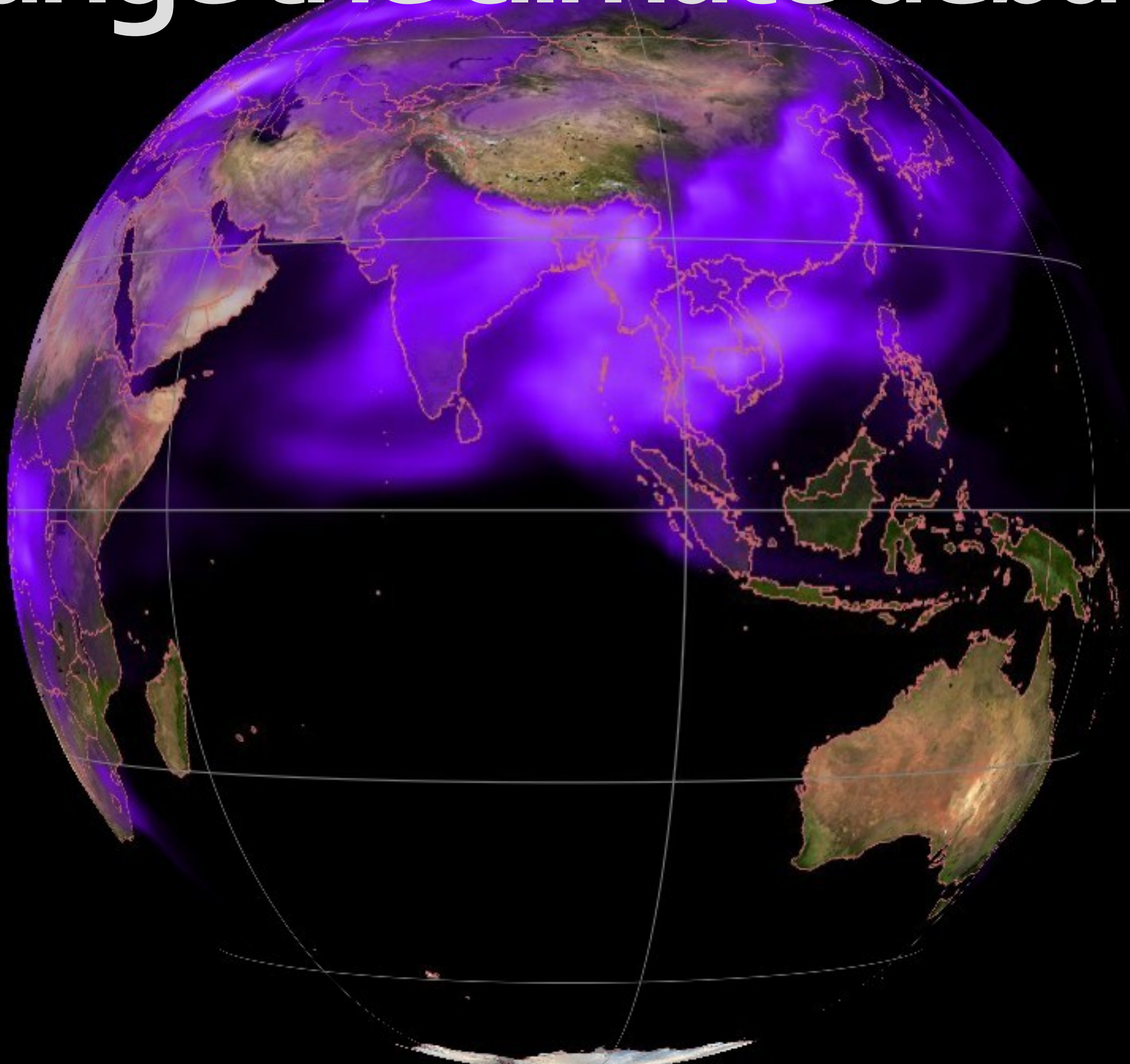
Climate Alert

A Publication of the Climate Institute | *Protecting the balance between climate and life on Earth*

How does black carbon change the climate debate?



With Analysis of

Sources • Effects

Challenges • Solutions

Autumn 2009 — Volume 19, No. 4

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A Message from the President

The past three years have seen a cascade of findings suggesting that climate change may be happening far faster than any of us had anticipated, and that it may be feeding on itself much as a cancer devastates a previously healthy body. However, thanks to recent enterprising work by climate scientists, perceptive analysts, and leaders of small island states, humanity may have an opportunity to prevent catastrophic climate change.

In March 2008, Ramanathan and Carmichael published an article indicating that black carbon, a key component of soot from incomplete combustion of fossil fuels and biomass, plays a very powerful role in the radiative forcing driving the climate change that we are now experiencing. Refining the calculations used by the IPCC in its Fourth Assessment Report published in early 2007, they estimated that the warming caused by atmospheric black carbon between 2000-2003 was equivalent to 55% of the warming caused by atmospheric CO_2 over the same period. Even 55% may underestimate black carbon's total effect, as it does not allow for the changed albedo from deposition of black carbon on Himalayan, Andean and other glaciers and on snow and ice across the planet.

In June 2008, Dr. Michael MacCracken, the Climate Institute's Chief Scientist for Climate Change Programs, wrote a landmark paper proposing North-South reciprocal climate action. Under this plan, richer countries would move on all fronts toward climate stabilization while industrializing countries would focus on reducing emissions of black carbon and short-lived greenhouse gases such as methane, as well as implementing win-win CO_2 control measures such as ending deforestation and increasing energy efficiency. Working with Frances Moore, Dr. MacCracken has proposed a Lifetime Leveraging Framework that would enhance incentives to achieve near- and medium-term reductions. These would include establishing a value for black carbon in emissions trading and related credit systems and moving toward a shorter time period, perhaps 20 years rather than 100, to calculate Global Warming Potential (GWP).

Already, much greater attention is being paid to the need for accelerated reductions of black carbon. The Pacific island nation of Micronesia, working closely with the Institute for Governance and Sustainable Development, has managed to include discussions of black carbon reductions in the ongoing climate negotiations. The United Nations Environment Programme (UNEP) has launched a concerted effort to assess how black carbon reductions might play a role in climate stabilization. The United Nations Foundation, already committed to a clean cookstove initiative to save lives, now sees this effort as having added value in reducing the radiative forcing that is driving much of the current warming, melting polar ice, and threatening island states and coastal regions alike.

There is a huge win-win potential if we can get this right. About 26% of black carbon comes from the residential sector - essentially from incomplete combustion in cookstoves that burn fossil fuel and biomass. The health and climate benefits of transforming the world's stove culture are enormous. Over 1.9 million people worldwide, roughly 85% women and children, die annually from indoor air pollution from stoves. Technologies already exist that can make a difference at manageable costs even if applied to the roughly 780 million traditional cookstoves across the planet: about $100 will buy a solar oven that achieves 100% black carbon reductions, and $25 buys a more efficient burner of biomass or fossil fuel that can achieve 80% reductions. Besides saving millions of lives over the next decade and freeing women from much of the drudgery in biomass gathering, the potential climate benefits are startling. Eliminating all black carbon emissions from cookstoves over 20 years would be roughly equivalent to changing every car and light truck on Earth to a zero carbon dioxide emitter. About 19% of black carbon emissions globally are attributable to the transportation sector (from inefficient two stroke engines, diesel particulates, etc.) and about 8% to the industrial sector. Together with residential sector emissions, these are a major factor in the outdoor air pollution that claims about 800,000 lives each year.

An innovative strategy to slash black carbon may have many elements:

- Establish a value for black carbon in greenhouse trading systems;
- Build black carbon into a life cycle analysis of greenhouse drivers being developed for an ISO that may shape investment patterns;
- Move GWPs to a shorter time frame to encourage more near-term reductions in radiative forcing;
- Foster experimentation with strategies that combine climate and air quality protection (already several states in Central Mexico that hope to have a regional emissions agreement in place before COP 16 seek to include black carbon);
- Highlight benefits of black carbon reductions in reducing particulate deposition in regions such as the Himalayas and thus slowing glacial melt that affects future water supplies;
- Develop a cookstove transformation that engages the ingenuity of grassroots NGOs, entrepreneurs and communications media; and
- Remove barriers to recycling of industrial waste heat for electricity.

It is short-sighted to view black carbon as a problem only for developing countries. In the US, per capita emissions are slightly above the global average. Reductions are underway in the transportation sector due to tougher diesel particulate standards and fleet turnover. Still, archaic anti-competitive rules inhibit energy recycling. Not only do these rules squander low cost reductions of carbon dioxide, they also forego large potential additional reductions in black carbon emissions. A concerted effort in countries North and South alike would not only save many lives but also give hope to the people of the Maldives and Micronesia that they may have a future in the 22nd century. ☼

Commentary by John C. Topping, Jr.

Black Carbon: An Emerging Climate Change Culprit

Sir Crispin Tickell, Climate Institute Chairman Emeritus

In the last few years, climate change in one form or another has entered public debate. Of course global climate and local weather are always changing, but it is the idea that human activities, particularly since the industrial revolution, are responsible for dangerous and accelerating change, that is now causing alarm. Successive Assessments of the Intergovernmental Panel on Climate Change have brought out the role of such greenhouse gases as carbon dioxide and methane in promoting global warming and climatic destabilization, but so far the importance of black carbon, otherwise known as soot has been underestimated. This is now changing as a result of current scientific research, notably by V. Ramanathan at the Scripps Institution at La Jolla.

Soot is usually associated with local pollution rather than global warming. It comes from smoke arising from burning in all its forms, ranging from forest fires, power stations and cooking stoves to diesel exhaust from vehicles. It has created the famous atmospheric brown cloud which, when seen from space, covers much of Asia, and sprinkles black droplets as far away as the Arctic and the Antarctic. The science is far from simple or even certain. Some of the components of black carbon can reflect solar radiation back into space, and therefore have cooling effects. But in general it has warming effects, notably on ice and snow cover, whether at the Poles or along such mountain ranges as the Himalayas and the Andes. It may reduce moisture in the atmosphere and thus affect patterns of rainfall. The monsoon could be particularly affected. It is also profoundly damaging for human health, particularly for those, usually women, who live by home cook fires in India and China.

Radiative Forcing (watts per square meter)	
From IPCC AR4 (2007)	
Carbon Dioxide (CO_2)	1.66 W/m^2
Methane (CH_4)	0.48 W/m^2
Black carbon in the atmosphere	0.44 W/m^2
Black carbon deposited on snow and ice	0.10 W/m^2
From Ramanathan & Carmichael (2008)	
Black carbon in the atmosphere	0.90 W/m^2

In the light of recent research it has been suggested that the warming effects of black carbon exceed those of all greenhouse gases except carbon dioxide. Obviously many uncertainties remain. But at least it should be a prime subject for discussion at the forthcoming meeting of the signatories to the UN Framework Convention on Climate Change (COP 15) at Copenhagen in December. Unlike the effects of greenhouse gases which remain in the atmosphere for hundreds of years, reductions in black carbon could have effects within days or weeks.

It is never easy to attribute responsibility for black carbon emissions, but in global terms the largest emissions come from South and East Asia as a product of biomass burning, and in per capita terms from the United States, Europe and the OECD countries as a product of power generation and use of diesel in cars and heavy trucks. There is obviously room for contentious debate at Copenhagen not only on responsibility for what is already happening but also on issues of human health. We also need properly funded research to improve understanding of an especially complex set of issues.

What then should be done if black carbon emissions are to be reduced? There is the usual difficulty in fixing priorities. They relate to most other issues at Copenhagen. Obviously we need to tackle energy policy, reduce dependence on fossil fuels, improve energy efficiency and invest in new transport technologies. We also need to ban or regulate slash-and-burn clearing of forests, limit combustion of agricultural and other wastes, and introduce new systems for home cooking stoves and heating. Sequestration of biochar will also be important. The list is long and connected with virtually all other environmental problems, including resource depletion, human population increase and migration, and loss of biodiversity.

Perhaps most difficult will be how to combine practical measures on the ground with distribution of financial help between countries. In short, who should pay for what. Still more important will be the creation of some institution to regulate and enforce whatever agreement can be reached. My own view is that sooner rather than later we need a World Environment Organization to be the partner of the World Trade Organization, and coordinate the 200 or more environmental and related agreements which already exist. Reduction of black carbon is too important to become the occasion for point-scoring in conference debate. It is overwhelmingly in the interest of every country and every person in the world. It is also a great opportunity for helping to avert what could otherwise be a climate tragedy of unknowable proportions.

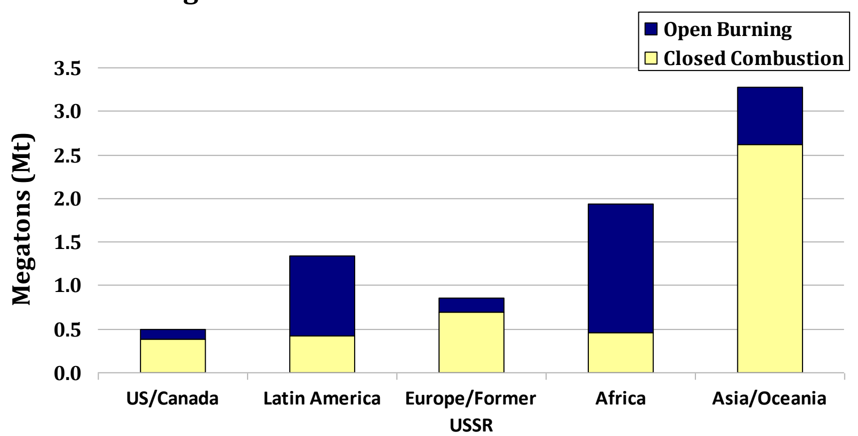
The warming caused by **one ton of black carbon** over its 1-2 week lifetime is equal to: *Based on IPCC data*	The warming caused by **460 tons of CO_2** over a 100-year period
	The warming caused by **1600 tons of CO_2** over a 20-year period

THE ACHIEVABLE PATH TO CLIMATE PROTECTION

Dr. Michael MacCracken, Chief Scientist for Climate Change Programs, Climate Institute

The world is warming, sea level is rising, sea ice and glaciers are melting back, permafrost is thawing, ice sheets are losing mass, ranges of plant and animal species are shifting poleward, and, depending on location and time, extreme precipitation is becoming more intense while drought and wildfire are likewise intensifying. There is no question that the climate is changing, and there is no viable alternative to the primary cause of global warming being combustion of coal, oil, and natural gas. Continuing to rely on these fossil fuels for energy and allowing unconstrained emissions of carbon dioxide will surely lead to much more warming, many more impacts, and quite possibly exceeding thresholds that could greatly accelerate the pace of warming and associated impacts.

Figure 1: Black Carbon Emissions in 2000



Data from: Bond et al, 2007

Even if societies around the world could adapt to all of these impacts, the rising atmospheric CO_2 concentration is pushing more and more CO_2 into the ocean. As this occurs, the ocean is becoming more acidic. The result is that organisms that make their shells and skeletons from the dissolved carbonate are less able to do so. Indeed, the depth in the ocean at which shells and skeletons dissolve is rising toward the ocean surface, especially in the colder waters in high latitudes. But this is a problem as well in lower latitudes, and the CO_2 concentration projected for 2050 will cause ocean chemistry to be unsuitable for coral reefs around the world. Thus, not only are the coral atolls that are home to many island nations threatened by sea level rise, but also by the more acidic ocean waters.

> **The problem is that roughly 80% of the world's energy comes from fossil fuels; the only way to cut CO_2 emissions to near zero is to completely transform the global energy system, and this will take decades, decades the environment cannot easily withstand.**

The world community simply has to take action to halt this destructive onslaught, and many favor taking action. The problem is that roughly 80% of the world's energy comes from fossil fuels; the only way to cut CO_2 emissions to near zero is to completely transform the global energy system, and this will take decades, decades the environment cannot easily withstand.

So, is there no hope? Have we simply waited too long after the first report on this problem went to President Johnson and Congress in 1965? Has all the clamoring about the details of the science not being firm enough cost us the global landscape and coastline on which we all directly or indirectly depend? Are all the conflicts in viewpoint between the developed and developing nations just imitating Nero, playing games while the world starts to burn?

We believe there is still a path through to a world with only modest impacts to the environment and society—but it is a narrow path and the sides are closing in relatively quickly. The world must start acting aggressively and comprehensively to reduce emissions. First, the developed nations, which have relatively high per capita emissions, must make very large reductions in their emissions of CO_2 and the other (i.e., non-CO_2) greenhouse gases. Without such reductions, there is no chance of limiting global warming to the 2°C (3.6°F) increase over preindustrial that is increasingly being recognized as the threshold for 'dangerous' consequences and impacts.

The more challenging question is to define the role for the developing nations, because their contribution to reducing climate change over coming decades has to allow for generation of the additional energy needed to raise their populations out of poverty — basically, if one is not going to survive until next year, it makes little sense to worry about impacts over decades. Fortunately, there are actions that can be taken by developing nations that will both limit climate change and simultaneously improve their economies, their environment, and the health and well-being of their citizens.

> **The under-appreciated path to climate protection is for the developing countries… to substantially reduce their emissions of the non-CO_2 greenhouse gases and climate warming black soot.**

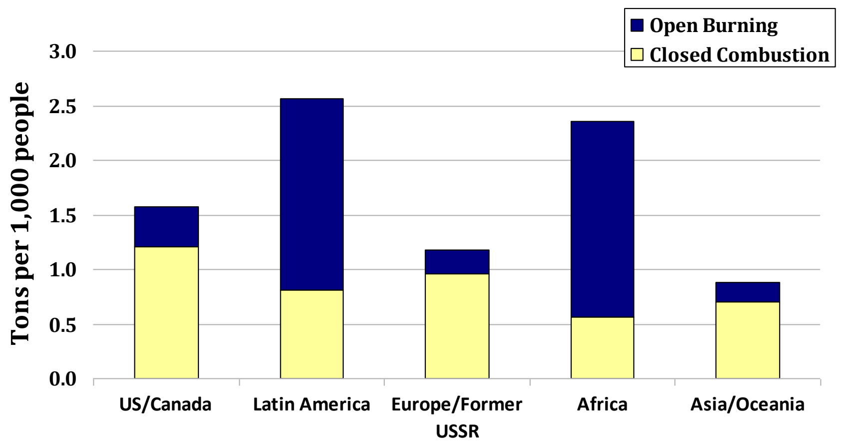
The under-appreciated path to climate protection is for the developing countries, in addition to committing to substantial improvement in energy efficiency (which will improve their economic development) and reversing deforestation (which will help preserve valuable soils and biodiversity), to substantially reduce their emissions of the non-CO_2 greenhouse gases and climate warming black soot. The non-CO_2, and particularly short-lived, greenhouse gases include methane, air pollutants that increase the tropospheric ozone concentration, and black carbon, which is the subject of this issue of *Climate Alert*.

Each of these species exerts a very large warming influence on the atmosphere compared to the same mass of emissions of carbon dioxide. For methane the ratio is 22 if integrated over 100 years, but, more importantly, is 75 if integrated over the 20 years when its influence is strongest. Methane (CH_4) emissions can be economically reduced by capturing leaks from coal mines (causing explosions if not evacuated), waste treatment, landfills, and the fossil fuel distribution system. Even emissions from agriculture (rice growing, ruminants, etc.) can be substantially reduced. Once captured, methane (chemically equivalent to natural gas) is an energy source, which helps to pay for its capture.

The air pollutants leading to tropospheric ozone include emissions of volatile organics, nitrogen oxides, and carbon monoxide. The largest ozone influence is typically in and around major cities where the more common name for this mixture is photochemical smog. For the health and well-being of their citizens, it is vital that developing nations reduce their high pollution levels, and many are already setting automobile emission standards to do just this. Not only will such actions improve health, but they will also lead to lower costs by improving fuel efficiency and, fortunately, and quite fortuitously, these actions will also help to limit global warming.

For black soot, the case is even stronger. Emissions of black soot are just throwing away unburned fuel, plus they are a very important health threat. With respect to their climatic influence, on a per unit mass basis, black carbon exerts a warming influence hundreds of times as much as CO_2; in addition, if the black carbon is deposited on mountain glaciers, melting is accelerated, and so greatly affecting water resources. Cost effective technologies exist to reduce these emissions, as has largely, but not yet sufficiently, been accomplished by the developed nations.

Figure 2: Black Carbon Emissions 2000, Per Capita



Data from: Bond et al, 2007; UN Statistics Division

Thus, not surprisingly, although developing nations are generally unwilling to accept hard limits on their overall CO_2 emissions as that would relegate their people to a seriously limited standard of living, reducing their emissions of methane, ozone-producing pollutants, and especially black carbon would substantially reduce the near-term warming influence of their overall emissions and temporarily offset the growth in warming influence caused by their ongoing CO_2 emissions. By contributing in this way until the developed countries demonstrate how a modern economy can prosper with low per capita greenhouse gas emissions, the developing nations would be making a very substantial contribution to the partnership that must develop among all nations in order to have a good chance of really protecting the climate.

Further black carbon reading from Climate Institute authors:

Scientific Expert Group on Climate Change (SEG), 2007: *Confronting Climate Change: Avoiding the Unmanageable and Managing the Unavoidable*, Rosina M. Bierbaum, John P. Holdren, Michael C. MacCracken, Richard H. Moss, and Peter H. Raven (eds.), Report prepared for the United Nations Commission on Sustainable Development by Sigma Xi, Research Triangle Park, NC, and the United Nations Foundation, Washington, DC, 144 pp.

MacCracken, M. C., 2008: Prospects for Future Climate Change and the Reasons for Early Action, *Journal of the Air and Waste Management Association*, **58**, 735-786.

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Moore, F. C., and M. C. MacCracken, 2009: Mitigation of Short-Lived Greenhouse Gases as the Foundation for a Fair and Effective Climate Compromise between China and the West, submitted to the Conference on China and Global Climate Change, June 18-19, 2009, Lingnan University, Hong Kong, China. Conference website: http://www.ln.edu.hk/caps/conference.php

Moore, F. C., and M. C. MacCracken, 2009: Lifetime-leveraging: An approach to achieving international agreement and effective climate protection using mitigation of short-lived greenhouse gases, *International Journal of Climate Change Strategies and Management* **1**, 42-62.

Opportunities to Reduce Black Carbon Emissions

John-Michael Cross

Black carbon is a major contributor to climate change. Fortunately, technologies to reduce black carbon are, for the most part, available and cost-effective. The primary obstacles to black carbon mitigation are the distribution and adoption of these technologies. Black carbon emissions per capita are spread fairly evenly by region, (see Figure 2 on p. 5) meaning mitigation must be a global effort. Countries should adopt appropriate technologies according to each country's emissions profile and economy.

Eight megatons of black carbon are emitted annually. Of that, 4.7 megatons, or 59%, are emitted through closed combustion sources, including cooking fires and diesel engines. The remaining 41% is emitted through the open burning of biomass. (See Figure 4 on p. 7) For the purposes of this article, open burning will be set aside, as it is too intertwined with the issues of deforestation and land degradation to go into detail here. Offered instead are means to reduce emissions in the three key areas of closed combustion: residential, transportation, and industrial sources.

Residential emissions constitute 26% of global black carbon. Emissions result from inefficient combustion of fuel for home heating and cooking, largely in the developing world. Wood and coal use account for two-thirds of residential black carbon, with the rest from burning agricultural residue, animal waste, and diesel fuel.

Portable cookstove technology is the primary short-term solution to address residential black carbon. Longer-term options are tied in closely with development, such as the ability to cook with electricity or gas. The two main categories of portable cookstoves are improved-combustion stoves and solar-powered stoves.

Solar stoves eliminate the need for fuel and thus emit no black carbon. This alone makes solar stoves a promising option, but the technology presents several issues. For one, as is the case with any solar technology, lack of adequate sunshine makes the stove inoperable, which limits its usefulness. There are also durability issues, as well as cultural barriers to switching to non-flame-based heat, as this will have an effect on the taste of food. Finally, the cost of some models, US $100 for a single-family stove and $400 for a community stove, will likely prove prohibitive when compared with improved-combustion stoves.

Improved-combustion stoves use traditional fuels, but with an optimized airflow that reduces emissions through cleaner burning and improved fuel efficiency. Black carbon savings vary by stove design, with the high end roughly near 50%. Stoves have mostly been designed to reduce particulate matter in general, but stoves engineered specifically for black carbon could potentially see reductions closer to 80%. Envirofit International, a non-profit clean energy product developer, has designed a cookstove that reduces total particulate emissions by 80% and fuel consumption by 60%. The cookstove, which retails for US $25 and comes with a 5-year warranty, has sold 60,000 units in India in the past year and will soon be introduced to new markets.

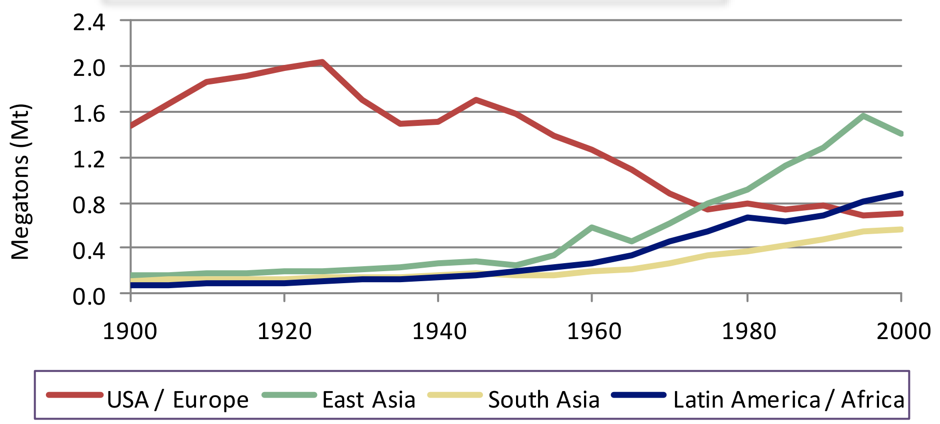
The transportation sector emits nearly 19% of global black carbon. On-road engines account for 62% of these emissions, with the remainder due to off-road sources such as ships, trains, construction vehicles, and farming equipment. Both on- and off-road emissions are predominantly attributable to diesel fuel use. Black carbon from transportation is heavily concentrated in urban areas; reducing these emissions will lead to improved urban air quality.

Reducing black carbon from the transport sector first requires an upgrade to higher quality, low-sulfur diesel fuel. In many countries, the sulfur content in diesel is often 500 parts per million or higher. Black carbon reductions are best achieved with the use of ultra-low sulfur diesel (ULSD), defined as 15 parts per million sulfur or less. In the United States, ULSD costs a premium of US $0.08 per gallon at retail.

On its own, ULSD only marginally reduces black carbon. It must be used in tandem with improved engine technologies to achieve the maximum benefit. Thus, there is a need to accelerate the turnover of diesel fleets to new, more efficient models. 2007-model diesel engine buses and trucks emit 90% less pollution than 2004 models, including a 99% reduction in black carbon and other fine particulates. Ensuring that these standards are present in all of the 350,000 buses sold globally each year will lead to large gains as fleets turn over. Accelerating the rate of turnover

Figure 3: Black Carbon Emissions from Closed Combustion 1900-2000

Data from: Bond et al, 2007



Local Air Pollution and Human Health

Dr. Devra Davis, Climate Institute Board of Directors; Author, When Smoke Ran Like Water

Much of the public discussion on climate change has been focused on long-term effects such as warmer temperatures, higher sea levels, extreme weather events, alterations in the ecology of infectious diseases, and radical changes in land use. However, what is frequently left out of the conversation is the fact that some of the same actions that reduce the long-term accumulation of greenhouse gases (GHG) can also yield powerful benefits to public health in the short-term by reducing the adverse effects of local air pollution. Decreasing fossil fuel combustion will reduce GHG emissions and simultaneously reduce associated co-pollutants that affect human health: black carbon is one such co-pollutant.

Black carbon, as a component of soot, can constitute a major component of air pollution as either an aerosol or suspended particulate matter. Found in both indoor and outdoor air pollution, black carbon can have a variety of negative impacts on human health. Worldwide, three billion people rely on traditional cooking and heating methods, which comprise the main source of indoor air pollution that typically includes black carbon as a major component. The WHO estimates that as a result of indoor air pollution, 1.9 million people die each year. The great majority of deaths from this pollution, some 85%, occurs in women and children. Overall, more than half of the burden from air pollution on human health is borne by people in developing countries as a result of traditional cooking or heating methods in the home. In addition, citizens in these regions usually lack access to cleaner technologies in industry and transportation, two sectors that contribute the most black carbon to outdoor air pollution.

Scientists have long understood that the size of particles is directly linked to their potential for causing health problems: smaller particles less than 10 micrometers in diameter pose the greatest problems because they can infiltrate deep into the lungs. Those particles that are small enough to slip through the cell

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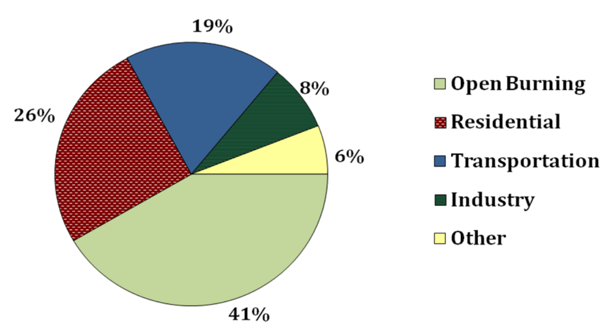
will yield greater short-term benefits. Natural gas-fueled vehicles are a low-black carbon alternative, but are more expensive and require a separate fueling infrastructure.

Figure 4: Global Black Carbon Emissions, by Sector



Data from: Bond et al, 2004

Realistically, many developing countries will continue to rely on older, heavy-polluting diesel vehicles, and a healthy market for used buses and trucks will continue to exist. Engine retrofits can be used to reduce black carbon from older vehicles. One such retrofit is the diesel particulate filter (DPF). The filter is inserted as part of the vehicle's exhaust stream and can be used in both on- and off-road vehicles. DPFs typically cost between US $5,000-7,500 and reduce particulate matter (PM) emissions, black carbon included, by 85 to 97%. However, these results have only been achieved on models built since 1994. Like new engines, DPFs only work well when in combination with ULSD.

One final method of reducing black carbon from transportation is to phase out the use of two-stroke engines. Two-strokes are highly popular in the developing world both for scooters and motorized rickshaws. Four-stroke engines, while more expensive and larger, offer similar performance and greatly reduce black carbon and other pollutants. One two-stroke scooter emits fifty times the particulate matter that a car does. Retrofit technology transforms two-stroke engines into fuel-injection engines, reducing emissions by 70% at a cost of $350. However, the logistics of retrofitting a substantial number of existing two-strokes are difficult. Black carbon reductions may be best achieved through regulation and economic incentives to steer new scooter and rickshaw purchases toward four-stroke and fuel injection technologies.

Emissions from **the industrial sector** account for 8% of global black carbon. While coal-fired power plants may come to mind as the culprit, in truth they emit just 0.1% of the annual total, mostly from older plants that are being phased out. Coal indeed is the source of industrial black carbon, but the vast majority is due to the coal used in iron and steel production. Coal is used in these industries to fuel coke ovens and blast furnaces. Modern techniques and existing emissions trapping technologies can significantly lower black carbon emissions. Proper regulations and self-monitoring in heavy steel and iron-producing countries, combined with technology transfer, can bring about swift drops in industrial black carbon.

Substantial black carbon reductions are possible in the transportation, residential, and industrial sectors. The technologies to do so are largely already available at competitive prices. Wider distribution, combined with economic assistance and incentives, will likely lead to large scale adoption of these technologies. Reduced black carbon emissions results in greater economic efficiency, improved human health, and cleaner air. These reasons alone warrant aggressive action on black carbon. It is, however, the opportunity to mitigate the severity of near-term climate change that gives the international community the greatest incentive to implement these technologies immediately.

The High Stakes for Small Islands

Hon. Tom Roper, Climate Institute Project Director, Global Sustainable Energy Islands Initiative

Global warming and climate change are accelerating. The grave conclusions of the last Intergovernmental Panel on Climate Change Report (IPCC) are being overtaken by events. Emissions of carbon dioxide, the most common greenhouse gas, grew at a rate of 3.5 percent per year between 2000 and 2007, up from 1.1 percent between 1990 and 1999. Temperatures are increasing. Sea levels are rising some 3.1 mm per year.

Nowhere is the urgency of climate change more visible and immediate than in Small Island Developing States (SIDS). Already, many Pacific countries report regular flooding, and in Papua New Guinea, the world's first climate refugees are being evacuated. They are unlikely to be the last. John Church, one of the lead authors of the most recent IPCC Report's chapter on sea level, predicts a 21st century sea level rise of at least 1 metre. NASA's James Hansen predicts 2 metres. Even a sea level rise of half a metre would place SIDS like Tuvalu, the Marshall Islands, Kiribati, and the Maldives in existential danger.

The plight of Small Island States, which have been responsible for less than 1 percent of global greenhouse gas emissions to date, demands immediate and drastic action. But progress on a new international climate agreement has been slow, and even if major emitters were able to mobilize swiftly to reduce their carbon dioxide (CO_2) emissions, the CO_2 that has already been emitted will remain in the atmosphere for centuries to come, continuing to warm the earth. At current rates of sea level rise, SIDS can not afford to wait for centuries. Reductions in emissions of short-lived greenhouse gases, especially black carbon, will be necessary to buy time for these most vulnerable members of the international community.

While rising sea levels may be the most obvious threat they face, SIDS will also be exposed to increasing extreme weather events. Higher temperatures will bring more heat waves, and higher sea levels will exacerbate flooding during storms and king tides. More frequent floods will bring salt water incursions, threatening islands' meager water resources. Higher temperatures will also change sea water chemistry, endangering reefs and fisheries that sustain the islands' environment and economy. Altered weather patterns will change the ranges of disease-carrying species, increasing islanders' exposure to new illnesses.

Courtesy of the Associated Press

The Maldives held an underwater cabinet meeting to demonstrate the urgency of sea level rise

Small Island States are already at the mercy of the elements. In 2008, the insurance company Munich Re reported that in Oceania, 50 natural catastrophes such as storms, cyclones, and flooding caused US $2.4 billion of damage, some half of which was in the Islands. In April 2004, Cyclone Sudal destroyed or damaged 90 percent of homes in Yap. Many scientists believe that higher water temperatures, which hit a record in June and July, make cyclones more powerful and multiply their threat to life and property.

The governments of Small Island States have been active in educating the world of the dangers, and they are increasingly setting an example by adopting ambitious targets for reducing their own dependence on fossil fuels. At the Alliance of Small Island States summit on September 21 of this year, the representatives of the SIDS declared, "While SIDS contribute the least to global emissions, and have limited human, financial, and technical resources, our nations continue to take significant actions towards the reduction of our own emissions." As a symbolic gesture of the dangers to come, the President of the Maldives called an underwater meeting on October 17 for his cabinet, who wore scuba gear.

For the SIDS, most of whom generate 100 percent of their power from imported diesel, transitioning to renewable energy makes good economic sense. These small, largely resource-poor economies are as vulnerable to changes in the price of oil as the islands are to the changing climate. Higher diesel prices have had a huge impact on both national balances of payment and national economies. Some islands can barely afford for the tanker to call. Last year Kiribati fuel imports were 25 percent of GDP. Customers in the Cook and Solomon Islands are paying US $0.50 or more per kWh. Majuro residents were taking out light bulbs and turning off necessary appliances.

Renewable energy, including wind, solar, hydro, biomass, and even coconut oil, is now cost competitive with diesel. More and more, islands are turning to renewable energy to provide their residents with power. Individual systems are beginning to provide light to the 70 percent of Pacific Islanders with no access to the diesel-based grid, as countries like the Marshall Islands plan to "solarize" their outer atolls. The Global Sustainable Energy Islands Initiative (GSEII) has partnered with islands in the Pacific and Caribbean to develop sustainable energy plans, investigate renewable energy options, improve energy efficiency, and educate residents about the benefits of mitigation.

But GSEII and our island partners know that unless the major emitters can learn from the islands' example and act soon to reduce heat-trapping emissions, the SIDS will have to spend all of their resources on adaptation to our changing climate. Currently, financing for adaptation and mitigation efforts on SIDS is inadequate. All too often donors are generous with emergency aid but miserly with funds to reduce future impacts. The SIDS are littered with too many failed

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Community-level Technology Transfer

Lynn Kirshbaum

Technology transfer has been central in climate change discussions between developed and developing countries. Though much of this debate has focused on cleaner high-tech, industrial technologies at the state level, transfers of simpler technologies for community or individual household use are also essential for black carbon reduction. At the individual level however, there have been social, cultural, and institutional barriers to adoption of new technologies. The implications of reducing black carbon are immense for climate change, but technologies intended to mitigate black carbon emissions are useless if not implemented effectively.

Since the 1970s, governments and non-governmental organizations in the developing world have promoted improved cookstove programs with varying degrees of success. The efficacy of a new technology's implementation can be attributed to factors in three overarching categories: financing, local conditions, and community involvement.

Financing

Financing is an integral component of any new technology program, especially at the individual level. Whether a new technology is affordable can be a key determinant in its widespread adoption. Subsidies provided either by the host government or by donor countries or organizations can make new technologies affordable, but ultimately diminish the value placed on them by the users. In western Africa, for example, the market for improved stoves decreased dramatically in the late 1980s when there was no longer project financing by the state or by international donors. Such examples have led many in the development community to believe that new products and technologies should not be given out for free or at a drastically reduced cost. Various cases have shown that a consumer is more likely to value and use a product she had to pay for than one that was given to her for free. Therefore, programs should require users to purchase new products so as to reinforce their value and encourage their use. Nepal's latest improved stove program, which began in 2000 and gave no subsidies to end users, demonstrated that such a program could be successful, and suggests that in fact "direct end user subsidy should be discouraged for the continued use of ICS and the sustainability of the program."

However, new clean technologies cannot be priced equivalently in developing and developed countries, and inappropriate pricing schemes have been the downfall of many new technology dissemination programs. In an improved stove program in Nicaragua, the initial price of a new stove (US $35 and $45 for two different models) was too high for potential buyers, being equivalent to about one month's salary for many households. Though people were interested in purchasing the cleaner technology, the initial mispricing of the stoves ultimately caused the program to fail even after the program organizers lowered prices and employed credit mechanisms. Pricing a new product too high will disallow individuals from purchasing it, even if they desire to adopt the new technology.

Local Conditions

New technology implementation is greatly affected by the conditions within a particular country or community. Even different regions within a country will have varying levels of success with the same product due to different hyper-local conditions. First, the rural-urban divide affects the adoption of a technology: while urbanites buy the products they need, in rural areas those same products are grown, made or traded by individual households within a community. Prior to a USAID program in Bangladesh, "the households in the target communities did not typically purchase stoves, but instead constructed them at home," adding another challenge to the program's implementation. Furthermore, any new technology that is implemented effectively on a broad scale must be accessible to residents of both urban and rural communities: sound infrastructure, availability of information, and replacement components of new technologies are important for sustained adoption.

The extent to which a new technology is transferable to a community will also greatly affect the extent to which it is adopted. Technologies that are not perceived as better or do not fit with traditions will not be embraced. Improved technologies that use materials that are not native or readily available on the local market will fail. Though use of easily attainable materials is an important factor, so is the local production capacity: local producers that cannot meet local demand will be ineffectual in promoting adoption and sustained use of new technologies. Inability to meet demand could arise from a lack of materials, production equipment, or workers. Ensuring that these three resources are available to local producers will help to promote the success of an improved technology program.

Community Involvement

Community engagement in designing and implementing new technology programs greatly enhances their success: new technologies that are attuned to local needs and are promoted by local people are more likely to not only be adopted, but to enjoy sustained use and improvements. A community that is aware of its need for improved technology will be far more likely to adopt it. In the case of cookstoves, those communities that lack fuel wood or understand the health impacts of traditional cooking methods are more eager to adopt a new program. Community members should also be involved in the design and production of new technologies, as programs that do not employ traditional designs or local producers are more likely to fail. The engagement of women is also an effective method of increasing the success rate of new technologies, especially those that are primarily used in the home, such as cookstoves.

New technology implementation is by no means guaranteed even with the most well-planned programs, but success rates can be increased drastically by considering the factors outlined above. By ensuring that these challenges to implementation are overcome, new technology programs will be much more effective.

Reassessing Responsibilities

Fran Moore, Yale School of Forestry and Environmental Studies

As laid out in other articles in this issue, it is increasingly apparent that black carbon is playing an important role in global climate change and, because of its short lifetime, offers substantial opportunities to *reduce* radiative forcing. In a paper published in 2009 (available on the Climate Institute website), Michael MacCracken and I outlined the 'lifetime leveraging' proposal – a framework for an effective climate change agreement in which high-income countries commit to substantial reductions of all greenhouse gases while middle-income nations work to reduce short-lived greenhouse gases such as black carbon, methane and ozone until they are rich enough to begin reducing CO_2 emissions.

This article evaluates the lifetime leveraging proposal with respect to the UNFCCC principle that mitigation burdens should be shared according to the common but differentiated responsibility and respective capabilities of nations. This principle is reiterated in the Berlin Mandate (1995, paragraph 1), the Kyoto Protocol (1997, Article 10), the Marrakesh Accords (2001, paragraphs D and H) and the Bali Roadmap (2006, paragraph 1).

Responsibility

The common but differentiated responsibility (CBDR) principle has become near-universal in mitigation burden sharing proposals. Despite its ubiquity, multiple metrics for responsibility have been put forward by countries. Figure 5 shows three of the more commonly used responsibility metrics for fossil fuel CO_2 emissions and closed combustion black carbon emissions: absolute emissions, per-capita emissions, and emissions intensity. Emissions from land use changes and open burning are excluded.

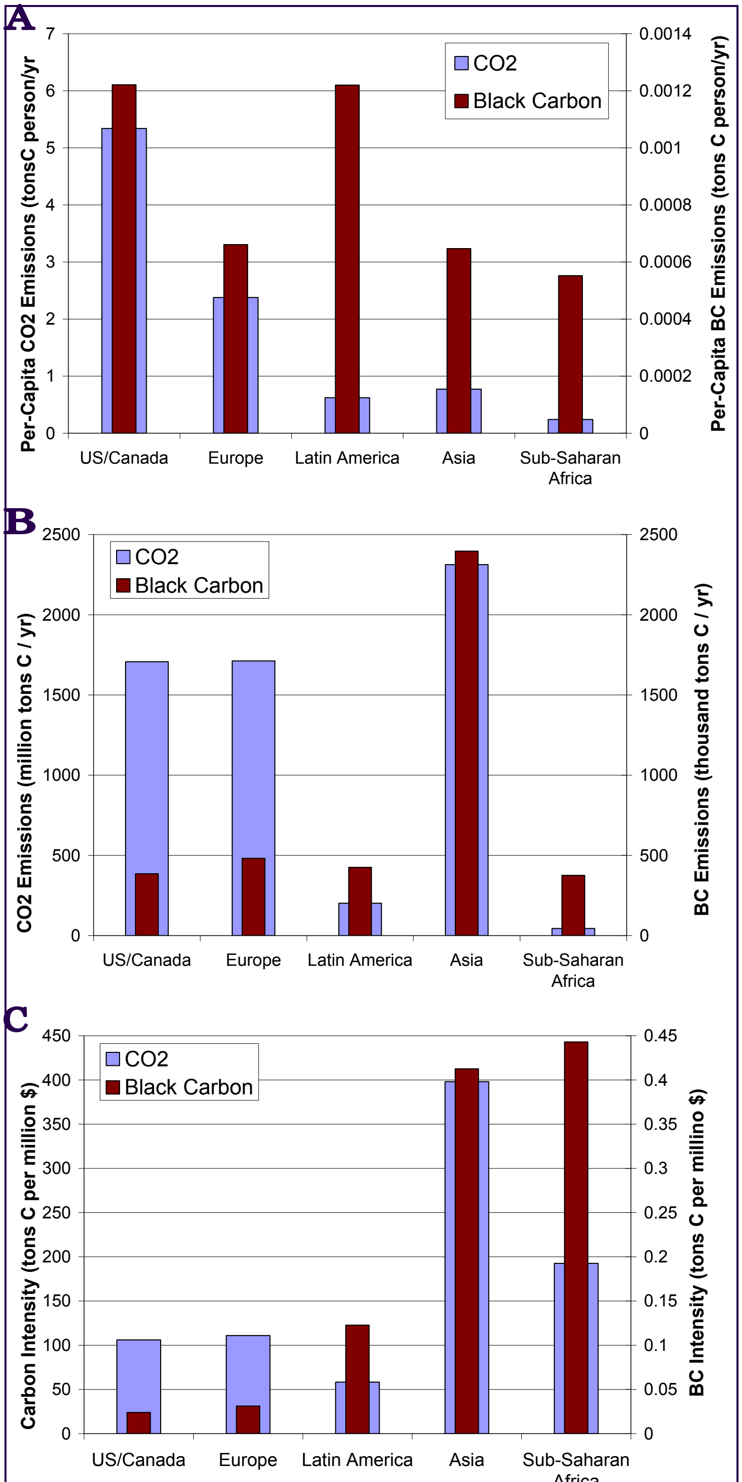


Figure 5. *A: per-capita CO_2 and black carbon emissions. B: absolute emissions. C: CO_2 and black carbon intensity (normalized by GDP). (Bond, et al., 2007; WRI, 2008).*

The first graph (figure 5A) shows per-capita emissions for both CO_2 and black carbon. It is interesting in that a key feature of the climate change problem, namely up to an order of magnitude difference in per-capita CO_2 emissions between developed and developing countries, is not reproduced in the black carbon graph. Instead, per-capita black carbon emissions in all regions are roughly comparable. In particular, developing regions such as Asia and sub-Saharan Africa have the same per-capita black carbon emissions as Europe. This homogeneity in per-capita black carbon emissions, in contrast to CO_2 emissions, results from the fact that abatement technologies have been developed and deployed in high-income countries during industrialization because of air pollution concerns.

Assigning responsibility solely on the basis of absolute emissions would again result in North America and Europe having high responsibility for CO_2 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 CO_2 and black carbon emissions. So while North America, Europe and Asia are responsible for roughly equal proportions of total CO_2 emissions (30-40 percent), Asia is responsible for a far greater proportion of the black carbon emissions (59 percent) than either Europe (12 percent) or North America (9 percent). Similarly, Africa is responsible for less than one percent of CO_2 emissions but just under 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. The intensity metric, however, 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 CO_2 emissions but with almost 20 times more black carbon emissions than an equivalent unit produced in North America, suggesting significant scope for black carbon emission reduction.

Most importantly, all responsibility metrics show the developing world as *relatively* more responsible for black carbon than for the CO_2 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 developed nations 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' 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. 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.

Figure 3 (page 6) shows the historical trends in black carbon emissions, particularly the differences between developed and developing regions. 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 CO_2 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. Table 1 compares the geographical and temporal distribution of direct benefits from the abatement of black carbon and fossil-fuel CO_2 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 in the distant future.

From Table 1, it is clear that abatement of black carbon 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. Integrating these existing and emerging air pollution policies with climate change mitigation efforts could both generate significant improvements for the climate and overcome the developed-developing state deadlock in the negotiations.

Conclusion

It is clear from the evidence presented above that middle-income, industrializing countries are both more responsible for black carbon emissions than for fossil-fuel CO_2 emissions and are more capable of reducing those emissions. Thus a lifetime-leveraging framework not only is effective in keeping temperatures below 2-2.5 degrees (demonstrated in Moore & MacCracken, 2009), but is also consistent with principles of fairness embodied in the UNFCCC. While this may not mean the proposal is necessarily immediately politically feasible, it does suggest that political hurdles may not be insurmountable.

		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 1. *Comparison of the geographical and temporal distribution of benefits for black carbon and fossil fuel CO_2 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).*

Arctic Amplification

Saya Kitasei

The Arctic, an area with a small population and even smaller political influence, is also one of the most important – and the most vulnerable – to climate change. Research warns that the Arctic, with the rest of the planet in tow, could approach major tipping points within decades, allowing less time than we thought we had to act on global warming. If we are to prevent these outcomes, immediate and serious mitigations in carbon dioxide emissions must be complemented by reductions in short-lived warming agents such as black carbon and methane.

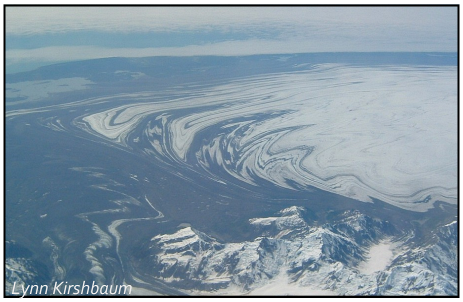
The Arctic is warming twice as fast as the rest of the planet. According to the Arctic Climate Impact Assessment, while global average surface temperatures rose 0.78°C between 1890 and 2007, the Arctic warmed by a total of 1.9°C. This breakneck warming is disrupting the delicate balance between ice, water, and sun in the Arctic – a balance which plays a vital role in maintaining the Earth's climate as we know it.

The Arctic's iconic sea ice and glaciers are vanishing. Peter Wadhams, a leading polar scientist from the UK, recently announced new evidence that the Arctic Ocean will be ice-free during the summer within twenty years. The rapid decline in Arctic sea ice portends serious consequences for the entire climate system. This October, the National Oceanic and Atmospheric Administration's Arctic Report Card noted that the loss of summer sea ice is affecting large scale wind patterns as well as Arctic plant, animal and fish species. Scientists at Rutgers University and the University of Delaware warn that a warmer Arctic will affect weather throughout the Northern Hemisphere.

As Arctic ice melts, it also contributes to sea level rise, a serious threat to small island and low-lying coastal populations as outlined by Tom Roper in this issue. The IPCC estimates that if the 2.9 million km^3 of ice contained in the Greenland Ice Sheet melted, sea level would rise about 7.3 meters.

Because feedback loops in the Arctic amplify the effect of global warming, a destabilized Arctic could initiate dangerous chain reactions in the global climate system.

First, reduction in snow and ice cover accelerates warming. Some incoming solar radiation is reflected by the Earth, while the remainder is absorbed, warming the planet's surface. Fresh snow and sea ice reflect 80-90 and 50-70 percent of incident sunlight, respectively, thereby helping to regulate the planet's temperature. As glaciers and sea ice retreat, they reveal much darker surfaces like bare soil or water, which reflect only a fraction of the light that snow and ice can. Thus as the Arctic warms and ice and snow melt, the Earth's reflectivity, or albedo, decreases, driving further warming and further melting.



An aerial view of a thawing ice shelf in Northern Canada; note the thaw pond in the upper left corner.

Second, higher temperatures could release large amounts of carbon dioxide currently stored in the Arctic Ocean and permafrost. This month, a joint study by the Arctic Monitoring and Assessment Program, the Climate in the Cryosphere Program, and the International Arctic Science Committee announced that the Arctic accounts for 10 to 15 percent of the global carbon sink. Normal soils contain decomposing organic matter, which emits carbon dioxide, but permafrost, or permanently frozen soil, does not decompose – as long as it stays frozen. But warmer temperatures are causing permafrosts to thaw, and scientists worry that this large volume of ancient organic matter will resume en masse the carbon-emitting process of decomposition that has been on pause for thousands of years.

Finally, global warming is transforming once-frozen soils into waterlogged incubators for methane-producing organisms. The Arctic currently releases as much as 50 million metric tons of methane per year. Even higher emissions of methane, a greenhouse gas 23 times more potent than carbon dioxide, will significantly accelerate global warming by compounding the effects of carbon dioxide emissions. "If the response of the Arctic carbon cycle to climate change results in substantial net releases of greenhouse gases," the study's lead author warned, "this could compromise mitigation efforts that we have in mind for controlling the carbon cycle."

Black carbon plays a central role in Arctic warming and so must play a central role in preventing the Arctic from undergoing irreversible climate change. In a *Nature Geoscience* review published last year, Veerabhadran Ramanathan and Greg Carmichael conclude that the deposition of black carbon, which absorbs solar energy and heats the ice and snow below it, is responsible for 0.5 to 1.0°C (or up to 50 percent) of temperature increase in the Arctic. Even organic carbon, light-reflecting particles that tend to be emitted together with black carbon and normally mitigate the effect of black carbon by increasing albedo, is less reflective than snow cover and can contribute to local warming.

New atmospheric models reveal that black carbon emitted north of 40°N is most likely to be transported to the Arctic. Thus while Europe, North America and the former Soviet Union are responsible for only about 17 percent of the world's black carbon emissions (Europe: 7 percent; North America: 6 percent, former Soviet Union: 4 percent), these countries' emissions have a disproportionate effect on the Arctic and, in turn, on the global climate. These countries have the resources and the responsibility to curb their black carbon emissions and protect the Arctic.

A great deal is at stake in the Arctic. The lifestyles of indigenous peoples, the health of local economies, and the survival of arctic species hang in the balance. But the Arctic also plays a major stabilizing role in the global climate system, and warmer temperatures in the Arctic will amplify existing climate impacts. Swift action to reduce black carbon and other short-lived greenhouse gases could prevent disastrous Arctic melting that would have ramifications across the globe.

(Health, continued from page 7)

wall can enter the blood stream. In many cities, the average annual levels of particulate matter (PM) 10 exceed 70 micrograms per cubic meter, though guidelines say that to prevent ill health, those levels should be lower than 20 micrograms per cubic meter. The extent to which an individual is harmed by air pollution usually depends on their total exposure to other damaging chemicals and their underlying nutritional status and health conditions. Thus both the duration of exposure and the concentration of the chemicals must be taken into account, along with underlying health status. Therefore, those who spend time in the home around traditional cook stoves and those who are consistently outside in heavily polluted cities will be the most affected by air pollution. The WHO estimates that by reducing PM10 pollution from 70 to 20 micrograms per cubic meter, we can cut air quality related deaths by around 15%, thereby preventing around 300,000 deaths annually. The smallest and most dangerous particles are emitted from fires that produce soot, as well as industrial and transportation emissions from diesel exhausts.

If fossil fuel combustion and its contributions to climate change are avoided, then related air-quality shifts, such as rising ozone air pollution from higher temperatures, can also be avoided. There are hundreds of reports from developed and developing countries consistently showing that short- and long-term exposures to current air pollution levels of particulate matter and ozone negatively affect death rates, hospitalizations and medical visits, complications of asthma and bronchitis, days of work lost, restricted-activity days, and a variety of measures of lung damage in children and adults.

A total of 2.3 million people die each year from respiratory infections, lung cancer, and cardiopulmonary disease attributable to air pollution. Nearly 665,000 of those deaths alone are caused by smoke from solid fuel use, a major component of which is black carbon.

Indoor and outdoor air quality are two of the main environmental factors contributing to acute and chronic lower respiratory infections. Estimates have shown that 36% of lower respiratory infections worldwide were attributable to solid fuel use alone, and 1% of all respiratory infections to outdoor air pollution. For upper respiratory infections, 24% in developing countries were attributable to environmental risk factors including outdoor and indoor air pollution, and globally 1.5 million deaths occur annually from respiratory infections that are attributable to the environment.

Lung cancer causes the largest disease burden of all cancers globally, or about 15% of the burden of all cancers: about 5% of the disease burden of lung cancer is attributed to outdoor air pollution, and 1% to exposure to indoor smoke from solid fuels. In the U.S. the American Cancer Society found that persons living in more polluted areas of the country who are not smokers had a 30% increased risk of developing lung cancer.

One WHO estimate holds that exposure to outdoor air pollution accounted for approximately 2% of the global cardiopulmonary disease burden. Furthermore, exposures to indoor smoke from solid fuels accounted for 22% of the burden of global chronic obstructive pulmonary disease (COPD), a slowly progressing disease characterized by a gradual loss of lung function. Outdoor air pollution accounted for 3% of cardiopulmonary mortality. It is interesting to note that the attributable fractions of COPD risk factors vary greatly among countries and by gender: in countries where solid fuel is widely used in homes for cooking or heating, indoor smoke levels can be high, and mean attributable fractions often exceeded 40%, with higher values for women than for men.

The costs of air pollution in terms of human health are very high: healthcare costs, lost productivity, and human welfare impacts cost billions of dollars each year. It is therefore advisable that countries with high black carbon emissions work to reduce them to improve both indoor and outdoor air quality, and as a result improve the health of their populations. New technologies could have beneficial effects for energy efficiency, reducing the energy intensity and possibly energy use, as well as for human health and related health costs.

These largely unappreciated air pollution reduction-related health benefits could be a strong motivator for GHG mitigation action, especially in developing countries that emit much of the world's black carbon. The challenge to the policymaking community will be to forge specific practical strategies to encourage the funding and adoption of more efficient, less polluting technologies. If the substantial public health impacts of reducing air pollution associated with GHGs become more widely recognized, their full economic and social impact can be better integrated into discussions of climate policy. Thus, active consideration of public health issues could prompt a major rethinking of the climate debate and help break the present impasse.

(Islands, continued from page 8)

energy projects with often inappropriate technology and lack of local training and ownership. On one Marshalls atoll, solar home units were installed but the donor didn't even translate the 'how to' guide into English. Unsurprisingly, the batteries failed and the Marshalls Electric Company had to come in and renew almost the whole system.

The world must change its strategy on climate change. The ponderous process of negotiations on reducing carbon dioxide emissions must be injected with new urgency and augmented by measures like reducing black carbon that can buy time. Although their membership in the United Nations has given SIDS, many of whom acquired independence only recently, an opportunity to shape the global debate on addressing climate change, this platform can only amplify the Islands' voices, not their actions. Large, developed countries must draw inspiration from the SIDS' efforts to eliminate their contributions to climate change, and act swiftly to reduce this global threat.

Cookstove Technology Standards

Scott Cooper, Vice President, American National Standards Institute

More than two billion people worldwide burn traditional biomass (e.g., wood, dung, crop residues and charcoal), indoors on a stove or three-stone fire for their home cooking and heating. The health effects from the resulting indoor air pollution ranks as the fourth worst health risk in poor countries. According to the World Health Organization, breathing elevated levels of indoor smoke results in the premature deaths of an estimated 1.9 million people each year – over 4,000 each day – with women and children most significantly affected. Exposures to particulate matter in developing countries are often hundreds of times the levels acceptable in the U.S. for ambient air.

The use of current inefficient cookstoves, which require on average 50% more fuel than efficient cook stoves, is also a major contributor to deforestation and desertification in countries where they are used. Recent studies show that poorly-combusted biomass (commonly called soot, or black carbon) is likely responsible for up to 18% of the planet's warming, making it the #2 contributor to rising global temperatures, after carbon dioxide. As the *New York Times* stated in an article earlier this year (4/16/09), "Replacing primitive cook stoves with modern versions that emit far less soot could provide a much-needed stopgap, while nations struggle with the more difficult task of enacting programs and developing technologies to curb carbon dioxide emissions from fossil fuels."

A sustainable and market-efficient means of reducing cookstove emissions is to foster the design, manufacture, distribution and use of clean, efficient cookstoves. However, according to the WHO, there are currently no commonly accepted standards for cookstove emissions criteria, or methods to assess them. One of the primary challenges in arriving at a consensus on standards is that there is no differentiation between "clean" and "unclean" cookstoves in the marketplace. Cheap, inefficient cookstoves can look very similar to efficient, more durable ones. In a classic application of Gresham's law, bad cookstoves can easily drive good cookstoves from the marketplace.

A potential solution to this challenge is to develop a set of internationally recognized testing and inspection protocols that establish a common mechanism for ensuring that relevant benchmark levels for cookstove emissions are met. By promoting agreed-upon testing protocols, individual countries or organizations could set their own benchmark level, but the same standards would be used to determine compliance with the requirements. Test protocols for cookstoves have been developed, but are currently in only sporadic use by individual companies and organizations.

A cookstove by Envirofit, one of many companies developing clean stove technology

There is however, wide-spread agreement that getting efficient cookstoves into the marketplace –and thus into homes in developing countries– is an important health and environment issue. If the implementation issues were easy, given the consensus about the seriousness of the problem, they would have been overcome by now. But there are still many problems that must be addressed.

For one, cooking styles and food preparation vary widely by region. Some cultures stir pots vigorously, which means that tipping controls are important. In other places, an attached griddle must cook food under an intense, hot heat. In other places a slow, prolonged heat is required. Furthermore, stoves must be both durable under daily use and yet cheap enough to induce mass production. Simple lab tests, such as how much fuel and/or how long it takes to bring water to boil, are not all that helpful. A lot more field testing is needed.

These variables have impeded current efforts to scale the use of efficient cookstoves. There are many admirable projects to build stoves in a number of regions of the world, but the production rates are –at best– in the tens of thousands annually. The problem to be addressed measures in the millions.

There are signs of hope, however. The House-passed Energy bill (H.R. 2454) directs the EPA Administrator to work with the State Department (and others) to develop programs to scale cookstoves to 20 million homes in five years with goals to increase stove efficiencies by 50%, reduce black carbon by 60% and reduce the incidence of pneumonia in children under five by 30%. All those goals are achievable, and should be a down payment for a continuing series of improvements as we learn more about how to build, test, scale and situate efficient cookstoves in the nearly one billion homes that will greatly benefit from their use.

There needs to be collaboration between all those who recognize both the seriousness of the issue, and the compelling opportunity to effectuate solutions that will make significant improvements in the lives of billions of people and in the health of our planet. The World Health Organization, the United Nations, and the World Bank can all play a role in meeting this challenge. Governments, foundations, standards developers, NGOs and the private sector all need to participate in developing practicable solutions. And I expect when solutions <u>are</u> found, we will then wonder why it took so long to solve such an obvious and compelling problem. But to get to that point, we need to call the initial meeting to order.

Stove Revolution: Cookstove Improvement Projects in China

Elisa Chih-Yin Lai

China is responsible for 19% of global black carbon emissions, equivalent to 1.5 times the black carbon emissions of European and North American countries combined.

The major source of black carbon in China comes from the residential sector in the North and the industrial sector in the South. Residents in Northern China use biomass or coal as their major energy source for heating and cooking. Southern China on the other hand is rapidly industrializing, and coal is burned in power, iron, and steel plants. These uses combine to make coal the primary contributor to black carbon emissions in China.

Black carbon reduction projects in China have focused on improving traditional cookstoves, especially in rural areas where they are most prevalent.

National Improved Stove Program

Since the 1980s, China has progressively implemented numerous cookstove improvement projects to benefit public health and air quality. The Chinese National Improved Stove Program (NISP), initiated by the Ministry of Agriculture, ambitiously replaced and introduced 129 million stoves to rural areas between 1982 and 1992. More than 60% of traditional stoves in rural households were replaced by improved stoves, and 90% of improved stoves that were installed globally were installed in China. In Shaanxi, the new cookstoves saved 2.7kg of coal per day, or 900kg per year.

The coordination of the central government and the cooperation of the local government formed a strong chain of policy implementation from the top down. The direct cost of purchasing and installing the stoves was mostly borne by households and only subsidized marginally by the government. In addition, the governmental subsidization system was tailored according to different needs of provinces, allowing the system high flexibility and efficiency in expenditure. Instead of fully subsidizing improved stoves, the government spent most funding on R&D, training, product demonstration and public outreach.

NISP's educational campaign eased public anxiety about using new products. The investment in R&D and training laid the foundation for NISP's successful implementation. However, reviewing NISP a decade later, there is a glaring lack in project sustainability. Some rural families shifted back to using traditional cookstoves because stoves installed by NISP gradually deteriorated and improved fuel was more costly than coal and wood.

Improved cookstoves could save 900 kg/year of coal per household in Shaanxi, China

A New Wave

After NISP, stove improvement projects were no longer implemented at a national level. City- and provincial-level projects, such as those sponsored by the Wuhan city government and the Guizhou provincial government became the norm. Recently China's private sector has taken a lead role in updating cookstoves. In 2007, the Camco Group and Pioneer Carbon initiated a stove replacement project in cooperation with the Government of Yanqing County. The project aimed to install over 1 million stoves within a 3 year period, eliminating 28 Mt of CO_2 emissions in the first five years. The Daxu stove, a central feature of the project and the winner of the 2007 Ashden Award for Sustainable Energy, is projected to be over 40% more efficient, reducing emissions by about 8 tonnes of CO_2 per year. Camco and Pioneer have exclusive rights to the carbon credits produced; this carbon financing keeps the stoves' retail cost affordable and ensures the project's economic viability.

Furthermore, this year in sunny Ningxia Province, a local company called Ningxia Fenlian Co. Ltd. conducted a CDM project financing 120,000 solar cookstoves to poor farmers. The use of the solar cookstoves is expected to save 1.2 million tons of coal during the 10 year implementation period.

Projects in which private companies take advantage of CDMs to promote improved cookstoves are relatively new, and it is still too early to assess project sustainability. However, the public-private-academia cooperation will likely be an ideal model for implementing future cookstove projects.

Learning from Past Lessons: Policy Recommendations

NISP succeeded largely due to its use of public education and training. However, public outreach and education are not integrated in current cookstove improvement projects. Enhancing the public's understanding of black carbon's impacts on health and the environment should be incorporated as part of a long-term strategy.

The price of fuel is a major determinant for whether households continue to use clean cookstoves. Some rural households shifted back to traditional cookstoves because of the low price of government-subsidized coal. Revealing the true cost of coal, including its health costs, may make alternative fuels more competitive.

The model of private-public-academia cooperation through CDMs may be the most efficient and effective way to implement cookstove improvement projects. Private companies implementing cookstove replacement through the CDM would gain carbon credits and thus have more incentive to fund future cookstove projects. Hu Jintao's recent statements have demonstrated China's positive attitude on clean technologies. Under the scope of CDM, private companies in China may increasingly undertake cookstove improvement projects and other black carbon reduction initiatives.

CLIMATE INSTITUTE

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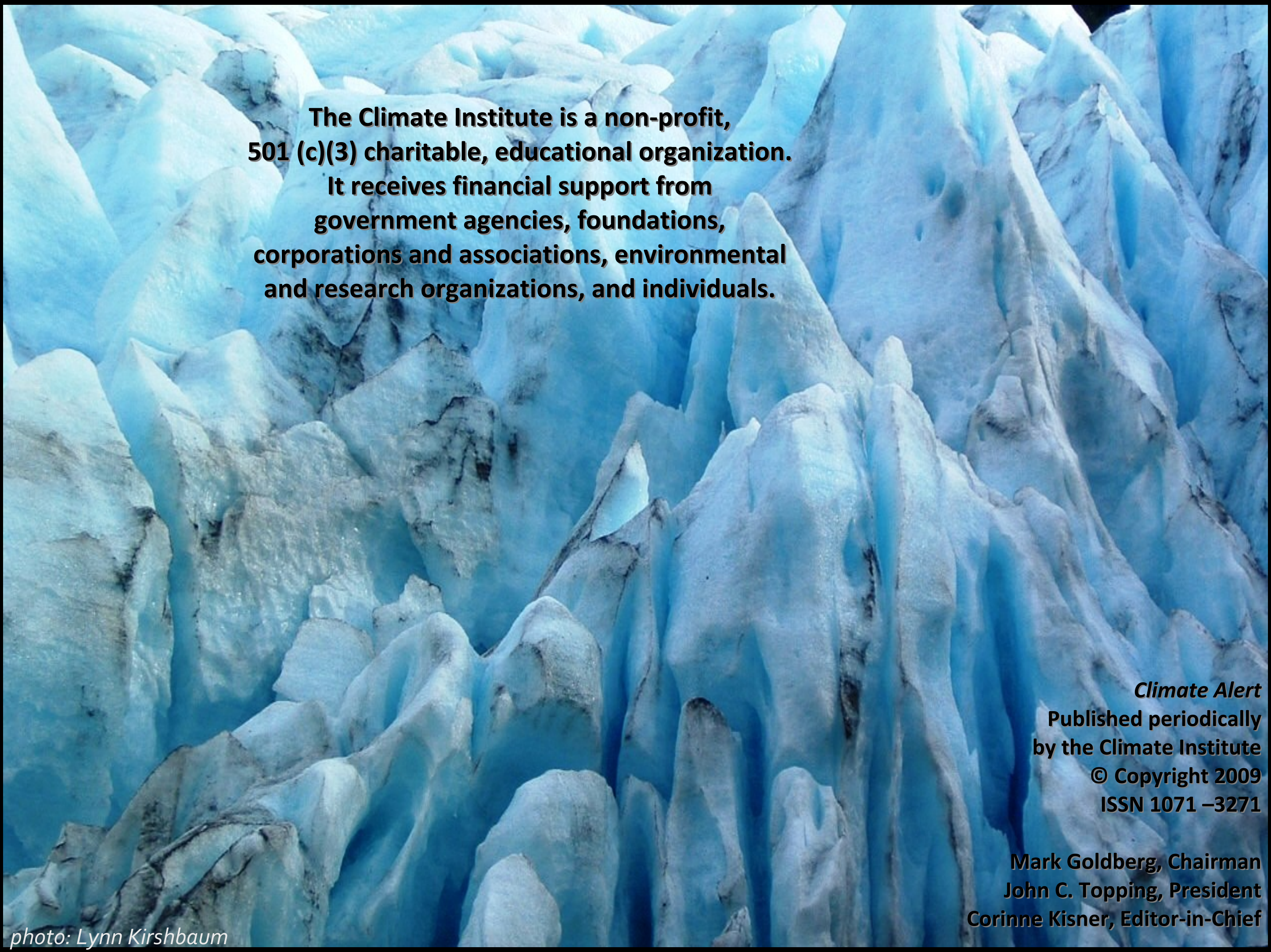

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photo: Lynn Kirshbaum

Front cover image: Black carbon concentrations in the atmosphere, February 2007. Credit: NOAA.

Editor's note: While sizable uncertainties exist in the black carbon data, only midrange values are included in this issue. For more detailed information regarding the data, as well as for all citations and references, see the electronic version of this newsletter at www.climate.org.