Aggressive action to reduce soot emissions needed to meet climate change goals

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Without aggressive action to reduce soot emissions, the time table for carbon dioxide emission reductions may need to be significantly accelerated in order to achieve international climate policy goals such as those set forth in last December's Copenhagen Accord, according to "Assessing the climatic benefits of black carbon mitigation," a study published online June 21 in the *Proceedings of the National Academy of Sciences (PNAS)*.

The Princeton University researchers assessed the climatic contribution of "carbonaceous aerosols," fine particulates emitted into the atmosphere and commonly known as soot. Soot is produced by the incomplete combustion of organic matter and comes from a variety of sources, ranging from diesel engines and coal combustion to biomass cook stoves, crop burning and wildfires.

Soot has complex effects on the global climate when airborne or deposited on snow. It has two main components: black carbon and organic carbon. Black carbon is dark and absorbs radiation, thus warming the atmosphere; organic carbon is light colored and reflective, so tends to have a cooling effect. Their effects on climate are complicated, in part because they depend on how they are mixed with other particles in the atmosphere, and in part because both types of aerosols can cool the climate through their effects on cloud formation. Black carbon also warms the Earth's surface when it is falls out of the atmosphere and lands on snow or ice, darkening it.

"Because of uncertainties in these many effects, and because of differences in whether and how these effects get incorporated into various models, past studies of soot's contribution to global warming have ranged widely," said Robert Kopp, a post-doctoral researcher jointly in Princeton's Woodrow Wilson School of Public & International Affairs and its Department of Geosciences. "We took several key studies, put them all on a common footing, and assessed what emerged."

Using four sets of highly cited but disparate studies that span the range of past estimates, Kopp and Denise Mauzerall, associate professor of environmental engineering and international affairs, attempted to reconcile and standardize the results into one, common global metric.

Their best estimate indicates that eliminating soot pollution from "contained combustion" sources such as diesel engines and poorly-controlled coal sources would provide the world with an additional eight years (with an uncertainty range of about one to 15 years) to reduce carbon dioxide emissions. Conversely, if these sources of carbonaceous aerosols continued at levels seen in the 1990s, more aggressive reductions in carbon dioxide emissions than previously recognized would need to occur for the world to meet the goal of avoiding "dangerous anthropogenic interference with the climate system".

"Unfortunately, most climate change mitigation scenarios used in policy contexts have focused exclusively on heat-trapping gases," Mauzerall said. "This means those eight years aren't actually eight years we can gain by cutting soot emissions; rather, our results suggest that we need to accelerate carbon dioxide emissions by about eight years relative to these scenarios if we don't also act to reduce soot emissions."

Not all soot emissions have the same effect on climate. Effects can vary depending on both where the emissions take place and what sources they come from. Black carbon that can travel to the Arctic and heat Arctic ice

during the spring and summer months, for instance, has a stronger warming effect than soot confined to lower latitudes. Further, different soot sources have different ratios of light-absorbing black carbon to light-reflecting particles like organic carbon and sulfate; sources that emit a greater amount of black carbon generally have a greater warming effect. Reducing emissions from low-sulfur diesel engines and industrial coal therefore has clearer benefits for the global climate than reducing emissions from sources such as biomass cookstoves and crop burning.

"But effects on global climate aren't the only reason to reduce soot emissions," Mauzerall cautioned. "The public health case for reducing emissions of fine particles, including soot, is unequivocal, and aerosol pollution can have significant regional climate effects. For instance, soot pollution from India and China that is transported to the Himalayan glaciers can enhance glacier melting and hence influence water supplies in India, China and Bangladesh - potentially contributing to increased flooding in some regions in the short-term and reduced water availability in the longer term ."

Whereas carbon dioxide emissions tend to increase with income, some of the largest soot sources are in middle-income countries. In 1996, for example, China and India are believed to have accounted for about 40 percent of global black carbon emissions.

"Because some of the largest sources are in middle-income countries, and because the co-benefits of soot emission reductions can be felt quickly locally, black carbon reductions could serve as a catalyst for engaging these countries in climate change mitigation efforts," Mauzerall suggested.

The wide range in the study's estimate of the soot contribution to warming emphasizes the need for further research. "There's a great deal of uncertainty remaining, both in the inventories of aerosols emissions

and in the physical processes - particularly those involving cloud formation - by which aerosols affect climate," said Kopp, who is currently a AAAS Science & Technology Policy Fellow in Washington, D.C.

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