

Mitigation of Short-Lived Greenhouse Gases as the Foundation for a Fair and Effective Climate Compromise between China and the West

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ABSTRACT

Short-lived greenhouse gases that also contribute to air pollution are playing a major role in global warming. Black carbon alone is likely the second or third most important climate forcing agent. The short atmospheric lifetime of these pollutants means that, unlike CO₂, reducing emissions produces a *decrease* in atmospheric concentration and a reduction of the radiative forcing that drives climate change. Black carbon and tropospheric ozone also have large negative effects at the regional and local level contributing substantially to indoor and urban air pollution and the formation of Atmospheric Brown Clouds that disrupt regional climate. Moreover, technologies to reduce emissions are available, cost-effective, and have already been widely deployed in developed countries.

Reducing these short-lived greenhouse gases is therefore a mitigation pathway for industrializing countries that is both appropriate to their level of development and highly climatically effective. It is also consistent with both responsibility and capability fairness principles, both of which play important roles in the international climate regime. As such, it offers a way out of the current deadlock between developed and developing countries in which each group asks for more substantial emissions reduction commitments from the other before taking action. China, as the world's largest black carbon emitter, should push for substantial CO₂ mitigation commitments from the developed countries in return for aggressive action to reduce its own soot emissions. This action is consistent with China's own development strategy and would contribute substantially to the mitigation of climate change.

Introduction

The U.N. Framework Convention on Climate Change (UNFCCC), signed at the Rio Earth Summit in 1992, sets as its objective the stabilization of greenhouse gas concentrations at a level that would avoid "dangerous anthropogenic interference with the climate" (Article 2). Although 'dangerous' is a perhaps deliberately subjective terminology, a limit of no more than 2 degrees Celsius above pre-industrial temperatures has been widely discussed and was proposed by the European Union as the policy target for global mitigative action (European Commission, 2009). In order to have a reasonable chance of meeting this target, total global emissions need to peak and begin declining no later than 2020 (Meinshausen, 2006).

Despite the urgency of the climate change problem, the current international regime has been relatively ineffective. The Kyoto Protocol that came into force in 2004 limits the emissions of relatively few states and sets a goal of only 5 percent emission reductions below 1990 levels in the 2008-2012 compliance period. Moreover, a number of states including Canada, New Zealand and Japan are unlikely to meet even the limited commitments they have undertaken through the Kyoto Protocol (Barrett, 2008).

Governments are currently negotiating a successor to the Kyoto Protocol, due to be agreed in Copenhagen this December. The likely compliance period (2013-2017) means that this treaty will be critical in determining whether or not global warming is constrained to below the two degrees threshold. A key element of the negotiations has revolved around how to engage major industrializing countries in mitigation activities. Developing countries currently account for only 25 percent of global radiative forcing but this will grow to over 70 percent by 2100 (Moore & MacCracken, 2009).^{1, 2} Developing countries have nevertheless refused to accept caps on emissions, pointing to the substantially larger per-capita emissions in the developed North as well as the historical association between use of fossil fuels and economic development (for example, Singh, 2008). On the other hand, developed nations have pointed to the rapid growth in emissions from industrializing countries as a reason why a future climate agreement should have full participation from major emitters (for example, Connaughton, 2007).

China plays a critical role in this part of the negotiations. In 2006 it surpassed the United States to become the world's largest greenhouse gas emitter. Moreover, its rapid economic growth means emissions grew a remarkable 80 percent between 2000 and 2006 alone (Boden, Marland, & Andres, 2009). Nevertheless, its per-capita emissions are only just above the global average (1.27 tons of carbon in 2006 as compared to an average of 1.25), its per-capita GDP is less than half the global average, and more than a quarter of its population lives on less than \$2 a day (WRI, 2008). China will therefore be a critical player in solving the climate change problem but, along with other developing countries, is wary of any proposal that would require it to cap its carbon dioxide emissions. Overcoming the current deadlock between developed and developing countries will require finding ways around the major standoff over who should reduce CO₂ emissions in order to identify energy sources and mitigation options that are at once consistent with national development strategies in industrializing countries and have the potential to substantially mitigate global warming.

This paper will outline one such strategy, namely the mitigation of short-lived greenhouse gases that are also air pollutants, and will evaluate it with respect to principles of fairness embodied in the international climate regime, particularly the principles of responsibility and capability. The following section will summarize the role played by short-lived greenhouse gases that are also air pollutants and will outline the key

¹ Radiative forcing is a useful measure for directly comparing diverse factors that affect the Earth's climate. Measured in Watts per meter squared (Wm^{-2}), the value describes the equivalent change in net solar irradiance at the tropopause (top of the troposphere) caused by a given climate driver (for example, an increase in greenhouse gas concentration or a change in albedo).

² Based on the IPCC B2 scenario (IPCC, 2000).

elements of the ‘lifetime-leveraging’ proposal. Then the burden sharing of the mitigation effort that would result from such an agreement will be assessed relative to fairness principles based on both responsibility and capability metrics.

Short-Lived Greenhouse Gases and the Lifetime Leveraging Proposals

Climate change has for a long time been considered the quintessential long-term environmental problem with the most serious impacts affecting the grandchildren and great-grandchildren of current decision-makers. While it is true that much of the carbon dioxide released now will remain in the atmosphere for tens of thousands of years, it is also the case that some pollutants are short-lived (i.e., have an atmospheric lifetime of weeks to decades) and have a substantial impact on climate over policy-relevant decadal timescales (Archer, 2005). For example, the atmosphere already contains enough long-lived greenhouse gases to raise global temperature by over 2°C (assuming a climate sensitivity of approximately 3°C). Of that, 0.8°C of warming has already been realized, 0.6°C will be realized as the climate system comes to equilibrium, and the remainder is being offset by the cooling effect of (very short-lived) sulfate aerosols (IPCC, 2007b, p. 204).

Agent Emitted	Net Change in Radiative Forcing in 2005 due to Emissions 1750-2005 (Wm^{-2})	Atmospheric Lifetime	Primary Sources
CO ₂	1.56	Centuries-Millennia	Fossil fuel burning, deforestation and land use change, cement production.
CH ₄	0.86	12 years	Landfills, natural gas leakage, agriculture.
N ₂ O	0.14	114 years	Fertilizer use, livestock sector, fossil fuel combustion.
CFC / HCFC	0.28	100-1000 years	Aerosols, cleaning products and refrigerants.
CO / VOC (O ₃ precursors)	0.27	CO – months VOC – hours (O ₃ – days)	CO – incomplete fossil fuel combustion; VOCs – petroleum production and consumption, solvents.
Black Carbon	0.44-0.9	1 week	Fossil fuel combustion, biomass burning.

Table 1. Change in radiative forcing from 1750 to 2005 due to emission of various agents
Source: IPCC (2007b, p. 33, 207) and new results for black carbon from Ramanathan and Carmichael (2008).

Table 1 summarizes the major warming agents, their relative importance, atmospheric lifetime and principal sources.³ The Intergovernmental Panel on Climate Change (IPCC) estimates forcing from black carbon at 0.44 Wm^{-2} , making it the third most important anthropogenic warming agent after carbon dioxide and methane (IPCC, 2007b, p. 207). New results from Ramanathan and Carmichael (2008) that include observational evidence suggest that warming from black carbon may be as high as 0.9 Wm^{-2} , making it the second most significant warming agent. Black carbon, moreover, has a disproportionate warming effect in vulnerable regions: it is scavenged out of the atmosphere by ice and snow particles, so changing the albedo in sensitive areas such as the Arctic and alpine regions (Hansen & Nazarenko, 2004; Jacobsen, 2004). In addition, black carbon emissions in South Asia have a particular impact on China because many remain in the region and contribute to the formation of Atmospheric Brown Clouds (ABCs), the largest of which sits over the Himalayas where it contributes to the retreat of glaciers on the Tibetan Plateau that form the headwaters of the Yangtze and the Huang He rivers and disrupts the Asian monsoon cycle (Menon, Hansen, Nazarenko, & Luo, 2002; Ramanathan, et al., 2008; Ramanathan, et al., 2007). Tropospheric ozone is not included in Table 1 because it is not emitted directly but the IPCC estimates that it is responsible for 0.39 Wm^{-2} of warming (IPCC, 2007b, p. 207).

Apart from their role in global climate change, black carbon and tropospheric ozone both contribute to air pollution. Approximately 20 percent of black carbon emissions come from the burning of traditional biomass fuels (IGSD, 2008). These emissions are a major component of indoor air pollution, globally the 8th most important health risk factor responsible for 2.7 percent of the global burden of disease (WHO, 2005). In China alone, indoor air pollution is responsible for over 380 thousand deaths a year, or 16 percent of the annual total (WHO, 2007). In addition, both pollutants contribute to urban air pollution, which causes an additional 275 thousand premature deaths in China each year (WHO, 2007). Finally, ozone pollution causes cellular damage in plants and has a substantial effect on primary productivity both in natural and agricultural ecosystems. Ozone-associated agricultural losses in Asia are expected to reach \$8 billion by 2020 (Wang & Mauzerall, 2004).⁴

The multiple order of magnitude differences in atmospheric lifetime shown in Table 1 have significant policy implications. The long-lived greenhouse gases regulated by the Kyoto Protocol are ‘stock’ pollutants in that a reduction in emissions will reduce the rate of increase of atmospheric concentration but can not reduce the total amount of gas in the

³ Although tropospheric ozone and black carbon are collectively referred to in this paper as ‘short-lived greenhouse gases’ for convenience, it should be noted that black carbon is strictly speaking not a gas but a particle aerosol. [Just a grammatical note—“particulate” is an adjective—as in particulate matter, so one needs to use both words, or shorten it to “particle”]

⁴ Ozone is also an important part of what may become a significant carbon-cycle feedback. Warmer temperatures due to global warming accelerate the rate of ozone production which in turn harms forest ecosystems, weakening the land carbon sink and accelerating the build up of CO_2 . Modeling studies indicate that the indirect radiative forcing from this feedback effect in 2100 will be comparable to the direct forcing from elevated O_3 concentrations (Sitch, Cox, Collins, & Huntingford, 2007). Ozone abatement policies can thus directly mitigate global warming while also protecting the land carbon sink.

atmosphere.⁵ In contrast, black carbon and tropospheric ozone are ‘flow’ pollutants, meaning that a reduction in emissions will decrease the atmospheric concentration and the corresponding radiative forcing. Figure 1 shows the implications of this difference for climate policy. Because of its long lifetime, halting emissions of CO₂ today would result in a decrease in associated radiative forcing of only 38% by 2050. In contrast, halting emissions of black carbon, methane and ozone precursors would eliminate the radiative forcing from these pollutants. With the world already flirting dangerously with the two degree warming threshold, mitigation of short-lived greenhouse gases offers one of the only opportunities to actually reduce radiative forcing in the near term, so ‘buying time’ to control and begin reducing emissions of long-lived greenhouse gases.

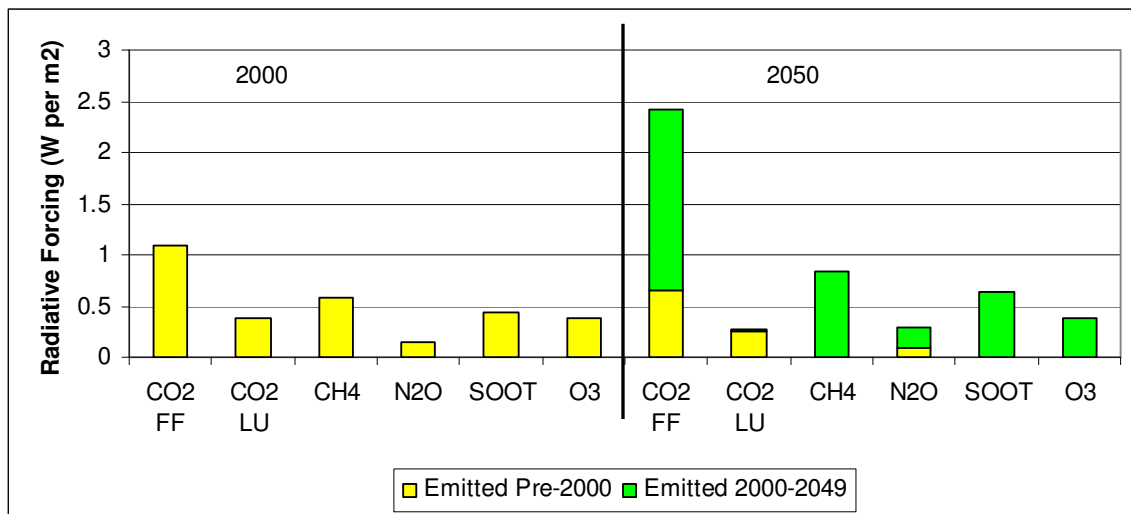


Figure 1. Radiative forcing from CO₂ from fossil fuels, CO₂ from land use change, methane, nitrous oxide, soot (black carbon) and tropospheric ozone in 2000 and 2050. Yellow represents warming from emissions that have already occurred. Green represents warming from emissions taking place between 2000 and 2049 which can therefore be controlled through emissions policies put in place today. Adapted from Moore and MacCracken (2009).

In a 2009 paper, Moore and MacCracken outlined a ‘lifetime leveraging’ proposal for a post-Kyoto agreement that would use mitigation of short-lived greenhouse gases to achieve early reductions in radiative forcing that would offset continued growth in CO₂ emissions from industrializing countries (Moore & MacCracken, 2009). In the ‘lifetime leveraging’ architecture, developed nations (those with a per-capita GDP greater than \$10,000) would commit to ambitious reductions in all greenhouse gas emissions, middle-income nations (per-capita GDP \$3,000 to \$10,000) would commit to similar reductions of black carbon, tropospheric ozone and methane, as well as improvements in energy efficiency and carbon intensity. Countries would graduate between groups and take on additional mitigation commitments as they developed, with graduation based on both per-capita and emissions and per-capita GDP indicators. Preliminary modeling shows that for realistic but ambitious emissions cuts by developed countries, on the order of 80 percent

⁵ Methane, the only one of the bundle of six greenhouse gases regulated by the Kyoto Protocol with an atmospheric lifetime less than a century, is the exception. With a 12 year residence time, methane might be considered a stock pollutant for the purposes of the (5 year) Kyoto commitment period but is a flow pollutant for the purposes of long-term (multi-decadal) policy-making.[good point]

by 2050 and 90 percent by 2100, this proposal would result in an equilibrium temperature increase of between 2 and 2.5 degrees Celsius (MacCracken & Moore, 2009).⁶

In order to be effective, a post-Kyoto treaty must be both climatically rigorous, with a reasonable chance of limiting warming to less than two degrees above pre-industrial temperatures, and within the ‘political-contract zone’ of major emitters if it has any chance of being agreed to and enforced. Climatically, in addition to the sharp emission cutbacks in the developed nations, the key to the ‘lifetime leveraging’ proposal is the early abatement of short-lived greenhouse gases in middle income countries. This action produces a reduction in radiative forcing that offsets continued growth in CO₂ emissions in industrializing nations, which remain uncapped for several decades.⁷ Politically, the question is whether the central trade-off in which middle-income countries begin working on short-lived greenhouse gas mitigation in return for uncapped CO₂ emissions in the near term will be considered fair and politically acceptable to those governments and constituencies. The following sections will consider the fairness question by evaluating the ‘lifetime-leveraging’ framework with respect to the fairness principles of common but differentiated responsibility and respective capabilities embodied in the UNFCCC under Article 3.

Responsibility

Perhaps because it is a principle that can mean many things to many people, the common but differentiated responsibility (CBDR) principle has become near-universal in mitigation burden sharing proposals. CBDR is usually understood to mean that while all nations have an interest in the protection of the Earth’s climate, their duty to protect it is linked to the degree of responsibility they bear for the problem. Nevertheless, its interpretation has not been uncontested since the signing of the UNFCCC in 1992. While developing countries argue that CBDR means they should have no binding emission reduction commitments until developed countries have made substantial progress on cutting emissions, developed nations, particularly the United States, have focused on the ‘common’ nature of the responsibility to argue for universal participation in the mitigative effort (Harris, 1999).

Even if the CBDR principle is accepted in theory, implementing it in practice by assigning mitigation commitments according to some responsibility metric is not a purely objective exercise. Instead, the flexibility of CBDR interacts with national political-

⁶ This would not be the warming in 2100 because the Earth’s temperature takes some time to equilibrate to changes in radiative forcing. Instead this equilibrium temperature rise would be realized over the course of one to two centuries.

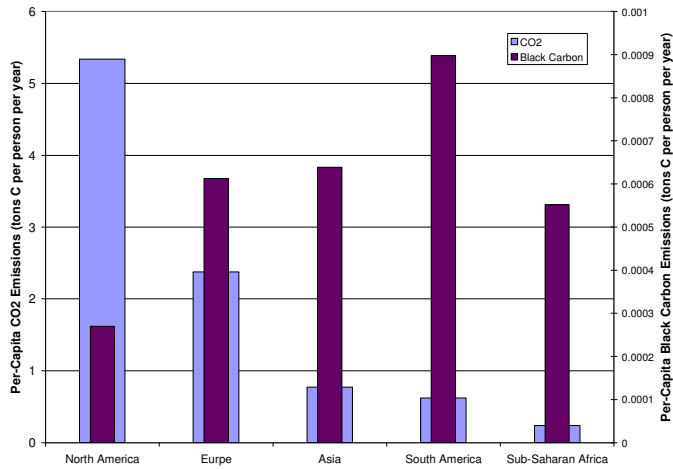
⁷ To the extent that the industrializing nations can begin reducing the growth in their CO₂ emissions and prepare for later beginning to cut emissions back, there would be a further reduction in the warming influence. [One of the interesting results from the EMF-22 study was that the overall costs for mitigation are lower if the industrializing countries early on set the date that they will join in starting to reduce CO₂ emissions—this has the effect that those in the industrializing nations plan ahead and do not keep constructing coal plants right up to the time of the changeover, etc.—so there is a push to get those countries to set a date certain to join in cutting emissions—and this would require looking ahead more than 5 years.]

economic circumstances to produce a multitude of proposed responsibility criteria, usually not unrelated to the self-interest of those proposing them (Ringius, Torvanger, & Underdal, 2002). A principal question is whether responsibility should be differentiated according to current emissions or, given the long atmospheric lifetime of CO₂, whether historic emissions should be taken into account? With a long industrial history, the United States has repeatedly rejected taking past emissions into account (Grubb, 1995).⁸

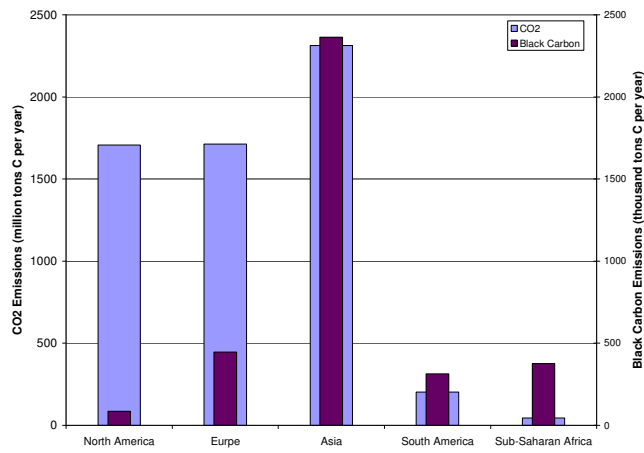
Basing responsibility purely on absolute emissions is also unsatisfactory because it fails to take into account variations in national circumstances between countries. For example, China and the United States produce roughly the same amount of greenhouse gas emissions but China has four times as many people and so many would agree it should be considered less responsible than the US. The principle of per-capita emissions as a metric for assigning responsibility, stemming from the idea that all should have equal access to the atmospheric commons, is perhaps the most widely-accepted responsibility metric (for example, Baer, Athanasiou, Kartha, & Kemp-Benedict, 2008). Nevertheless, other normalizing criteria have been suggested. The Bush administration evaluated progress on combating climate change based on carbon intensity (emissions per unit GDP), reflecting an assumption that economic growth and production are socially-beneficial and should not be sacrificed to protect the climate (White House, 2002). Similarly, Russia, the largest country in the world, proposed that responsibility should be based on greenhouse gas density (emissions per unit land area; Ringius, et al., 2002). This analysis will look at both per-capita, absolute emissions and intensity metrics (since the greenhouse gas density proposal has received little support in the international negotiations), though recognizing that the per-capita principle is better established as a responsibility metric and that significant controversy remains around the use of carbon intensity. The analysis will also focus on black carbon and fossil fuel CO₂ emissions, for which good emissions data are available, as representative examples of short- and long-lived greenhouse gases respectively.

Figure 2 shows emissions of fossil fuel CO₂ and black carbon in major regions, as well as emissions normalized by population and GDP. The per-capita emissions graph is particularly interesting, showing an almost perfect inverse relationship between per-capita CO₂ emissions and per-capita black carbon emissions. North America, with by far the highest level of per-capita CO₂ emissions nevertheless has the lowest per-capita black carbon emissions. Similarly, Asia, South America and sub-Saharan Africa have very low per-capita CO₂ emissions but high black carbon emissions. This difference is a combined result of the deployment of black carbon abatement technologies that has reduced industrial emissions in the US and Europe, inefficient and polluting coal combustion technologies in use in industrializing economies, and the widespread burning of traditional biofuels in Africa and Asia.

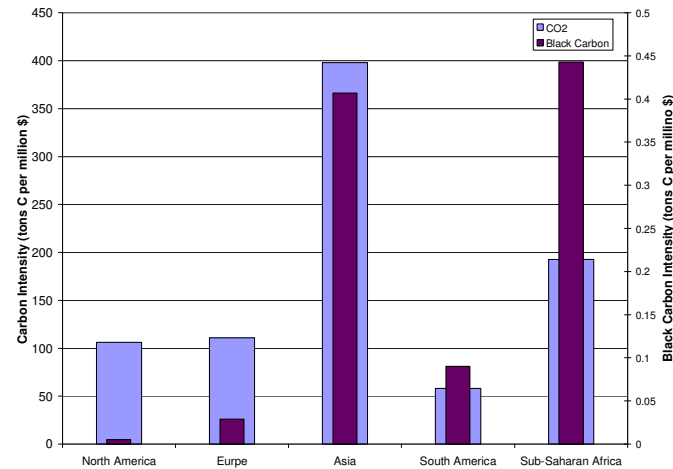
⁸ Note that the question of historic emissions is less relevant for short-lived greenhouse gases because they are rapidly removed from the atmosphere. Nevertheless, because of a lag in the equilibration time between radiative forcing and global temperature, a long history of short-lived greenhouse gas emissions adds energy to the Earth system that has an impact even after emissions have ceased and the gasses have been removed from the atmosphere.



A



B



C

Figure 2. A: per-capita CO₂ and black carbon emissions. B: absolute emissions. C: CO₂ and black carbon intensity (normalized by GDP). (World Bank, 2008; Bond, et al., 2007; UNPOP, 2009; WRI, 2008).

Assigning responsibility solely on the basis of absolute emissions would again result in North America and Europe having high responsibility for CO₂ emissions but far lower responsibility for black carbon. Asia is responsible for high-levels of both while South America and sub-Saharan African release minimal levels of both. In the context of this paper it is interesting to note the relative responsibilities for CO₂ and black carbon emissions. So while North America, Europe and Asia are responsible for roughly equal proportions of total CO₂ emissions (30-40 percent), Asia is responsible for a far greater proportion of the black carbon emissions (66 percent) than either Europe (12 percent) or North America (2 percent). Similarly, Africa is responsible for less than one percent of CO₂ emissions but over 10 percent of black carbon emissions.

Using the carbon intensity metric shows low responsibility in the service-based economies of North America and Europe but high responsibility in both Asia and Africa. As noted above, the intensity metric is of dubious use as an indicator of responsibility because it obscures the historical increase in greenhouse gas emissions associated with GDP growth, which is a key structural fact of the climate change problem. Nevertheless, comparing the most efficient with the least efficient gives an impression of the scope for improvement. So a unit of wealth produced in Asia is associated with 3.5 times more CO₂ emissions but with over 75 times more black carbon emissions than an equivalent unit produced in North America. At first glance, this suggests there may be significant scope for improvement, though this conclusion is questioned by some researchers that point to an offshoring of environmentally-damaging production by rich countries to poorer countries, resulting in artificially low carbon intensities in wealthy nations (Heil & Selden, 2001; Roberts & Parks, 2006, pp. 163-169).

Fairness principles based on responsibility are more difficult to apply than it would first appear because widely varying political and economic national circumstances lead to conflicting claims over fair ways of evaluating responsibility. In a complex and morally-ambiguous world in which understandings of fairness are contextual and socially-constructed, it is counter-productive to arbitrarily select any one definition of responsibility. Instead, a useful way forward is to evaluate multiple metrics and develop policy based on findings that are robust under multiple assumptions. The analysis above shows that under all measures of fairness Asia is responsible for a high proportion of the black carbon problem whereas North America and, to a lesser extent, Europe have a low level of responsibility. In contrast, the two commonly used measures of responsibility (per-capita and absolute emissions) show the developed world as having a large responsibility to mitigate CO₂ emissions. Moreover, all responsibility metrics show the developing world as *relatively* more responsible for black carbon than for the CO₂ problem. In the face of mitigation resource constraints, this finding suggests that it is fair for mitigation actions to be differentiated according to the 'lifetime-leveraging' proposal so that industrializing nations such as China work on reducing long-lived greenhouse gas emissions and industrializing nations work on short-lived emissions and particularly black carbon.

Capability

Although less frequently cited as a principle of mitigation burden sharing than CBDR, differentiating responsibilities based on ‘respective capabilities’ (Article 3, UNFCCC) is also an important principle of the Convention. The principle finds its roots in a long-standing and fundamental tradition of international environmental policy – that developing nations should not have to sacrifice scarce resources to environmental improvement in the face of more pressing basic development needs (Bernstein, 2002). Implementation of this principle has seen many international environmental treaties include temporary exemptions for developing countries or financial transfers from the North to the South to aid compliance with commitments.

In terms of climate change specifically, implementation of the capability principle has been developed through research into the determinants of mitigative capacity. Originally proposed by Yohe (2001), mitigative capacity has been defined by the IPCC as “a country’s ability to reduce anthropogenic greenhouse gases or enhance natural sinks” (IPCC, 2007a, p. 696). The determinants originally proposed by Yohe include the range of viable technological options available to a country or community, the range of viable policy instruments, institutional structure and the stocks of human and social capital (Yohe, 2001). In developing the concept further, Winkler et al (2006) explicitly link mitigative capacity with development pathway and use two indicators of capability, the Human Development Index and per-capita GDP. Similarly, indicators proposed by the World Resources Institute include life expectancy, literacy rate, per-capita GDP and energy use (Jones, 2009 citing WRI, 2008).⁹

A solid theoretical foundation for differentiating mitigation commitments based on capacity (essentially synonymous with level of development) exists in the literature and is being employed in the international climate regime. However, the lack of any empirical evidence that high mitigative capacity actually corresponds to mitigation (Jones, 2009) suggests that the mitigative capacity concept may be playing a normative role in the negotiations: it is not so much that countries with high mitigative capacity (developed countries) can or do mitigate more, so much as they *should* mitigate more. Seen this way, the capability-based fairness principle is already playing an important role in the negotiations.

As can be seen from Table 2, there are significant disparities in the proposed mitigative capacity / development indicators, particularly in the GDP per capita and energy use variables. Not only are the developing countries of Asia, South America and Africa less responsible for the climate change problem (as demonstrated in the previous section),

⁹ In its current formulation, mitigative capacity can become conceptually confused with responsibility because it is generally accepted that the capacity to reduce emissions increases with emissions (note both the technological options determinant proposed by Yohe (2001) and the energy use indicator included by WRI (2008)). This is a result both of the observed relationship between economic development and emissions and of the idea of subsistence emissions (the emissions needed to provide basic human needs) as opposed to luxury emissions that are easier to mitigate (Shue, 1993). This not only makes it more difficult to distinguish between responsibility and capability principles, but also results in the paradoxical conclusion that enhancing mitigative capacity requires increasing emissions (Jones, 2009).

they are also less able to implement solutions. This is may be part of the reason why so much of the climate negotiation process seems to revolve around entrenched divisions between developed and developing countries (Grubb, 1995). Nevertheless, climate change can not be solved by developed countries alone: even if emissions in OECD countries were to go to zero in 2013 after the expiry of the Kyoto Protocol, the two-degree threshold of radiative forcing would be reached before 2050 based solely on emissions growth in the developing world (Moore & MacCracken, 2009). Given that key industrializing countries will have to be part of an effective climate agreement, the rest of this section will ask whether these nations are *more* capable of mitigating short-lived as opposed to long-lived greenhouse gases, again using black carbon and fossil-fuel CO₂ emissions as representative examples.

	Life Expectancy	Literacy Rate	Per Capita GDP	Energy Use
	Years	Percent	\$ per Year (PPP)	Tons of Oil Equivalent per Person per Year
North America	78.1	99	41,141	7.9
Europe	74.8	98.7	21,513	3.8
Asia	68.9	78.4	4,547	1.1
South America	72.4	90.8	8,263	1.2
Sub-Saharan Africa	49.9	59.9	1,755	0.7

Table 2. Selected capability indicators from WRI (2008).

Figure 3 summarizes the key differences between mitigation of short-lived and long-lived greenhouse gases, using the US and East Asia as examples of developed and developing regions respectively. Technologies to reduce black carbon (and to a lesser extent tropospheric ozone) have already been developed and deployed in the United States in order to abate air pollution, resulting in a reduction of black carbon emissions by over half between 1950 and 2000 and by almost three quarters since emissions peaked in 1920. Similar declines have occurred in Western Europe since the 1950s. In contrast, no developed nation has managed to truly bring fossil fuel CO₂ emissions under control and there are no examples of large, wealthy countries with per-capita emissions low enough to be considered sustainable. In other words, it is as yet unclear what a low carbon society with a high standard of living would look like, which is not the case for short-lived greenhouse gases that are also air pollutants.

The fact that air pollution abatement technologies were deployed in the North long before global warming became a serious policy concern speaks to another element of the capability principle. Pollution control confers benefits as well as costs and a country is more capable of controlling pollution to the extent that it can benefit from those efforts – not only does it make it more economically beneficial, but also more politically feasible in that measures can be justified to constituents on the basis of local environmental improvements. However, in the case of long-lived greenhouse gas emissions, this aspect of capability becomes irrelevant because it would require states likely to suffer the most from climate change to be responsible for the most mitigation. This not only runs in direct opposition to the responsibility principle but is entirely impractical given that the most vulnerable states are the least developed countries with extremely limited resources (Ringius, et al., 2002). Nevertheless, in the context of mitigating short-lived greenhouse

gases, which has substantial local and regional co-benefits, the distribution of abatement benefits may have a significant impact on a country's capability to take action.

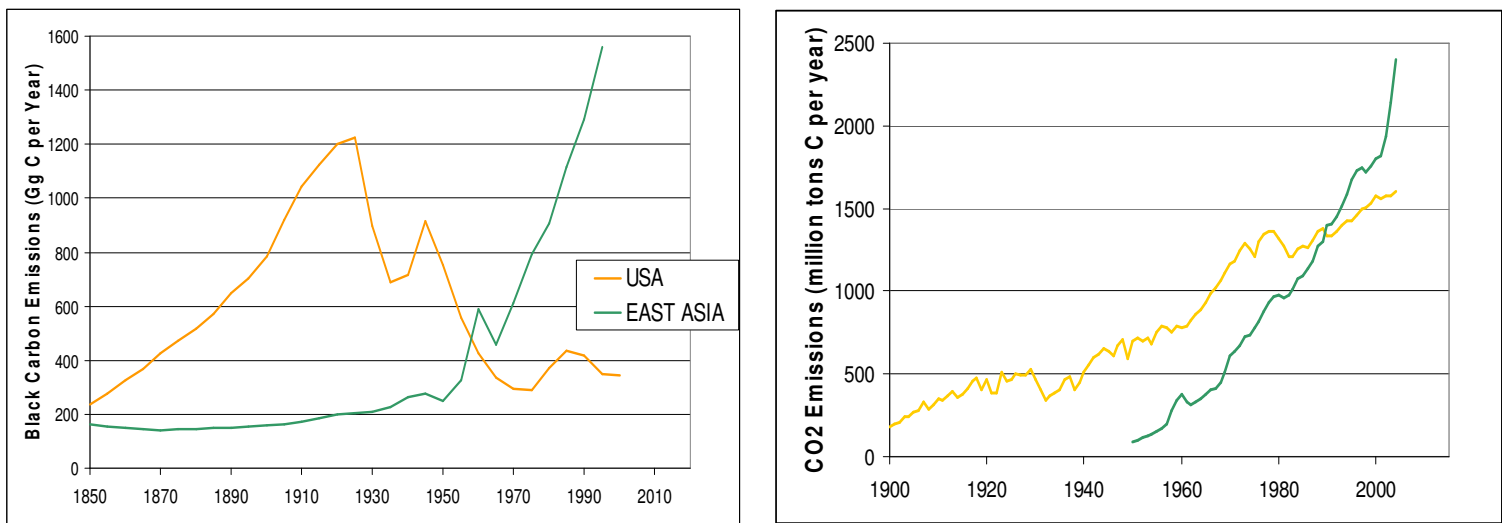


Figure 3. Left – black carbon emissions in the US and East Asia. Right – Fossil fuel CO₂ emissions (Bond, et al., 2007; WRI, 2008).

		Local	Regional	Global
Black Carbon and O ₃	Benefit:	Reduced morbidity and mortality from indoor and urban air pollution.	Reduced ABC formation and associated glacier melt, monsoonal disruption and surface dimming.	Reduced impacts from global climate change.
	Relative Magnitude:	Substantial	Small to moderate	Moderate
	Time Scale:	Immediate	Immediate to decadal	Multi-decadal
Fossil Fuel CO ₂	Benefit:	None	None	Reduced impacts from global climate change.
	Relative Magnitude:	NA	NA	Very Substantial
	Time Scale:	NA	NA	Multi-decadal

Table 3. Comparison of the geographical and temporal distribution of benefits for short-lived greenhouse gases and fossil fuel CO₂ emissions. The magnitude of the benefits is subjectively assessed and is relative to the total benefits for that action. Variations in time scale result from differential responses of different natural systems. Based on Ramanathan (2008) and WHO (2005).¹⁰

¹⁰ Mitigation of fossil fuel CO₂ emissions can have significant side benefits in terms of reduction of co-emitted air pollutants such as sulfates, NO_x, and particulate matter (including black carbon; IPCC, 2007a, pp. 619-690). The magnitude of these benefits will vary depending on mitigation strategies used. For example, they may be substantial for fuel switching to renewables but minimal for carbon sequestration.

Table 3 compares the geographical and temporal distribution of direct benefits from the abatement of short-lived greenhouse gases and fossil-fuel CO₂ emissions. Industrializing countries will be more capable of mitigation to the extent that a greater fraction of benefits occur locally and immediately as opposed to globally and in the distant future. In this respect, it is clear that abatement of short-lived greenhouse gases is a far better fit with the capabilities of industrializing countries in that it would result in an immediately-apparent improvement of local air quality. In fact, governments in developing countries are already implementing policies to improve local air quality: New Delhi is switching the municipal bus system to compressed natural gas to reduce air pollution while Beijing is considering making pollution-control measures implemented for the Olympics permanent (Oster, 2008). Integrating these existing and emerging policies with climate change mitigation efforts could both generate significant improvements for the climate and overcome the developed-developing state deadlock in the negotiations.

It appears from the analysis above that industrializing countries will be more capable of mitigating short-lived greenhouse gases than CO₂ emissions. Not only does the technology to reduce these emissions exist, but it has already been widely deployed in developed countries with demonstrated success. Moreover, these policies were implemented because of air quality concerns alone, which are becoming increasingly serious in major industrializing countries. Many of these countries are already looking to improve air quality. Because of this, incorporating these policies into the climate regime, with its associated financing and technological transfer benefits, is far more likely to be within the capacity of developing countries than setting a cap, even an expanding cap, on fossil fuel emissions.

Conclusions: China and Lifetime Leveraging

Despite the fact that it is still an emerging economy, China, as the world's largest greenhouse gas emitter, is coming under increasing pressure to reduce its role in global climate change. Partly in response to these concerns, the Chinese government has already adopted ambitious energy intensity, carbon intensity and renewable energy targets (Wong & Light, 2009). Moreover, the country is one of the world's largest investors in renewable energy with a rapidly growing wind energy sector and the world's largest solar hot water market (Martinot & Junfeng, 2007). Nevertheless, it has continued to resist accepting a binding cap on its greenhouse gas emissions in the international negotiations (Doyle, 2009).

Adopting aggressive mitigation of short-lived greenhouse gases such as black carbon, tropospheric ozone and methane as proposed in the 'lifetime leveraging' architecture would not only reduce China's contribution to climate change by reducing the atmospheric burden of these pollutants and the associated radiative forcing, but would also address its substantial air quality problems. China contains four of the ten most polluted cities in the world and urban air pollution is responsible for approximately 1 in ten of every death in China (WHO, 2007). Policies to improve industrial combustion efficiency, to replace traditional biomass burning with improved stoves, and to reduce tropospheric ozone formation all have substantial health co-benefits consistent with

China's national development strategy. Moreover, the technology to implement these policies exists and has already been deployed in developed nations.

The analysis above of the responsibility and capability fairness principles has shown that 'lifetime leveraging' would be a fair and highly climatically effective way for China to engage in climate change mitigation. Furthermore, engaging in such a strategy would give China political leverage to demand more ambitious mitigation targets for long-lived greenhouse gases from the developed world, as well as similar cuts in short-lived greenhouse gases from other industrializing nations. Taken together, these actions by developed and industrializing countries would be enough to give the world a good chance of avoiding the two degree threshold and of achieving the UNFCCC objective of avoiding 'dangerous anthropogenic interference with the climate'.

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