilities based on GDP levels. Much of this debate, however, has proven divisive and often resulted in the search for a minimum acceptable level of individual action.

We therefore begin by examining the limitations of these approaches by questioning the ‘right to emit’, noting its tenuous relationship with basic human rights. We further highlight the limitations of ‘burden-sharing’, using a leading model to show that different approaches lead to largely similar outcomes, and hence add little value. We go on to suggest alternative apporaches based on the ‘right to development’ and the need for collaboration to take advantage of opportunities. While the outcomes of most of these approaches in terms of emissions would look little different from those resulting from ‘burden-sharing’, the outcomes in terms of economic development would be meaningfully different, and would encourage greater ambition and more collaboration to improve the affordability of, and increase the opportunities from, decarbonisation.

In the first quarter of 2015, countries are expected to put forward their pledges on national actions (so-called ‘intended nationally determined contributions’ or INDCs) to address climate change, which they propose to deliver as part of the international agreement. In this context, much of the discussion domestically and internationally is about reconciling the urgency and ambition required to tackle climate change with the affordability and equity of efforts by countries. While INDCs may include actions on adaptation, the focus of this paper is on mitigation and potentially related actions on finance, technology cooperation and capacity-building to support it.

The main criteria for determining national mitigation pledges are domestic political agendas reflecting popular opinion, institutional arrangements, and leadership stances. To some extent these INDCs are likely to reflect national circumstances, including (i) the cost of action, taking into account natural endowments, such as reserves of fossil fuels, or the energy intensity of production (for example the presence of industry dependent on coal); (ii) anticipated local damages from climate change; and (iii) the benefits which accrue from policies that aim to reduce emissions and that attain other policy goals, such as reductions in local pollution, increases in efficiency or improvements in energy security. When formulating their pledges, countries will also consider what others are doing to ensure comparability of effort and equity. These considerations will then be assessed against the global action required to address climate change.

As part of the process of submission and negotiation of national pledges, countries are likely to be asked to substantiate their proposed level of action and to explain why they consider it to be ‘equitable’. However, a common definition of equity is unlikely to be agreed because individual countries have generally only endorsed definitions that match their national intentions or negotiation position. Therefore, the evaluation of pledges could be based on a variety of elements, including (i) relative contribution to global emissions reductions; (ii) national circumstances; and (iii) comparison with the level of effort that other countries propose to undertake.

This paper seeks to contribute to a re-framing of the debate on the equitability and ambition of actions to address climate change. It examines a sample of seven ‘burden-sharing’ approaches to setting mitigation targets which have been proposed during discussions about a new international agreement on climate change. The paper then analyses the indicative levels of ambition that would be required by the major emitters of greenhouse gases under each of the seven ‘burden-sharing’ approaches, if a particular top-down formula were to be implemented. This analysis concludes that, with the exception of a ‘carbon budgets’ approach, the resulting levels of mitigation effort that would be required from the major emitters under different approaches to ‘burden-sharing’ tend to be clustered around similar outcomes. This is because these approaches are driven by two factors: the requirement to reach an ambitious global end-point target, in terms of limiting the rise in global mean surface temperature, and the growth in the economic size of countries and regions. While there are some variations between the individual levels of effort depending on which formula is applied, all major emitters would need to reduce their emissions significantly below ‘business as usual’ levels. These individual approaches, however, are unrealistic in terms of political economy because they fail to take into account the national self-interest of countries and their domestic political and economic priorities.

The paper then presents a broader approach to equitable mitigation actions that steps away from the discussion of a fair distribution of the 'right to emit' or the burden associated with emissions reductions. It focuses instead on the 'right to sustainable development', including a safe climate, a clean environment with less congestion and pollution, secure access to energy, and other opportunities associated with low-carbon growth. It recognises the importance of the distribution of the causes and impacts of climate change, as well as the different individual historical responsibilities and relative capabilities among countries, in determining the level of effort and support undertaken by each country. However, it also emphasises the need to enable equitable access to sustainable development through consideration of the benefits of climate action. Approaches that are based on 'burden-sharing' and the 'right to emit' miss out a key insight, namely that all countries stand to gain some benefit from reducing greenhouse gas pollution.

This paper shows through several examples how taking into account both the benefits of climate action and the opportunities to attract investment through collaborative partnerships could help to increase the level of ambition in managing the risks of climate change, while also advancing other development goals.

1. Rights-based approaches to determining 'equitable' levels of mitigation

Most of the discussions about mitigation efforts in the context of international climate change negotiations take a top-down, internationally-agreed and quantified objective as a starting point, and then apply various sets of distributive justice criteria to determine the relative levels of effort required by individual countries. The key attraction of such approaches is that they provide certainty about the overall collective level of mitigation effort.

There is no single agreed method that can be used to define what a country's contribution to mitigating climate change should be. Many different approaches have been proposed, each based on a different underpinning equity principle.[1] These can lead to different results, even where approaches are based on the same principle.

The two most prominent approaches consider a limited 'atmospheric space' in determining the equitable level of ambition for climate change mitigation. These are based on the application of various principles of distributional justice to either the 'right to emit' (based on resource-sharing) or alternatively to a negative right or a duty to take on the 'cost of reducing emissions' (based on 'burden-sharing'). The discussion starts with

[1] For a more extensive overview see Averchenkova, A., and Green, F., forthcoming. *The philosophy, politics and policy of climate change: in search of a new narrative*. Policy paper, Grantham Research Institute on Climate Change and the Environment and ESRC Centre for Climate Change Economics and Policy, London School of Economics and Political Science.

identifying a global threshold for greenhouse gas emissions (or a global emissions reduction target) and then determines an appropriate distribution of this atmospheric space or emissions reductions burden among the countries.

Different principles of distributive justice are then applied to operationalise this approach, often through formulas for allocating the entitlements to emit or ‘the burden of emissions reductions’. Three in particular dominate the literature including: (i) equality, based on an understanding that human beings should have equal rights; (ii) responsibility for contributing to climate change, linked to the ‘polluter pays’ principle; and (iii) capacity to contribute to solving the problem (e.g. Heyward, 2007; Höhne *et al.*, 2014). Some authors add cost-effectiveness as a further potential criterion for determining the distribution of effort, although this principle is not based on a particular moral theory and is not an equity principle in itself.

The ‘atmospheric space’ approaches - and the notions of equity, historical responsibility for emissions, and capacity to pay - have figured prominently in international climate change negotiations. The United Nations Framework Convention on Climate Change (UNFCCC) states that “Parties should protect the climate system … on the basis of equity and in accordance with their common but differentiated responsibilities and respective capabilities”. This statement can be interpreted in a number of ways but is commonly understood to mean that countries with higher emissions (responsibility) and levels of development (capability) should take a greater share of the burden of mitigation.

The ethical considerations upon which operational distributional approaches for determining an equitable level of greenhouse gas emissions or mitigation effort have been founded include:

- Egalitarian principle, based on *equality* in individual right to access carbon space. Countries receive an identical amount of permits or quotas to emit greenhouse gases in the form of an equal level of greenhouse gas emissions per capita.
- ‘Historic responsibility’ based on the ‘polluter pays’ principle, which assigns countries *responsibility* for the emissions now and those made historically. With time, the cumulative contribution to emissions reflects a measure of some historical emissions. There is much disagreement; however, about the timeframe that should be considered in determining historical emissions. Some approaches start with 1850 as the reference point, while others use the 1970s or 1990s.[2]

[2] 1850 is sometimes chosen as representing the pre-industrial era and the earliest data point for emissions estimates (although many of these emissions will no longer be present in the atmosphere). 1990 is sometimes chosen as that is the year of the Rio conventions, so the first time the world came together to acknowledge the issue. Before 1990, it has been argued, there is a stronger case that greenhouse gases were emitted in ignorance of their impact on the climate. Since 1990 it is difficult to argue that the world was not aware of the potential consequences of greenhouse gas emissions, even if more recent scientific evidence has sharpened our understanding of the scale of the risks.

- ‘Capacity to pay’ — the principle that countries that have greater *capacity* or ability to solve a joint problem should contribute more than countries with less capacity and ability. The mitigation burden is allocated progressively based on the national income.

In recent years, a number of practical proposals have emerged, based on these distributive principles, including: the carbon budget or carbon space approach and contraction and convergence (based the on equality principle); the index-based/ ‘Brazilian proposal’ (based on responsibility); cost proportional to GDP and income classification approaches (capacity principle); or on a combination of several principles, such as common but differentiated convergence (equality and capacity).

However, there is very little agreement about how exactly these principles should be applied and how much more mitigation effort is required from countries with greater responsibilities and capabilities. A further challenge is that sovereign states prioritise their own interests and therefore these principles are given more or less self-serving interpretations by each country. The resulting policies are therefore generally the outcome of political compromise rather than the direct application of ethical principles.

Another major criticism of the ‘atmospheric rights’ approaches is that, by assuming a static, fixed-resource distribution, they fail to capture the dynamic aspects of climate change, such as uncertainties about the science and modelling (Heal and Millner, 2013), and uncertainties about the co-benefits of climate mitigation (Stern, 2013), especially if pursued collaboratively, at scale and through well-designed and income-progressive policies. We consider these concerns in the following sections.

2. Determination of post-2030 pledges based on ‘burden-sharing’ approaches

This section evaluates how mitigation efforts beyond 2030 would be distributed among the major emitting countries should a ‘rights-based’ or ‘burden-sharing’ approach be taken as the basis for determining the level of emissions reductions that individual countries undertake. It examines a sample of seven ‘burden-sharing’ approaches suggested for the international climate change negotiations, employing the various distributional criteria discussed in the previous section. For those approaches where cost of emissions reductions is a consideration, it uses the results of a leading model operated by the UK Department of Energy and Climate Change (DECC).

A recent study by Höhne *et al.* (2013) analyses what the literature on ‘burden-sharing’ or ‘effort-sharing’ approaches suggests for the level of national and regional targets, based on a review of over 40 studies. The study finds that a wide variation in the coverage of stabilisation scenarios, effort-sharing categories, timeframes and emission categories limits the comparability of modelling results delivered by projects on the different approaches to ‘burden-sharing’. Höhne *et al.* (2013) was used as the basis for figures on regional emissions reduction targets that were presented in the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. This paper extends that work by applying a range of 'burden-sharing' approaches to 13 countries and regions,[3] all of which are members of the Major Economies Forum, to determine the indicative level of effort that is required to limit global emissions, under three scenarios with various confidence levels of keeping global warming within 2°C, assuming emissions reductions are achieved domestically and that there is no trading among the regions. The three global emissions targets that were modelled are set out in Box 1.

2.1. Modelling approach

The analysis of distributional approaches which are based in some way on the cost of emissions reductions was carried out using the Global Carbon Finance model (GLOCAF) of the UK Department of Energy and Climate Change (DECC). GLOCAF runs pre-defined scenarios for effort-sharing, for a particular emissions level (e.g. 41 gigatonnes (Gt) of carbon-dioxide-equivalent (CO_2e) in 2030 – see Box 1), and estimates costs for each region of meeting the targets. The focus of this paper, however, is on the emissions targets rather than costs of emissions reductions.

Box 1: Choice of emissions pathway to 2030

There are a range of estimates of what annual global emissions level is needed in 2030 to be consistent with limiting the rise in global mean surface temperatures to no more than 2°C, depending on both the probability applied to achieving this goal and the pathway that is considered consistent with different goals. Some have argued that the aim should be to achieve a probability of at least 66 per cent of limiting the rise in temperature 2°C, and that pathways should be excluded they rely significantly on 'negative emissions technologies'. Others have argued that the 2°C target can be met, even with relatively high emissions in 2030, provided that emissions fall fast enough after 2030. To ensure this analysis remains relevant to a range of possible 2030 global targets, we have modelled three different levels of global ambition.

The Emissions Gap Report 2013 by the United Nations Environment Programme presents a wide range of possible emissions pathways largely similar to the set used by Working Group III of the Intergovernmental Panel on Climate Change for the Fifth Assessment Report, each of which would mean a different probability of a given temperature rise. The Met Office, as part of the AVOID2 research programme, extended this analysis, using the final set of emissions pathways published in the Fifth Assessment Report, to consider a wider range of emissions pathways that lead to a wider range of temperature rises.

This paper uses the UNEP (2013) median scenario for emissions in 2030 for cost-effective pathways that mean a 50-66 per cent chance of limiting the rise in global mean surface temperature to no more than 2°C above pre-industrial level, based on multi-

[3] Due to data limitations, the European Union's Member States are included as a single region and Australia is included in a regional grouping with New Zealand and Papa New Guinea.

model analysis. This means that global greenhouse gas emissions are limited to 41 gigatonnes of carbon-dioxide-equivalent in 2030, and 28 gigatonnes of carbon-dioxide-equivalent in 2050. Further details about the scenarios and the resulting allocations under various distributional approaches are presented in Annex 2.

The model includes ‘business as usual’ emissions projections and a regional specification of abatement costs based on local sectoral opportunities and technologies. This is expressed in the form of marginal abatement cost (MAC) curves for 24 regions (plus ‘international aviation and maritime’, which cannot be allocated to another region so are treated as regions in their own right - see Annex 3) and 27 sectors. The emissions reductions listed here are for 2030, the most politically relevant intermediate target given that the negotiations on the future framework in 2015 are more likely to consider longer term benchmarks than 2020. This year also corresponds with many assessments of the near-term costs and benefits of action to reduce emissions, including the New Climate Economy Report by the Global Commission on the Economy and Climate (2014).

At this point it is worth highlighting the major limitations of approaches based on MAC curves. Although the GLOCAF model does allow for some induced innovation, whereby costs fall as a result of stronger action early on, it is extremely hard to include the full benefits of learning and experience, network externalities and complementarities gained from developing and deploying mitigation options at scale.

A static model based on flows of emissions will also fail to capture the costs of delay. It does not measure dynamic costs such as those that result from the lock-in of physical infrastructure, institutions and behaviours, or the impacts on future productivity growth due to induced innovation, knowledge spill-overs, network effects and other complementarities which can lead to scale economies (Aghion *et al.*, 2014). The dynamics of lock-in and path-dependency underscores the urgency of action but are mostly absent from this analysis.

Another feature to note is that MAC curve analysis takes account only of costs at the margin and takes no account of the value of the stock of assets. For example, ambitious action to reduce emissions will have a dramatic effect on the value of fossil fuel reserves and fossil-fuel-intensive assets. The ramifications for wealth are likely to occur across investment portfolios and pensions, with the increased possibility of stranded assets, and are likely to induce significant ‘terms of trade’ effects, in particular for countries with extensive fossil fuel reserves and economies based on fossil fuels (Reilly *et al.*, 2012).

2.2. Description of the burden sharing approaches considered

The following ‘burden-sharing’ approaches are considered in this paper:

Carbon budget or carbon space based approach: A number of studies have proposed allocating the global carbon budget to individual countries on the basis of their population (BASIC experts, 2011). This approach is based on the distributive principle of equal emissions entitlements, which was discussed in a previous section. Countries are allocated an emissions budget for 1990-2050, based on the share of the global population over the same period. See Annex 1 for more detail about this approach.

Index based approach: This approach uses an index to distribute the total mitigation needed globally between individual countries. This analysis focuses on one index, referred to as the 'Brazilian proposal', which assumes that the share of mitigation a country needs to implement should be determined by its share of historical emissions (UNFCCC, 1997). In this case the period 1990–2020 is considered, while other studies have looked at other timeframes.

Contraction and convergence: This approach is based on the equality principle, namely that individuals have the right to emit an equal amount of greenhouse gases and should therefore receive an identical amount of permits, allowances, or quotas. A number of studies have proposed an emissions approach based on all countries converging to the same emissions per capita value by a specified date, such as 2050 (Meyer, 2000). As with the former two approaches and the next approach, abatement costs are not determinants of emissions reductions, and therefore the emissions pathways are exogenous to the GLOCAF model and calculated off-model.

Common but differentiated convergence: This approach is similar to contraction and convergence, but differentiates between countries according to their level of economic development (Höhne *et al.*, 2006). In this approach, a pre-determined threshold, such as emissions per capita, is used to differentiate between the actions that need to be taken by different countries. Those countries that are above the threshold converge to a 2050 equal per capita emissions target, and countries below the threshold continue with 'business as usual' emissions. Per capita emissions are therefore used as a proxy for level of development and historic responsibility. As total global emissions fall over time, more countries are required to reduce emissions.

Cost proportional to GDP per capita: Under this approach, all national targets are set so that each country faces the same mitigation costs as a percentage of GDP (Babiker and Eckaus, 2005). The principle in this case is that wealthier countries pay a higher per capita cost. Mitigation costs per capita are proportional to GDP per capita, making this approach equivalent to a flat tax on income, as a higher income country will pay more in absolute levels per capita, but the same proportion of its income than a lower income country. Because this approach takes into account mitigation costs, it is endogenous within the GLOCAF model, which has a regional specification of regional mitigation. An iterative process was used in the GLOCAF model to adjust each country's target up or down until its mitigation cost is within an acceptable tolerance of the global average (for example, within 0.025 per cent of GDP) and the required global emissions target is met.

The income classification approach: This is similar to the 'cost proportional to GDP per capita' approach because it also uses the principle that wealthier countries pay a higher per capita cost. Targets are set on the basis of their cost as a percentage of GDP, but a differentiation is made between high income and other countries, with the former being assigned targets that lead to estimated costs twice the level of the latter, as a proportion of GDP. As with the ‘cost proportional to GDP per capita’ approach, an iterative function within the GLOCAF model was used to calculate the targets.

Equal marginal cost: This approach is not strictly an ethical ‘burden-sharing’ approach, but produces a profile based solely on narrow efficiency: the distribution of global mitigation is determined purely on the basis of cost-effectiveness as determined by the regional MAC curves. Costs are minimised by equating the marginal cost of mitigation across all countries. In the absence of a global carbon market, or other mechanisms to transfer finance, these costs would be borne by states and regions. However, it is not assumed that the final costs need be borne by these countries nor that the geographical location of the emissions reductions matches the source of finance. This distribution is ‘Pareto optimal’ in so far as it is impossible to make any one individual better off without making at least one individual worse off. Subscribing to this principle increases the total envelope of resources available for distribution under all the forgoing principles. Irrespective of who pays the bill for any emissions reductions, so long as trading or transfers occur across borders, this approach provides the most cost-effective geographic distribution of reductions.

2.3. Results of the analysis: Potential level of mitigation effort for 2030 under ‘burden-sharing’ approaches

The modelling results (see Figure 1), which are presented in full in Annex 2, show that, under the carbon budget or carbon space based approach, some countries (United States, Canada, Australia) have nearly used up their budget already, which means that they need to make very rapid emissions reductions to roughly zero emissions by 2030. Other countries, such as India, are allocated a budget larger than their ‘business as usual emissions’ projection, and so are able to sell the surplus ‘hot air’ to other countries and are not constrained to reduce their emissions.

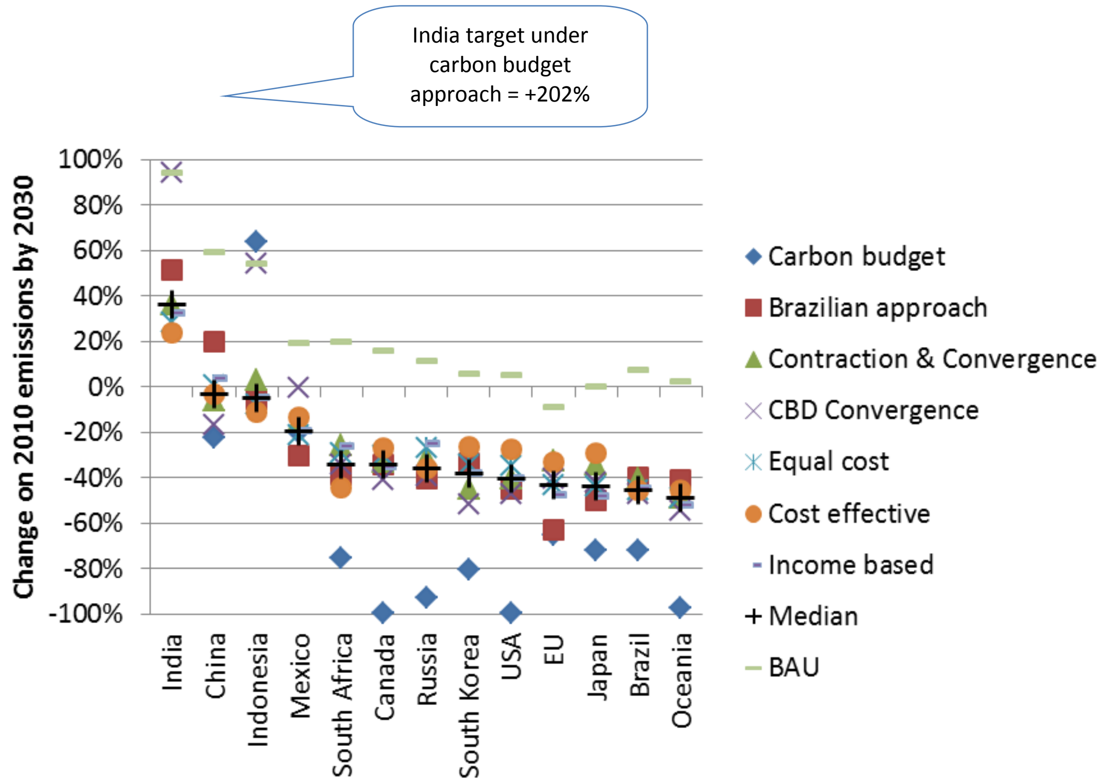
Under the ‘Brazilian proposal’ approach, all countries’ emissions are brought below ‘business as usual’, However, using 2010 as a starting point, countries with proportionally smaller shares of historical emissions (India, China) can increase emissions in the future. In practice, the large increases in global emissions expected up to 2020 are likely to require all major countries to reduce emissions over the period 2020 to 2030, though at markedly different rates. The modelling shows that contraction and convergence requires that all countries’ emissions are bought below ‘business as usual’ by 2030, but countries with low per capita emissions (India) can increase emissions relative to their 2010 level. Once again, in practice, that margin has been largely exploited already, suggesting all major countries must reduce emissions from hereon in. However, developing regions, such as India, China and the Middle East, would need to reduce emissions by more than in either of the other approaches which account for historical legacies. Common but differentiated convergence for many countries leads to a similar profile compared with the other approaches, but for India and Indonesia in particular, this approach has markedly different consequences. Given their low per capita emissions, India and Indonesia have space to continue along ‘business as usual’ pathways for almost the entire period as their emissions remain below the global average. However, in practice, since all countries need to take significant action after 2030, these countries would have to consider taking action before 2030 to avoid lock-in that increases future costs.

Under the cost proportional to GDP per capita approach, the results are similar to contraction and convergence, reflecting the fact that income is a key driver of per capita emissions. All countries need to reduce emissions below ‘business as usual’, but less developed countries, such as India, can increase emissions. Similarly, the income classification approach leads to all countries reducing below ‘business as usual’ by 2030, but countries without a historical legacy (India, China) can increase emissions.

It is of interest that the emissions reductions required for the ‘global efficiency under equal marginal cost’ approach are not too different from those based on other ‘burden-sharing approaches. However, in general, the ‘global efficiency under equal marginal cost’ approach suggests that there are greater opportunities for emissions reductions in less developed countries with lower historical emissions than in developed countries with larger historical emissions. This reflects the fact that there are proportionally more inefficiencies associated with energy and land use in low income countries, which can be cost-effectively remedied in order to cut emissions, than there are in richer countries. It also reflects the opportunity for developing countries to avoid investment in high-carbon infrastructure as they industrialise, urbanise and expand their transport and energy networks. Consequently, all countries would be better off if developed countries deliver transfers that support emissions reductions in developing countries with cheaper opportunities.

In a world of free trading, all approaches would move from the target starting point to the cost-effective distribution as there would be profitable trades. Exploiting such low-cost abatement would minimise total global costs. In reality, free trade is an aspiration. There are currently a limited number of trading schemes with different levels of stringency (and therefore varying carbon prices) and limited access to low-cost abatement opportunities in least developed countries due to high transaction costs. However, without trading or other transfer mechanisms to finance low-cost abatement opportunities, global costs would be much higher. It means that the further away other equity approaches are from the cost-effective ‘free trading’ distribution, the greater the risks that countries consider the costs to be prohibitive.

Figure 1. Post-2030 emissions targets under various ‘burden-sharing’ approaches for a median scenario of a 50-66 per cent chance of not exceeding a rise in global mean surface temperature of 2°C.



Source: GLOCAF
Note: 2010 base year; 41 Gt CO_2e global emission target in 2030

This analysis further concludes that, with the exception of the 'carbon budgets' approach, the resulting levels of mitigation effort that would be required from the major emitters under different approaches tend to cluster about similar values. Targets driven by formulaic approaches cluster because of the arithmetic, which in turn is driven by the requirement to meet an ambitious end-point emissions reduction target. These approaches, however, are based on a 'burden-sharing' approach to equity, and therefore are likely to be unrealistic in terms of political economy because they fail to take into account the national self-interest of countries through consideration of national benefits of climate action.

Many variants of these 'burden-sharing' approaches can be formulated, each suggesting different national targets. No single approach can be said to uniquely capture key principles such as a country's ability to pay or historical responsibility. All approaches will differ slightly and there will always be individual countries that are disproportionately affected by any one approach compared with another. This underlines the value of considering a collection of approaches which offers a more powerful indicator of the distribution of equitable commitments based on the key principles of historical responsibility and capacity to act.

The ethical perspectives that underpin the various approaches outlined here, while individually weak, are pertinent to underlying ethical issues and convey a collective message about what a 'fair' distribution of effort might be based on. Taken together they provide a more powerful steer than any individual approach and provide a useful perspective on the kinds of emissions reduction pathways required, given the arithmetic and ethical foundations. They provide a guide to the sort of targets that will be required by countries to be consistent with different temperature goals. However, considering these emissions reductions solely in terms of ‘burden-sharing’ leads to the omission of much of what is important to domestic economic performance in terms of managing and benefiting from the transition to a low-carbon global economy.

3. Re-framing the approach to mitigation: Raising the ambition level to meet development priorities and address climate change

The previous section showed that the arithmetic of ‘burden-sharing’, for the most part, points to the need for decisive action to reduce emissions pathways below ‘business as usual’ in most countries. However, framing climate change action in terms of ‘burdens’ and ‘costs’ is at odds with the growing evidence about the benefits of investment in resource efficiency and emissions reductions.

To determine what actions countries should undertake to reduce emissions, it is necessary to attempt to quantify additional outcomes that are likely to result from a low-carbon strategy. Many low-carbon policies deliver other benefits besides reducing greenhouse gas pollution, including greater energy security, less traffic congestion, improved quality of life, stronger resilience to climate change impacts and environmental protection. Many can help reduce poverty and improve health. This is in line with the arguments presented by the ‘new ways to grow’ frameworks. Countries are recognising the costs of a high-carbon model of economic development and growth, in ways that are often omitted from the standard academic approaches to assigning emission targets using approaches looking solely at estimates of greenhouse gas mitigation costs. Accounting for a broader array of costs and benefits will help inform the question of how big individual country investments need to be, how they are financed and how technologies are shared.

3.1. New approaches to ‘equitable’ mitigation efforts

Some new work has emerged recently encouraging a move away from ‘distributive justice’ and ‘burden-sharing’ towards a more collaborative approach, involving development-oriented partnerships between countries (Stern, 2013; Hedahl, 2013). Stern (2013) argues that such partnerships should be based on sharing technology, providing finance and supporting capacity-building (knowledge and institutions), which offer the potential for mutual gains between developed and developing countries, rather than on direct income transfers that have proved politically difficult.

‘Equitable access to sustainable development’ (EASD) emerged as a political concept at the 16th session of the Conference of the Parties to the United Nations Framework

Convention on Climate Change in Cancún, Mexico, in 2010, having been proposed by developing countries as a way to reach a compromise during the negotiations among the BASIC countries (Brazil, South Africa, India and China). No clear definition of EASD has been developed. Many analysts and negotiators still interpret it in the context of the traditional 'atmospheric rights' framework, emphasising access to carbon space (relating it to the 'right to develop' through growing emissions), sustainability and time for development, and labelling various 'burden-sharing' approaches as EASD (BASIC experts, 2011).

Other authors have suggested that by highlighting access to sustainable development, the concept of EASD provides an opportunity to re-focus the international debate on climate action, away from the 'fair' distribution of 'costs' and towards future growth pathways and the potential for development to happen in a low-carbon and climate-resilient way. By focusing on incentives and the benefits of climate action, this re-framing may help to overcome the impasse in international negotiations by focusing discussions on the dynamic transformation of economies and new forms of collaborative away, instead of a 'zero-sum game' (Romani *et al.*, 2012; Stern 2013; Hedahl 2013).

This new discussion goes hand-in-hand with the development of the 'new ways to grow' framework, which stems from the ideas about 'green growth', and seeks to combine the objectives of improving economic and social prosperity with environmental outcomes (Bowen, 2012). The key features of this framework are its focus on the sustainability of growth in the longer term, and on interactions between the economy and the environment. It also recognises the multiplicity of market failures that often attend climate policy-making. This makes for a more sophisticated incorporation of socio-political and political-economy dynamics in policy design than standard public-economic approaches focusing on the distributive effects of policies (Bowen, 2012; World Bank, 2012).

3.2. From 'zero-sum burdens' to 'positive-sum opportunities'

Once the framing of the debate on international climate action is expanded from a narrow focus on 'burden-sharing' to access to opportunity instead, there is a change in the incentives for individual countries to act. This is because the evidence suggests there is a growing number of worthwhile investments, from the perspective of both climate change action and national development, which are not easily funded or delivered due to a number of institutional, financial, information and knowledge, technical, political and other barriers, particularly in developing countries (CDKN, 2013). In this context, the fact that low-carbon investment delivers a global climate benefit, alongside a local development one, can provide a case for international support for it.

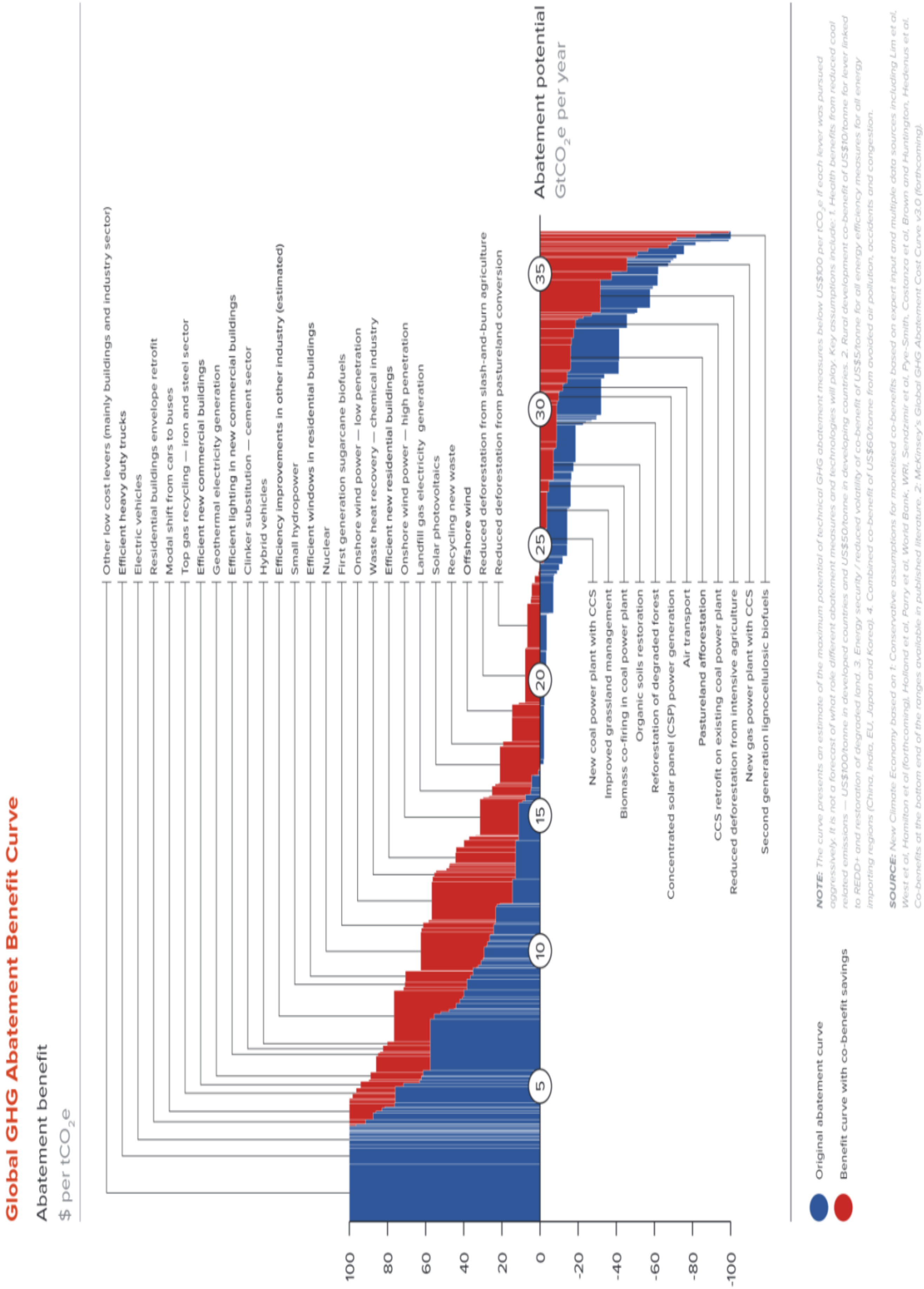
Introducing the *opportunity* principle in the analysis as an additional ethical principle on which international action on climate action should be based does not diminish the importance of *historical responsibility* and *capability* in the way we think about the problem of who does what. The rich historical polluters still have a responsibility to support lower income but fast-growing countries to move to a low-carbon economy. Identification of investment options in developing countries that reduce greenhouse gas emissions, while delivering long-term development benefits, but that require overcoming the barriers mentioned previously, makes a stronger case for financial and technical assistance from developed and emerging economies. Public climate finance and risk management and sharing instruments may be required to leverage private funds by bringing down the costs of capital.

The New Climate Economy Report (2014) identified emissions reductions that could deliver 50-90 per cent of the emissions reductions required to put the world on a pathway in 2030 that is consistent with the target of avoiding global warming of more than 2°C, and could simultaneously enhance economic performance. However, there remains an urgent case for discussing how to address the remaining 10-50 per cent of the required reductions that have not been identified as delivering near-term economic benefits.

This section focuses on the growing evidence of opportunities in the context of domestic climate change action and the role for international investment partnerships in helping realise these opportunities. It does not attempt the difficult task of determining a detailed mechanistic process for calculating what is in each country's self-interest i.e. best for individual countries' long-term growth and prosperity. However, it does lay out some of the key areas where action to reduce emissions can drive profitable returns to the economy and society. Boxes 2-4 present selected examples of the co-benefits of climate change mitigation in several developing and developed countries.

Moreover, we encourage future analysts to conduct a more rigorous quantification of costs and benefits, disaggregated across regions, with the ultimate aim of incorporating as much as possible within the MAC curve framework. For example, benefits from reduced congestion, pollution and fiscal reform can be illustrated using the MAC curve framework by plotting marginal costs against emissions reductions. The New Climate Economy Report (2014) presented a global MAC curve (see Figure 2) taking into account co-benefits of climate action. In the context of determining and agreeing national post-2030 pledges, it would be helpful to have such analysis at the country-level, although this would clearly constitute a labour-intensive and time-consuming undertaking and would need to be expressed in terms that go beyond the static MAC curve representation by allowing for complementarities and spill-overs that determine the economic development path. Nevertheless, a heightened understanding and quantification of the potential local social and economic benefits would help to inform decisions as to the level of emissions reductions that countries could undertake while reaping non-climate-related benefits.

Figure 2. Global greenhouse gas abatement benefit curve



Source: New Climate Economy Report (2014).

A number of specific sectors where potential non-climate benefits can be derived through ambitions emissions reductions have been identified by the New Climate Economy Report (2014).

3.2.1 Urban development

Cities are crucial engines of growth and prosperity. They generate around 80 per cent of global economic output (Seto and Dhakal, 2014) and around 70 per cent of global energy use and energy-related greenhouse gas emissions.[4] More compact and connected urban development, built around mass public transport, can create cities that are economically more dynamic and healthier, and that have lower emissions than today. Such an approach to urbanisation could reduce urban infrastructure capital requirements by more than US$3 trillion over the next 15 years (Rode *et al.*, 2012).

3.2.2. Agriculture

Restoring just 12 per cent of the world's degraded agricultural land could allow 200 million more people to be fed by 2030, while also strengthening climate resilience and reducing emissions.

While not only supporting the mitigation of greenhouse gas emissions, efficient livestock production offers a number of economic benefits to producers. In areas of Latin America, particularly Brazil, where pasture lands have a productivity of just one-third of their estimated potential, improvements to livestock production through lime and fertilizer pasture treatments, use of improved grass, legumes, shrubs and shade trees can support an increase in cattle exports of 50 per cent (Searchinger *et al.*, 2013). Improving the quality of fodder and forages is not only associated with reductions in enteric methane, it also increases daily weight gains, supporting quicker turnaround as animals are ready for market sooner (Global Commission on Economy and Climate, 2014).

3.2.3. Energy efficiency

Greater investment in energy efficiency – in businesses, buildings and transport – has huge potential to cut and manage demand. Market failures and poorly-designed policies combine in many economies to distort the efficient allocation of resources, and also increase greenhouse emissions. Markets which incorporate the full costs of production in energy and resource prices allow resources to flow to where they are most productive. Artificially low or subsidised fossil fuel prices, for example, encourage wasteful energy use. This means there are both economic and climate benefits to be achieved by phasing out fossil fuel subsidies. A strong and predictable price on carbon – achieved through nationally appropriate taxes or emissions trading schemes – can raise new revenues while discouraging fossil fuel energy use. Policies to promote energy efficiency

[4] The Intergovernmental Panel on Climate Change estimates that in 2010, urban areas accounted for 67–76 per cent of global energy use and 71–76 per cent of global carbon dioxide emissions from final energy use.

can free up resources for more productive uses and, if designed well, can be particularly beneficial to people on low incomes.

According to the International Energy Agency (2013), energy efficiency improvements in developed economies have cut the effective demand for energy by 40 per cent in the last four decades. No source of energy has contributed as much to both emissions reductions and cost-saving. A number of countries and regions, such as Sweden and British Columbia in Canada, have used the revenues from carbon pricing policies or other sources of expenditure to compensate households and to subsidise energy efficiency measures, which can help cut overall energy bills (OECD, 2013). Energy efficiency measures could increase the GDP of the United States by 1.7 per cent by 2030 and programs already in place provide $2 of consumer benefit, sometimes upwards of $5, for each $1 invested (Bianco *et al.*, 2014).

Box 2: Examples of co-benefits at the local level in China

Energy security and energy efficiency
Energy security is a one of the greatest development challenges in China. A tripling of the country's energy usage since 2000 has accompanied strong economic growth. Continuation of past trends would require China to import greater than 50 per cent of its coal in the next 10 to 15 years (BP, 2013). At the same time, the mining of coal and its subsequent use in energy generation requires significant water resources - thermal plants require several thousand litres of water per MWh of energy generated and coal plants require sometimes 10 times this amount. Water shortages have already compromised 70 per cent of coal mines in China (Wang *et al.*, 2013).

At the same time, as a result of aggressively pursuing renewables, the proportion of China's electricity generation from coal has dropped from 85 per cent to 50 per cent in the past decade and 15 per cent now comes from solar and wind, with another 30 per cent from hydropower. Furthermore, it has made nearly double the amount of investments on solar energy, and five times more for wind, compared with any other country (REN21, 2014).

In addition, the adoption of energy efficiency measures in China is predicted to increase the county's GDP by 3 per cent by 2030 (Global Commission on the Economy and Climate, 2014).

Urbanisation and urban sprawl
The New Climate Economy Report (2014) cites research from 261 Chinese cities in 2004 and finds that, in response to rapid urbanisation, doubling employment density in China would not only reduce the increased pollution and carbon intensity of urbanisation, but would also deliver gains in labour productivity of 8.8 per cent (Fan, 2006).

3.2.4. Fiscal reform

As noted above, both market and policy failures distort the efficient allocation of resources, while simultaneously increasing emissions. While subsidies for clean energy amount to around US$100 billion every year, subsidies for fossil fuels are now estimated to be about US$600 billion per annum. Phasing out fossil fuel subsidies can improve growth and release resources that can be reallocated to benefit people on low incomes. In addition, a strong and predictable price on carbon can drive higher energy productivity and provide new fiscal revenues, which can be used to cut other distortionary taxes, such as taxes on labour or saving. Well-designed regulations, such as higher performance standards for appliances and vehicles, are also needed. A recent study by the World Bank (2014b) shows that about 40 countries and over 20 sub-national jurisdictions now apply, or are planning to apply, carbon pricing (either through a carbon tax or emissions trading scheme). A further 26 countries or jurisdictions are considering carbon pricing. Altogether these schemes cover around 12 per cent of global emissions.

Box 3: Example of benefits at the local level in Brazil

Agriculture

Between 1970 and 2000, Brazil became a top three producer of sugar cane, soybeans and maize and achieved a quadrupling of crop yields and a doubling of livestock productivity (Global Commission on the Economy and Climate, 2014). This path of intensification provided increased resources for investments in the national agricultural research agency, further soil improvements, and crop breeds, as well as in expanding the credit available to agricultural agents and in improving rural infrastructure. Following the period of increased deforestation in 1990-2005 the implementation of anti-deforestation policies led to a decrease in deforestation by 76 per cent between 2005 and 2012. This was accompanied by a production growth in soybeans, sugar cane and beef by 29 per cent, 70 per cent and eight per cent respectively (Global Commission on the Economy and Climate, 2014).

Energy security and financial innovation

The Brazilian national development bank offers special long-term interest rates for infrastructure projects based on a commitment of about US$50 billion to low-carbon energy. It has removed the barrier of sustainable energy investment being more expensive than fossil fuel generation that would have persisted in the absence of this low-cost financing (BNEF, 2013). This resulted in the development of wind projects at a low average energy price of just US$58/MWh in auctions (Dezem and Lima, 2014).

Local pollution

A study by the World Bank found that Brazil’s GDP would be raised by more than US$13 billion, and 44,000 jobs would be created, if the country were to divert its solid wastes to methane and biogas electricity producing landfills (World Bank, 2014a).

3.2.5. Financial innovation

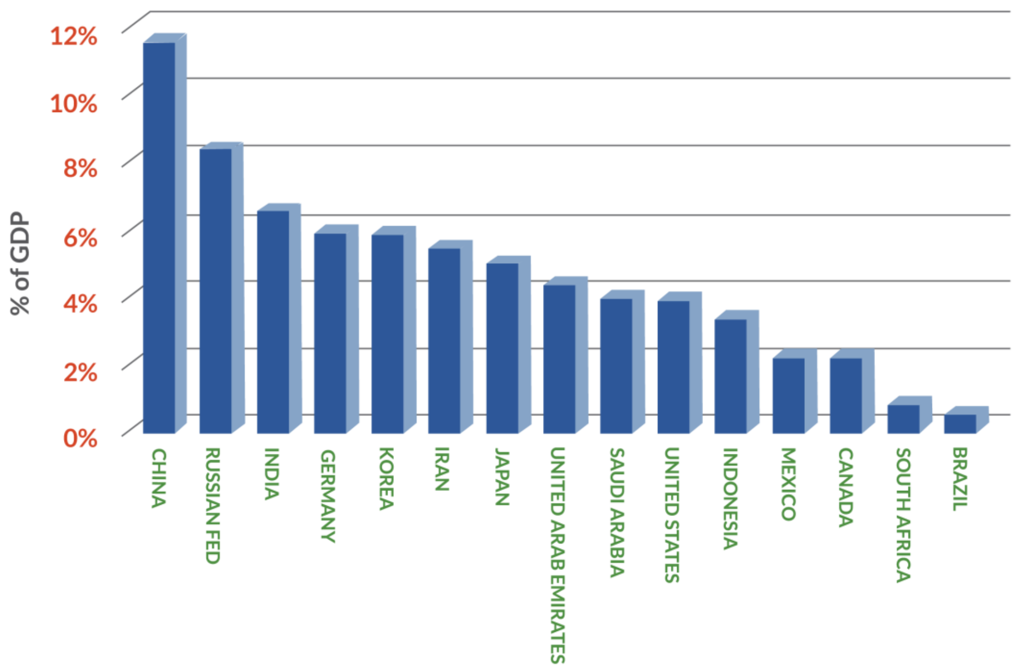
There is no shortage of capital in the global economy seeking profitable returns (Zenghelis, 2012). It results, in many countries, from a lack of public financing capacity and the market perception that investments are high-risk. Financial innovations, including green bonds, risk-sharing instruments, and products which align the risk profile of low-carbon assets with the needs of investors, can reduce financing costs, potentially by up to 20 per cent for low-carbon electricity. National and international development banks should be strengthened and expanded.

3.2.6. Local pollution and congestion

Air pollution has also emerged as a major economic and social cost, with outdoor pollution alone linked to nearly 4 million premature deaths per year (World Health Organization, 2014). The potential for a low-carbon transition to improve air quality in particular is significant (see Figure 3). New analysis for the New Climate Economy

Report (2014) values the health and mortality burden of air pollution in the top 15 emitting countries at an average of 4.4 per cent of GDP. For China, this figure corresponds to more than 10 per cent of GDP (Hamilton *et al.*, 2014). Substituting coal with natural gas and especially low-carbon energy sources such as renewables, hydropower and nuclear can therefore lead to major improvements in public health.

Figure 3. Estimates of health and mortality costs of air pollution



Note: The estimates are for mortality from exposure to particulate matter of less than 2.5 microns in diameter (PM2.5) in particular.
Source: Hamilton (2014).

3.2.7. Energy security

Investment in energy efficiency and clean generation can reduce emissions and reduce dependence on foreign energy imports. For example, India imports more than 50 per cent of the coal it requires and is likely to face higher import dependence in the future[5]. However, for some countries, measures to promote emissions reductions might reduce energy security. For example, countries with plentiful and cheaply accessible coal and lignite reserves might need to shift their energy mix in favour of imported fuels such as natural gas, which produces half the greenhouse gas emissions per unit of electricity generated compared with coal. Additional international support to rebuild energy security might be required to make this transition worthwhile for some countries.

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[5] See for example Planning Commission of the Government of India (2013). *India Energy Security Scenarios 2047*. Available at: http://indiaenergy.gov.in.

In developing countries, decentralised renewables can help provide electricity for the more than 1 billion people currently without access.

3.2.8. Stimulating innovation in technologies

Business models and social practices can drive both economic growth and emissions reduction. Advances in digitisation, new materials, life sciences and production processes have the potential to transform markets and dramatically cut resource consumption. But technology will not automatically advance in a low-carbon direction. It requires clear policy signals, including the reduction of market and regulatory barriers to new technologies and business models, and well-targeted public expenditure.

The New Climate Economy Report (2014) argues that to help create the next wave of resource-efficient, low-carbon technologies, public research and development investment in the energy sector should triple to well over US$100 billion a year by the mid-2020s. However, it must be noted that the technology requirements will differ from country to country and from region to region. Decentralised distributed energy, as well as forest and resource management, may be important technologies in rural parts of developing countries, while smart grids might be key in urban regions. This suggests that, in addition to direct technology transfers, developed countries may also need to support capacity-building mechanisms to allow developing countries to form enhanced partnerships with other countries in order to develop and deploy technologies domestically.

Consistent, credible, long-term policy signals are crucial. By shaping market expectations, such policy encourages greater investment, lowering the costs of the transition to a low-carbon economy. By contrast, policy uncertainty in many countries has raised the cost of capital, damaging investment, jobs and growth. In the long run, there is a significant risk that high-carbon investments may get devalued or ‘stranded’ as action to reduce greenhouse gas emissions is strengthened.

Box 4: Example of benefits at the local level in the European Union

Air pollution

The mitigation of greenhouse gas emissions to achieve the reduction target of 40 per cent compared with 1990 is estimated to reduce air pollution, mainly the emissions of SO_2, NOx and particulate matter, by 17 per cent by 2030. A reduction in air pollution yields health benefits by reducing mortality by about 3.5 per cent, exclusively as a co-benefit of greenhouse gas mitigation (Hof *et al.*, 2012).

Energy security

Fuel import dependency in the European Union, namely total net imports of fossil fuels as a share of primary energy consumption, could be reduced by 2 percentage points from the current level of around 55 percent. At the same time primary energy consumption per unit of GDP could decrease strongly by 15-16 per cent, leading to further reduction in the fossil fuel dependency in the European Union and greater resilience to changes in fossil fuel prices and oil shocks. (Hof *et al.*, 2012).

4. Financing investment needs through international partnerships

The economic and social benefits outlined in the previous sections are potentially within easy reach of developing countries because in general they have relatively cheaper abatement options available to them. However, they often lack the resources to take full advantage of them, which creates the rationale for rich countries to pay for cheaper and more productive abatement overseas in these countries before paying for more expensive domestic options.

If low-carbon investments are fruitful in terms of delivering economic and social returns, then it is reasonable to expect some to be funded by fast-growing developing countries, such as China and India, which have high savings and developed banking systems. However, many of fruitful low-carbon investment opportunities are not easily funded or easily delivered due to a number of barriers identified in previous sections. Moreover, the returns from investment in emissions reductions are less certain than the costs. In many cases the costs may be political or institutional in terms of political opposition from vested interests (e.g. big fossil fuel companies or striking taxi drivers).This could lead countries to be more cautious when assessing the opportunities from climate action. To the extent that the benefits from these investments are also global, the strong case for international support for such investments remains, in particular where it helps overcome specific barriers.

Furthermore, as discussed previously, according to the New Climate Economy Report (2014), the costs of 10-50 per cent of the reductions in emissions needed by 2030 to lower the risk of dangerous climate change cannot be offset by co-benefits.

In this context, international climate finance flows need to increase sharply if climate risk is to be reduced and developing countries are to achieve lower-carbon and more climate-resilient development paths. Developing countries will require help with finance and delivery and access to technologies, as well as capacity-building in project preparation and management.

The existence of local benefits from climate action does not diminish the strong ethical case for developed countries to provide access to affordable finance and support capacity-building in low income countries, especially where they cannot avail themselves of the potential gains without help. Aid is supposed to finance good projects. Indeed, if availability of good projects increases as a result of a more comprehensive assessment of costs and benefits, then that increases the case for aid. Aid should not be focused on projects with poor social rates of return. Moreover, if conventional aid projects also have additional pay-offs for other countries (e.g. because they reduce emissions or alleviate the demand on scarce global resources) then the case for aid, particularly in the form of access to finance and technology cooperation, correspondingly increases.

Investment needs can be met not only through traditional climate finance or aid channels, but through various other forms of partnerships (Combes and Llewelyn, forthcoming). Cooperation can take the form of information exchange, including about best practices (e.g. OECD Country Reviews, IEA Outlooks and the C40 Cities Climate Leadership Group). It can take the form of implicit coordination and the sharing of expectations, as with forecasting exercises by the International Monetary Fund, or it can take the form of more limited multilateral or bilateral agreements, such as the NAFTA or ASEAN trade agreements and various G7 and G20 initiatives. Finally, it can take the form of multi-country agreements, such as the Marshall Plan (1947), European Economic Community (1956), United Nations Convention on the Law of the Sea (1982); the Plaza Accord (1985); the Louvre Accord (1987), and the Montreal Protocol (1987). These can be accompanied by corresponding institutional changes, such as the establishment of the post-World War Two Bretton Woods institutions, the International Monetary Fund, the International Bank for Reconstruction and Development (later World Bank), the Organisation for Economic Cooperation and Development, the General Agreement on Tariffs and Trade (later the World Trade Organisation) and the European Economic Community (later the European Union). Cooperation in the private sector is becoming ever more important with globalisation.

Because international cooperation can proceed at various levels and can evolve from one level to another, outcomes do not have to be 'all or nothing'. Understanding opportunities from emissions reductions better serves countries' interests in pursuing various forms of evolving international cooperation than aiming to negotiate purely on the basis of an 'all or nothing' global agreement based on 'burden-sharing'.

This further favours the development of partnerships, not just binary North-South partnerships but also South-South, for example in the form of research partnerships among developing countries. It also suggests merit in developing sectoral agreements to provide a level playing field for trade while supporting structural transition across sectors. Examples could include sectoral emissions intensity targets and technology-sharing among global steel makers or cement manufacturers, or the sharing of innovative land-use techniques, with assistance for capacity- and institution-building, as well as technologies, coming from rich countries.

5. What does it mean for policy-makers?

This section assesses the consequences of the preceding discussion for policy-makers and considers the potential for moving to accelerated emissions reductions by complementing traditional rights-based approaches to international climate action with an assessment of the benefits they can also deliver. The conclusions will resonate in different ways with different audiences: for treasuries and domestic policy-makers interested in promoting economic growth, the impact of green policies on promoting efficiency and generating economic returns will be powerful. But for negotiators, arguments about equity and responsibility as a means of promoting a fair distribution of cost-sharing will tend to dominate. 'Burden-sharing' arguments remain pertinent to the distribution of residual investment costs.

The combination of ethical principles of *responsibility* and *capacity* with *opportunities* provides a strong basis for re-framing the negotiations over national 2030 mitigation pledges and ‘intended nationally determined contributions’. It also fits with the concept of ‘equitable access to sustainable development’ and the framework of ‘new ways to grow’ or ‘low-carbon growth’ currently emerging as the aspirational basis for the post-2015 framework in the negotiations under the United Nations Framework Convention on Climate Change. This framing allows countries to go beyond the one-sided (and often defensive) approach of determining the minimum acceptable level of their effort based on a corresponding share in the overall burden. Instead it may help them to focus on the maximum affordable level of mitigation ambition that corresponds to broader national interests of sustainable growth and development.

It suggests that the focus of negotiations on future climate action after 2015 could shift away from the assignment of blame and burden, and towards the discussion over:

- What is desirable from the point of view of avoiding global warming of more than 2°C.
- What is desirable and achievable from the national point of view given the co-benefits of low-carbon investment, national development priorities and investment capabilities.
- The ways to finance additional investment required through international, bilateral and other types of partnerships. This could be an important contribution to the efforts to raise ambition amongst the biggest emitters.
- How to most effectively address the 10-50 percent of global emission reductions that are not accompanied by economic co-benefits.

As noted above, targets born of broad equity principles may serve as a guide to the ‘fair’ quantitative distribution of emissions reductions, but a broad awareness among policy makers and ‘society at large’ of the economic implications of such targets is likely to make such pathways politically more feasible, allowing greater scope for integrated policy to unlock economic benefits.

The presence of regional opportunities from low-carbon investment does not diminish the responsibility of richer countries to support investment in poorer countries. The combination of climate and non-climate benefits and international and domestic incentives provides a strong case for partnerships to support pledges and their subsequent implementation. Domestic opportunities with global implications require coordinated support.

This paper does not provide reasons to dismiss completely ‘burden-sharing’ approaches to international action on climate change, but rather points to the potential limitations of ignoring the economic and social co-benefits of reducing carbon emissions. Indeed, ‘burden-sharing’ could help to provide an initial assessment of domestic commitments, while recognising that new opportunities provide the potential to increase global ambition while promoting local development. Indeed, it must not be forgotten that several countries are thinking about their domestic transition as part of a global shift to low-carbon. This can be seen in the European Union's roadmap to 2050, the UK's carbon budgets, California's renewable energy mandates, Korea's green growth ambitions and China's development of renewable and energy efficiency technologies. Delay, 'burden-sharing' and self-interest are not the only drivers to international agreements. Country and regional incentives are for more complex and multi-dimensional than just a race to be the last to move.

In this context, specific practical steps to consider for developing countries at the national level could include:

(i) Identifying and prioritising mitigation opportunities and the associated co-benefits in relation national and sectoral development goals.
(ii) Determining what part of these emission reductions can be implemented with domestic resources and investment, taking into account local co-benefits and also the level of effort that would be required as a minimum based on a combination of 'burden-sharing' approaches (using the latter as a guide to what may be expected in terms of the level of effort by other countries).
(iii) Identifying additional emissions reductions that can be achieved with financial, technological and capacity-building support (to remove the associated barriers), which carry high risks, or which entail political economy, rather than pure economic, costs.
(iv) Negotiating with developed and emerging economies (and also with other non-state partners) about support for a more ambitious levels of action, including actions not necessarily offset by opportunities. This support must in part be based on ethical responsibilities, such as historical responsibility, egalitarian principles and ability to pay. This can take the form of aid, technology cooperation, capacity-building, climate finance and other types of partnerships.
(v) Focusing on the co-benefits of reducing carbon emissions to build domestic political support.

The basic steps for developed countries and emerging economies are similar, in that they should also go through steps (i)-(iii) and (v), and, in addition, determine opportunities for helping to reduce emissions and foster economic growth and poverty eradication in developing countries. This means that under step (iv) they should negotiate with developing countries and other partners about opportunities to help achieve cheaper mitigation through carbon markets and other forms of partnerships, as discussed earlier.

6. Conclusion

This paper concludes that equity expressed as responsibility, equality and capability, remain important criteria for considering the appropriate and fair share of mitigation actions for reducing global greenhouse gas emissions. The results of the analysis presented here show that for the most part, the outcomes differ little between a variety of 'burden-sharing' approaches. In all regions, such approaches mean emissions reductions are determined as a matter of arithmetic - driven by the ambitious end-point target and the growth in economic size of each region. These effects swamp the ethical considerations in determining the distribution of emissions reductions. This suggests that, when taken together, various ‘burden-sharing’ approaches give a reasonable approximation of the sort of target that could be both effective and fair to deliver a given goal.

However, it has become increasingly clear that the standard technology-cost-based MAC approach in isolation is too limited. There is a growing recognition that there are strong opportunities for social and economic returns from investment in emissions reduction for many developing countries that are not captured in narrow MAC analysis. Recognising these opportunities strengthens the case for climate action in most regions, but does not diminish the responsibility of rich countries to support such a transition through technology cooperation, financing and capacity-building. Indeed, investing in domestic opportunities with global implications in terms of reduced emissions requires coordinated support.

Recent evidence suggests that more than half of emissions reductions required to meet an ambitious target generate co-benefits. For the remaining emissions reductions that do not, the principles of ‘burden-sharing’ and responsibility have a role in determining their distribution. Some countries should take greater responsibility for securing a safe level of the atmospheric stock of greenhouse gases, reflecting their wealth and their historical legacy in contributing to the problem. However, this paper finds that it is, in practice, more helpful to look at this from the perspective of growth and poverty reduction in order to successfully take advantage of the many forms of beneficial international cooperation.

Although more work is required to test this proposition, the distribution of mitigation actions that generate net economic benefits (separate from climate benefits) is unlikely to be so unbalanced across countries as to lead to a large shift in the targets required to deliver a given temperature goal. This means that, even before a thorough exploration of these benefits at a national and global level, the targets set out in the first half of this paper can still act as an approximate guide to the level of mitigation that is appropriate at national level to deliver the goal. However, the existence of these benefits means that policy-makers should be less reluctant when considering undertaking such targets.

The ultimate aim of international cooperation in the form of finance, technology cooperation and sectoral partnerships is the support of projects with high domestic returns and global climate benefits. All things being equal, if the availability of good emissions reduction projects goes up as a result of the recognition of new opportunities, it increases the case for supporting the diffusion of technologies, capacity- and institution-building and access to cheap finance.

The findings presented here highlight the need to move away from the narrow principles of ‘burden-sharing’, and towards incorporating the principles of equitable access to sustainable development and new ways to grow. They suggest that there are additional incentives for all countries to strive for and secure an ambitious and comprehensive international agreement to reduce emissions.

Annex 1: Detailed description of 'burden-sharing' approaches

The GLOCAF model includes 'business as usual' (BAU) emissions projections and MAC curves for 24 regions (plus international aviation and maritime, which cannot be allocated to another region so are treated as regions in their own right), and 27 sectors. Modelled data used to produce GLOCAF inputs are calibrated to approximate published IEA World Energy Outlook (WEO) 2013 Current Policies Scenario data. This means that projected totals used for data categories, such as regional level BAU projections, energy demand and power generation, will be similar to the WEO figures. The BAU data and MAC curves were procured through competitive tender from an international energy consultancy (Enerdata) for power and CO_2 sectors, from the Dutch Energy Agency for non-CO_2 gas sectors (Lucas *et al.*, 2007), and from IIASA for forestry and land-use sectors (Kinderman *et al.*, 2008; see Annex 3 for bunkers and peat).

The WEO 2013 Current Policies Scenario does not necessarily take into account all of the policies and measures countries have implemented. The analysis presented here therefore uses a Current Action policy scenario to estimate emissions in 2020, to ensure the analysis of post-2020 action uses an appropriate starting point. The assumptions made include that the European Union delivers a 21 per cent reduction compared with 1990 emissions, the United States meets its 17 per cent 2020 target and China delivers the measure included in the IEA WEO 2013 New Polices scenario. These policy assumptions lead to global emissions in 2020 being 3.6 gigatonnes (6 per cent) lower than BAU.

1. <u>Carbon budget or carbon space based approach</u>

For this analysis, the approach has been implemented as follows:

a) All countries are allocated an emissions budget for 1990-2050, based on the share of the global population over the same period.[6]

b) Each country's remaining budget is calculated for the period 2021-2050 by subtracting its historical and projected emissions for the period 1990-2020 from its allocated budget.

c) Each country is given a linear emissions trajectory for the period 2021-2050 which ensures the total emissions for the period 1990-2050 match the global budget.

d) To ensure the total global emissions match the relevant global target and enable a direct comparison between the 2030 targets suggested by different approaches, each country's emissions are pro-rated up or down so the global

[6] A country's share of global population is calculated as the sum of population for each year for the period 1990–2050. 1990 is used as a base year throughout these approaches due to the Rio Convention acting as a clear milestone for historical responsibility. Using an earlier time reference point will accentuate the extent to which the poorest developing countries have a large surplus of emissions and the highest emitting countries have exhausted their allocation. Allocating only future emissions has the opposite effect but still means developed countries would exhaust their allocation in the coming decades and surpluses for the lowest emitters.

total is the same (e.g. 41Gt). The 2030-2050 trajectory is subsequently recalculated, although this has no impact on the 2030 results.

2. Index based approach

This analysis assumes that the share of mitigation a country needs to implement should be determined by its share of historical emissions in the period 1990[7]–2020. The calculations are as follows:

a) The total mitigation needed is calculated as the difference between the global BAU emissions projection and the global target.

b) Each country's share of historical emission is calculated, based on cumulative emissions from 1990 to 2020.

c) The share of historical emissions is used to determine the quantity of mitigation (in Mt) each country needs to deliver. This is subtracted from their BAU projection to establish their 2030 targets.

3. Contraction and convergence

The calculation steps used in this analysis are:

a) The 2050[8] convergence point is calculated by dividing the global emissions target by projected population in 2050.

b) Each country is given a 2050 target based on the convergence point multiplied by its projected population, and a linear emissions path from 2020 to its 2050 target.

c) To ensure the total global emissions match the 2030 global target (e.g. 41Gt) and to comparisons between the 2030 targets suggested by different approaches, each country's emissions are adjusted up or down.

This approach takes no account of historical emissions (although to some extent there is a correlation between historical emissions and current per capita emissions). Abatement costs are not determinants of emissions reductions and therefore the paths are exogenous to the GLOCAF model and are simply calculated off-model.

4. Common but differentiated convergence

This analysis uses global average per capita emissions as the threshold. Countries above the threshold converge to a 2050 equal per capita emissions target, and countries below the threshold continue with BAU emissions. Per capita emissions are therefore used a proxy for level of economic development.

The approach has been implemented as follows:

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[7] The choice of base year still has an impact although it is far less pronounced than in carbon space based approaches as the share of total emissions shifts less over time (compared to the carbon space approach in which going further back exhausts more of the future allocation).
[8] Other target years for convergence could be used but 2050 is the one usually cited in the literature.

a) The 2050 convergence point is calculated by dividing the global emissions target by projected population in 2050.

b) Countries with emissions per capita above the global average are allocated a linear trajectory to their 2050 targets (based on the target per capita emissions multiplied by their projected population).

c) Countries with emissions per capita below the global average continue with BAU emissions, until they cross the threshold, at which point they also converge to the same per capita emissions by 2050.

d) To ensure the total global emissions match the 2030 global target (e.g. 41Gt), the emissions of countries above the threshold are adjusted up or down.

5. Cost proportional to GDP per capita

Under this approach all country targets are set so that each country faces the same mitigation costs measured as a percentage of GDP. The principle is that wealthier countries pay a higher per capita cost. Mitigation costs per capita are proportional to GDP per capita, making this approach equivalent to a flat tax as a higher income country will pay more in absolute levels per capita but the same proportion of their income as a lower income country. Because this approach takes into account mitigation costs, it is therefore endogenous to the GLOCAF model, which has a regional specification of regional mitigation. An iterative process was used within the GLOCAF model to adjust each country's target up or down until its mitigation costs are within an acceptable tolerance of the global average (e.g. within 0.025 per cent of GDP) and the required global emission target is met.

6. Income classification approach

This is similar to the 'cost proportional to GDP per capita' approach, with the principle that wealthier countries pay a higher per capita cost. Targets are set on the basis of their cost as a percentage of GDP, but a differentiation is made between high income and other countries, with the former being assigned targets that lead to estimated costs that are twice the level of those for the latter, as a portion of GDP. The high income grouping was based on the World Bank income group classifications. As with the previous approach, an iterative function within the GLOCAF model was used to calculate the targets. Again, all countries should reduce emissions below BAU, but countries without a historical legacy (India, China) can increase emissions.

7. Equal marginal cost

This approach is not strictly an ethical 'burden-sharing' approach, but creates a profile based solely on narrow efficiency. It simply distributes emissions reductions across regions and sectors in a way that minimises the global total costs by equating the marginal cost of mitigation across all countries. This means that no given amount of emissions abatement can be made cheaper anywhere in the world. This is not so much an equity principle as an efficiency principle: the distribution of global mitigation is determined purely on the basis of cost-effectiveness as determined by the regional MAC curves. All the most cost-effective projects internationally are selected. In the absence of a global carbon market, these costs would be borne by states and regions.

The GLOCAF model was used to calculate the amount of abatement each country would deliver for the uniform global carbon price that would be necessary to meet the global emissions reductions target. The model gradually raises the carbon price until enough abatement has been carried out to meet the global target. The end result is that the marginal cost of mitigation[9] is the same across all countries.

[9] The extra cost of reducing greenhouse gas emissions by 1 tonne.

Annex 2: Modelling results: Indicative mitigation effort by major emitters under various distributive approaches

Table 1 Modelling scenarios

Scenario	**2030 emissions ($Gt\ CO_2e$)**	**2050 emissions ($Gt\ CO_2e$)**	**Description**
A	34	20	The median level of emissions in 2030 for pathways that deliver a greater than 66% chance of limiting temperature rise to 2°C, excluding those pathways that require the deployment of substantial negative emissions technologies[10].
B	41	28	The median level of emissions in 2030 for pathways that deliver a 50-66% chance of limiting temperature rise to 2°C[11].
C	53	36	The median level of emissions in 2030 for pathways that deliver a 50-66% chance of limiting temperature rise to 2.5°C. This is also within the upper limit of the pathways that deliver a 50-66% chance of limiting temperature rise to 2°C, based on the UNEP (2013) report[12].

[10] Dessens *et al.*, 2014. Review of existing emissions pathways and evaluation of decarbonisation rates, AVOID 2 WPC1, June 2014.

[11] UNEP 2013. The Emissions Gap Report 2013. United Nations Environment Programme (UNEP), Nairobi. http://www.unep.org/pdf/UNEPEmissionsGapReport2013.pdf.

[12] Dessens *et al.*, 2014. Review of existing emissions pathways and evaluation of decarbonisation rates, AVOID 2 WPC1, June 2014.

Table 2 Greenhouse gas emissions targets in 2030 based on a range of effort-sharing approaches under the median scenario B of 50-66% chance of avoiding global warming of more than 2°C without substantial deployment of negative emissions technologies.

	BAU (Mt CO_2e)	BAU	Carbon budget	Brazilian approach	Contraction & Convergence	CBD Convergence	Equal cost	Cost effective	Income based	Median
India	5,297	94%	202%	51%	36%	94%	28%	24%	32%	36%
China	16,786	59%	-22%	20%	-6%	-17%	1%	-3%	4%	-3%
Indonesia	1,274	54%	64%	-6%	3%	54%	-8%	-11%	-5%	-5%
Mexico	852	19%	-20%	-31%	-15%	0%	-21%	-13%	-19%	-19%
South Africa	640	20%	-75%	-39%	-26%	-34%	-29%	-44%	-26%	-34%
Canada	941	16%	-99%	-34%	-33%	-41%	-30%	-27%	-36%	-34%
Russia	2,715	11%	-93%	-40%	-31%	-39%	-27%	-36%	-25%	-36%
South Korea	825	6%	-81%	-33%	-45%	-51%	-34%	-27%	-38%	-38%
USA	6,867	5%	-99%	-45%	-40%	-47%	-35%	-27%	-40%	-40%
EU	4,196	-9%	-65%	-63%	-33%	-40%	-43%	-33%	-48%	-43%
Japan	1,331	0%	-72%	-50%	-34%	-42%	-44%	-29%	-48%	-44%
Brazil	2,359	8%	-72%	-40%	-40%	-47%	-46%	-45%	-45%	-45%
Oceania	819	3%	-98%	-41%	-49%	-55%	-49%	-46%	-52%	-49%

Table 3 Greenhouse gas emissions targets in 2030 based on a range of effort share approaches under the scenario A for greater than 66% chance of limiting global temperature rise to no more 2°C.

	BAU (Mt CO2e)	BAU	Carbon budget	Brazilian approach	Contraction & Convergence	CBD Convergence	Equal cost	Cost effective	Income based	Median
India	5,297	94%	154%	38%	4%	94%	11%	7%	16%	16%
Indonesia	1,274	54%	35%	-24%	-20%	54%	-22%	-27%	-19%	-20%
China	16,786	59%	-35%	8%	-21%	-41%	-22%	-29%	-17%	-22%
Mexico	852	19%	-34%	-46%	-31%	-43%	-32%	-25%	-30%	-32%
South Korea	825	6%	-85%	-46%	-54%	-66%	-40%	-33%	-44%	-46%
Russia	2,715	11%	-96%	-56%	-42%	-56%	-39%	-48%	-36%	-48%
Canada	941	16%	-102%	-50%	-44%	-58%	-43%	-40%	-52%	-50%
South Africa	640	20%	-82%	-57%	-38%	-54%	-43%	-54%	-39%	-54%
Brazil	2,359	8%	-79%	-55%	-51%	-63%	-54%	-52%	-53%	-54%
Japan	1,331	0%	-78%	-66%	-45%	-59%	-50%	-38%	-58%	-58%
USA	6,867	5%	-102%	-60%	-50%	-62%	-52%	-41%	-58%	-58%
EU	4,196	-9%	-73%	-80%	-44%	-58%	-54%	-42%	-61%	-58%
Oceania	819	3%	-100%	-54%	-57%	-68%	-58%	-52%	-63%	-58%

Table 4 Greenhouse gas emissions targets in 2030 based on a range of effort share approaches under the scenario C for pathways that deliver at the top end of the 50-66% chance of limiting global warming to no more than 2°C range and a 50-66% probability of a median 2.5°C rise in temperature.

	BAU (Mt CO2e)	BAU	Carbon budget	Brazilian approach	Contraction & Convergence	CBD Convergence	Equal cost	Cost effective	Income based	Median
India	5,297	94%	279%	73%	86%	94%	65%	66%	67%	73%
China	1,274	54%	-3%	39%	19%	17%	32%	31%	34%	31%
Indonesia	16,786	59%	109%	24%	37%	54%	23%	13%	26%	26%
Mexico	852	19%	3%	-6%	10%	13%	-2%	2%	-1%	2%
South Africa	825	6%	-65%	-10%	-5%	-7%	-6%	-12%	-5%	-7%
Canada	2,715	11%	-96%	-9%	-17%	-18%	-10%	-10%	-13%	-13%
Russia	941	16%	-88%	-15%	-14%	-16%	-8%	-13%	-7%	-14%
South Korea	640	20%	-73%	-14%	-31%	-32%	-14%	-8%	-18%	-18%
USA	2,359	8%	-96%	-20%	-25%	-27%	-15%	-11%	-19%	-20%
Japan	1,331	0%	-61%	-25%	-17%	-19%	-22%	-11%	-26%	-22%
Brazil	6,867	5%	-61%	-16%	-24%	-25%	-21%	-35%	-17%	-24%
EU	4,196	-9%	-53%	-36%	-14%	-16%	-29%	-21%	-32%	-29%
Oceania	819	3%	-94%	-19%	-35%	-37%	-33%	-33%	-36%	-35%

Annex 3: Approach to international bunkers and peat emissions

International bunkers

Some emissions are generated from international aviation and maritime sources, which either cannot be allocated to a particular country or would cause significant economic disadvantage to do so. Therefore they are treated as separate bunkers. However, there is no GDP of aviation, and so cannot be easily allocated in equal cost and income approaches. Similarly for the other four approaches, as there is no population for aviation, it is not possible to calculate a contraction and convergence, or carbon space approach. Therefore, for every approach, the international bunkers were given a target for the mitigation required under the cost-effective approach. The rationale for this is that if all countries are taking ambitious global action it is expected that some action would be required from bunkers – it would be economically irrational for planes and ships not to make some efficiency measures and instead assign more emissions reductions to countries. In the absence of any other option, the cost-effective amount of reductions was decided as a realistic amount for bunkers to undertake.

Peat emissions

For GLOCAF modelling, the allowable emissions are reduced by 1.5Gt to take account of peat degradation and peat-fire emissions. Therefore, if the target is a global emissions level of 41 gigatonnes in 2030, the emissions allocated between all countries would be only 39.5 gigatonnes. The rationale for this is that these are not included in the BAU estimates, and the BAU for Indonesia (where many peat fires occur) in particular appears to be short by around this amount. We considered reducing the 1.5Gt in 2030 by the amount that Indonesia reduces its other emissions, on the grounds that if action is being taken elsewhere it is likely that some action would be taken against peat fires. However, in some scenarios the reduction for Indonesia was not large, so it was felt most justifiable to leave it at the same level as the present day, rather than having different reductions in different scenarios. There is significant uncertainty around acceptable emissions levels for particular temperature rises, so this more cautious approach helps to allow for some of that uncertainty.

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