TEXT REVISED, 16 December 2008

Reducing Black Carbon

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Black carbon, a component of soot, is a potent climate-forcing aerosol and may be the second-leading cause of global warming after carbon dioxide (CO_2). Unlike CO_2, however, black carbon remains in the atmosphere for only a few days or weeks. Therefore reducing these emissions will have an almost immediate climate mitigation impact. While substantial reductions of greenhouse gas emissions should remain the anchor of overall climate stabilization efforts, dealing with black carbon may be the fastest means of near-term climate mitigation and could be critical in forestalling climate tipping points.[1]

Black carbon is a product of the incomplete combustion of fossil fuels, biofuels, and biomass. The main sources are open burning of biomass, diesel engines, and the residential burning of solid fuels such as coal, wood, dung, and agricultural residues. (See Figure.) Black carbon contributes to climate change in two ways: It warms the atmosphere directly by absorbing solar radiation and converting it to heat and indirectly by darkening the surfaces of ice and snow when deposited on them. This reduces albedo, the ability to reflect light, and thereby increases heat absorption and accelerates melting. As large masses of both land and sea ice disappear, they reflect less and less solar radiation, so heat is increasingly absorbed at the surface. Thus not only do sea and land ice face tipping points of irreversible melting, but this melting can create positive feedbacks leading to even further warming.[2]

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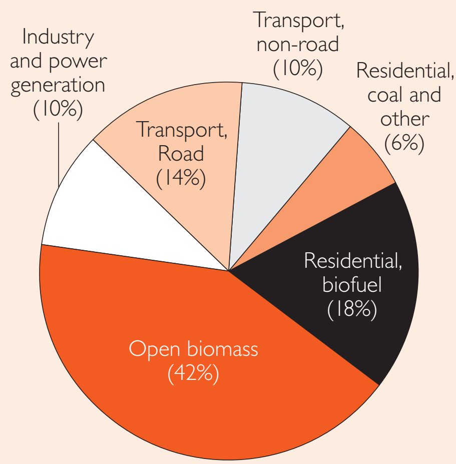
Combustion Sources of Black Carbon



Source: Bond

The ability of black carbon to accelerate snow and ice melt makes it a particular concern in Arctic and glacial areas, where tipping points for melting are considered among the most imminent. According to Charles Zender of the University of California, Irvine, black carbon on snow warms Earth about three times as much as an equal forcing of CO_2. Zender and others argue that forcing, which is a measure of the amount of heat a substance traps in the atmosphere, does not measure the amount of warming that a substance will actually cause. They claim that to most effectively address climate change, substances should be dealt with based on the amount of warming they cause. Melting glaciers are a concern not only because of the feedback warming they can cause but also because they feed rivers that supply water to hundreds of millions of people. As glaciers retreat due to melting, these water sources become threatened. V. Ramanathan and Y. Feng of the Scripps Institution of Oceanography claim that the world has already committed to warming in a range that could lead to "a major reduction of area and volume of Hindu-Kush-Himalaya-Tibetan (HKHT) glaciers, which provide the head-waters for most major river systems of Asia." And as land-based ice melts, the water flows into the oceans, contributing to potentially dangerous sea level rise.[3]

The 2007 report of the Intergovernmental Panel on Climate Change for the first time calculated the direct and indirect climate forcings of black carbon. It estimated the direct forcing from fossil fuel sources to be +0.2 watts per square meter (W/m^2) and from biomass and other sources to be +0.2 W/m^2. The report estimated the indirect forcing from black carbon's effect on snow and ice to be an additional +0.1 W/m^2, for a total forcing from black carbon of +0.5 W/m^2. More recent studies have estimated the figure is as high as +0.9 W/m^2 for direct forcing alone. This is equal to about 55 percent of the forcing from CO_2. Although the net impact of black carbon is squarely within a significant warming range, further study will be required to calculate its forcing more precisely.[4]

It is important to understand that when black carbon is emitted from incomplete combustion, other particles such as organic carbon, nitrates, and sulfates are emitted as well. Some of these other particles, such as sulfates, can have a cooling effect on the atmosphere. But because sulfates have been determined to harm public health, worldwide efforts are under way to reduce them. When this happens, further warming will be unmasked. Ramanathan and Feng claim that temperature-masking due to cooling aerosols is currently over 1 degree Celsius and that as aerosols continue to be reduced by local air pollution control measures, this warming will be felt—likely within the next 50 years. Thus it is all the more important to reduce black carbon to offset the increased warming that will result from the expected elimination of sulfates.[5]

A number of technologies for reducing black carbon emissions are available now and others are being developed. For diesel vehicles, highly effective diesel particulate filters (DPFs) can eliminate over 90 percent of particulate emissions, although DPFs require the use of ultra-low sulfur diesel fuel (ULSD), which is not yet widely available outside the United States, the European Union, or Japan. Increasing the availability of ULSD is an important step in reducing black carbon and other emissions from diesel vehicles worldwide. For vehicles without access to ULSD, other filters can be used. Newly developed flow-through, or partial, filters can eliminate 40–70 percent of emissions from vehicles using traditional diesel fuel. Programs for retrofitting diesel vehicles with the most efficient filters available will be essential, as older vehicles are often highly polluting.[6]

Ocean vessels generally use diesel engines as well and therefore emit substantial amounts of black carbon. Emissions from vessels in the northern hemisphere, especially those near the Arctic, can be especially harmful. Efficient DPFs for vessels are currently in development but likely could not be used until marine fuel sulfur levels are greatly reduced. Other means of reducing black carbon emissions from ocean vessels include reducing diesel fuel use by using shoreside electricity when at port and simply traveling more slowly at sea.[7]

Because of the higher ratio of cooling particles emitted with black carbon when biomass is burned, it is more complicated to get climate benefits from changing cooking and agricultural burning practices. But energy security and indoor air pollution concerns have already led to a variety of programs aimed at improving the efficiency of traditional cookstoves. A better understanding of the possible climate benefits of reducing black carbon provides further incentive to look closely at the potential to improve cooking techniques and agricultural burning practices. Several stoves being developed not only reduce black carbon emissions but also produce biochar, a stable form of carbon that can be stored permanently in soils and improve soil productivity.

Ensuring compliance and enforcement with existing national laws on black carbon can provide some relief from warming. This is being pursued by the International Network for Environmental Compliance and Enforcement. But new laws and regulations are needed at all levels for further and faster reductions. As a start, where ultra-low sulfur diesel fuel is available, diesel particulate filters should be required on both new vehicles and existing ones that may be used for many years. In addition, northern countries could restrict agricultural burning in the springtime melt season in order to reduce the impact of black carbon on snow and ice. Institutions such as the World Bank should make climate funding available for black carbon reduction programs.[8]

The faster-than-anticipated approach of dangerous tipping points is forcing society to consider the quickest ways to mitigate climate change. Reducing black carbon may be the fastest means of all.

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