CLEARING THE SMOKE: UNDERSTANDING THE IMPACTS OF BLACK CARBON POLLUTION

HEARING

BEFORE THE

SELECT COMMITTEE ON ENERGY INDEPENDENCE AND GLOBAL WARMING HOUSE OF REPRESENTATIVES

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CLEARING THE SMOKE: UNDERSTANDING THE IMPACTS OF BLACK CARBON POLLUTION

TUESDAY, MARCH 16, 2010

HOUSE OF REPRESENTATIVES,
SELECT COMMITTEE ON ENERGY INDEPENDENCE
AND GLOBAL WARMING,
Washington, DC.

The committee met, pursuant to call, at 10:10 a.m., in room 1310, Longworth House Office Building, Hon. Edward J. Markey (chairman of the committee) presiding.

Present: Representatives Markey, Inslee, Cleaver, and Sensenbrenner.

The CHAIRMAN. Good morning.

On December 5th, 1952, soot-filled smoke from London's factories and fireplaces settled on the city, and over the next few days thousands of people died from the soot and fumes. For years, the iconic image of Los Angeles was not the Hollywood sign; it was an obscured skyline. And while much progress has been made to clean up this pollution, clouds of sooty smoke continue to blanket homes from Mexico City to Mumbai, harming the health of millions of people.

Soot is the visible portion of carbon pollution from smokestacks and tailpipes, burning fields and forests. It sticks to our lungs. It causes asthma and heart disease. It is what gives smoke its ominous color.

And, as the saying goes, where there is smoke, there is fire. In this case, the fire is increased global warming. The black carbon in soot is one of the most potent warming agents affecting our planet.

From diesel trucks to inefficient factories, from the cookstoves in southeast Asia to the burning forests of the Amazon, black carbon and other components of soot rise into the atmosphere every time we burn fossil fuel or biomass. There, black carbon absorbs sunlight and traps heat. Stuck on water drops and ice crystals, black carbon reduces the cooling effect of clouds. And when black carbon eventually falls out of the air and settles onto ice sheets and mountain snow pack, it accelerates the melting of ice and snow, contributing to rising sea levels and threatening water supplies.

Cutting emissions of black carbon could yield rapid benefits for our health and climate. Black carbon only stays in the atmosphere for a few days to weeks before settling out. That means that a global effort to reduce these emissions would act fast to prevent respiratory disease and aid in the fight against global warming pollution.

And we already have the technologies needed to achieve deep reductions, including particle filters, improved diesel engines and efficient cookstoves. Developing and installing these technologies would create jobs and move us forward in the clean energy economy.

Now, I am sure there are some who would argue that if we cut black carbon pollution, we can delay on reducing greenhouse gasses like carbon dioxide. This simply will not address the momentous challenge that we face. For homebuyers, a solid downpayment can keep the mortgage more manageable, but they still have to make the monthly payments. If we want to keep the planet a viable residence, a downpayment in the form of black carbon reductions won't replace the need to make sustained investments in clean energy. Each year of delay will make it more difficult to keep temperatures from rising, and it will continue to put the American economy at a competitive disadvantage.

We recently took steps to cut black carbon and greenhouse gas pollution. Last year, the House passed the Waxman-Markey American Clean Energy and Security Act, which will set us on a pollution-cutting path and at the same time create millions of new jobs, making America the global leader of the clean energy economy.

Working with Representative Inslee, we incorporated a number of provisions that would cut emissions of black carbon here at home and seek opportunities to curb emissions abroad. This will provide innumerable benefits for our health and for our climate.

The deadly soot-filled London fog of 1952 encouraged the U.K. to enact their own clean air laws in 1956. My hope today is that, even in the fog of war that sometimes envelops our progress on clean energy and climate change, that we can still clear the smoke to find common ground on issues like black carbon.

I look forward to the testimony of our witnesses and hearing from them how Congress can help address this important issue.

I would now like to recognize the ranking member of the select committee, the gentleman from Wisconsin, Mr. Sensenbrenner.

[The prepared statement of Mr. Markey follows:]

THE SELECT COMMITTEE ON
ENERGY INDEPENDENCE AND GLOBAL WARMING

Opening Statement for Edward J. Markey (D-MA)

"Clearing the Smoke: Understanding the Impacts of Black Carbon Pollution"
Select Committee on Energy Independence
and Global Warming

March 16, 2010

On December 5th, 1952, soot-filled smoke from London's factories and fireplaces settled on the city and over the next few days thousands of people died from the soot and fumes. For years, the iconic image of Los Angeles was not the Hollywood sign, it was an obscured skyline. And while much progress has been made to clean up this pollution, clouds of sooty smoke continue to blanket homes from Mexico City to Mumbai, harming the health of millions of people.

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Mr. SENSENBRENNER. Thank you very much, Mr. Chairman.

There is so much controversy about how to confront climate change that sometimes there seems to be no common ground. However, by taking a realistic approach to black carbon, we can have a positive effect on the environment without breaking the bank, which is something that both Democrats and Republicans should support.

Black carbon, which is essentially soot, doesn't get the attention that CO_2 receives. That is too bad because the more focus on black carbon would produce immediate results for the environment without requiring the types of regulations that stifle the economy.

Scientists are learning that black carbon is one of the leading contributors to climate change. Most global emissions of black carbon come from energy-related combustion and the burning of biomass. By coating both the air and the planet's surface with soot, black carbon absorbs heat at a dangerous rate. But unlike CO_2, which hangs in the atmosphere for decades, black carbon lingers for only days at a time.

It is also easier for society to address the emissions of black carbon. There are already a number of ways to reduce these emissions without relying on the cost-prohibitive technologies that CO_2 regulations would require.

Most of the world's black carbon is produced in Asia. Surprisingly, when it comes to black carbon, the U.S. isn't cast as the bad guy, as North America produces less than Europe, South America, and Africa. But much of the black carbon produced in the developing world could be offset with simple technology and techniques.

Improved farming and forestry policies would go a long way toward reducing the soot. So would cleaner-burning stoves, which are already readily available and could be cheaply deployed in many of the developing nations where dirty, inefficient stoves are commonly used. It would be a lot cheaper to buy clean stoves for developing nations than to implement draconian CO_2 regulations.

As Congress struggles over how to confront climate change, black carbon reductions, targeted investments in research and development, and improved transmission are cost-effective options that could have large impacts without crippling our economy.

I want to welcome Dr. Drew Shindell of NASA Goddard Institute for Space Studies, who will talk about the immediate impact that could result from cleaning up black carbon emissions.

Hybrid truck legislation that I have introduced would also help black carbon. Diesel engines are a primary source of black carbon. Since most trucks use diesel, reducing fuel use in trucks would reduce both CO_2 and black carbon emissions. My bill would create a grant program in the Department of Energy to fund research and development of hybrid truck technology.

This is one approach that is simple and affordable. There are many others, and I hope today's hearing leads to more understanding of this problem and its solutions.

Thank you.

The CHAIRMAN. I thank the gentleman very much. All time for opening statements of Members has been completed.

[The prepared statement of Ms. Speier follows:]

Rep. Speier Statement
Select Committee Hearing
March 16, 2010

Thank you, Mr. Chairman, for holding this hearing.

This issue is really at the intersection of the two biggest items on Congress' plate: energy and health care reform.

A recent article in the New York Times cited a RAND Corporation study of the health costs of air pollution and how California has failed to meet federal air quality standards. According to the report, California's dirty air costs federal, state and private insurers $193 million in hospital visits. Most of the visits were black carbon-related, and the most commonly admitted patients were children with acute asthma. And if you include the thousands of premature deaths that result from diesel pollution each year, the cost is nine times as high.

But here's the kicker:

> "Medicare and MediCal, California's Medicaid program, paid for more than **two-thirds** of the [hospital] costs, while private insurers paid the rest."

So – as we dither on climate change legislation because we think the science is a hoax or it'll cost too much, and while we talk health care reform to near-death because we cry government takeover or – guess what, it'll cost too much –

well, we're polluting the air, we're killing our kids, and two-thirds of the hospital bill goes to the taxpayer.

We have the technology to help clean up black carbon both here and in the developing world. We finally have an EPA that relies on science, not ideology, and stands ready to enforce the law. But the bottom line is that without real change in the way we respond to these crises, we will not fix this problem.

It is time for us in Congress to defy conventional wisdom and do what is required: pass real health care reform and climate and energy legislation into law.

Thank you and I yield back.

The CHAIRMAN. We will turn to our first witness, who is Dr. Tami Bond. She is a professor in the Department of Civil and Environmental Engineering at the University of Illinois at Urbana-Champaign. Dr. Bond's research considers the interactions between energy use, the composition of the atmosphere, and the global science system.

We welcome you. Whenever you are ready, please begin.

STATEMENTS OF TAMI C. BOND, ASSOCIATE PROFESSOR, ARTHUR AND VIRGINIA NAUMAN FACULTY SCHOLAR, DEPARTMENT OF CIVIL AND ENVIRONMENTAL ENGINEERING, UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN; VEERABHADRAN RAMANATHAN, VICTOR ALDERSON PROFESSOR OF APPLIED OCEAN SCIENCES, DISTINGUISHED PROFESSOR OF CLIMATE AND ATMOSPHERIC SCIENCES, SCRIPPS INSTITUTION OF OCEANOGRAPHY, UNIVERSITY OF CALIFORNIA, SAN DIEGO; DREW T. SHINDELL, SENIOR SCIENTIST, NATIONAL AERONAUTICS AND SPACE ADMINISTRATION, NASA GODDARD INSTITUTE FOR SPACE STUDIES; CONRAD SCHNEIDER, ADVOCACY DIRECTOR, CLEAN AIR TASK FORCE

STATEMENT OF TAMI C. BOND

Ms. BOND. Thank you, Chairman Markey and Ranking Member Sensenbrenner and members of the committee. Thank you for this opportunity to discuss black carbon and its role in climate change. I am really honored to be here and to participate in the committee's important discussions as you explore a wide variety of solutions to clean energy and climate change.

I have been working on black carbon for about 15 years. I do everything from models of emissions in the atmosphere to measurements of diesel engines and cookstoves. So, although I sit in front of a computer most of the time, I have definitely gotten my hands dirty.

Black carbon is the dark component of smoke. I am going to start by giving you an idea of what a powerful climate impact it has, putting some numbers on what Mr. Markey said.

One ounce of black carbon in the atmosphere absorbs about the amount of sunlight that would fall on a tennis court. This light turns into heat and warms the atmosphere. One pound of black carbon absorbs about 650 times as much energy during its short lifetime as one pound of emitted CO_2 does during 100 years.

An old diesel truck, not our current regulations, but an old diesel truck driving for 20 miles would emit about a third of an ounce of black carbon. That is about the weight of two nickels. That would heat the atmosphere during its short lifetime as much as adding a home furnace to it. Now, after a week, that heating is gone because the particles fall out of the atmosphere. If they fall on snow, they can warm it and melt it.

Over that same 20 miles, the same truck will emit about 70 pounds of CO_2. And that would add five times the warming of the black carbon but spread over 100 years. So there are two mayor effects: one short, one long.

Estimates of black carbon "forcing" or the atmospheric warming today are between 20 percent and 60 percent of carbon dioxide's. We have high confidence that atmosphere and snow forcing by black carbon and its interaction with sunlight leads to warming and is significant in comparison with greenhouse gasses. One of the uncertainties, however, is how those same emissions change clouds.

I would like to add an analogy to that of Mr. Markey. Reducing black carbon emissions is a short-term solution to climate change. It is a bit like applying an emergency brake to a car that is out of control. You slow the vehicle quickly, get a little time to think, but your vehicle will still run away if you don't take your foot off the gas pedal, if CO_2 emissions are maintained.

The estimated emission rate of black carbon is about 8.3 million tons per year. Total emissions from the United States are about 460,000 tons. That is about 5.5 percent of the global total. Of this total—that is, the global total—diesel engines provide about a quarter. Solid fuels like wood and coal burned for home cooking and heating are also about a quarter. Small industries are about 10 percent. And open forest and grassland burning is the remaining 40 percent.

There are uncertainties in global emissions. The totals are probably underestimated, especially in developing countries. However, we are confident that the sources I mentioned are very large contributors to global black carbon.

It is important to note that there are international initiatives working on both diesel engines and cookstoves. This doesn't mean that they have all the resources they need.

I have given you a very simple picture. However, sources that emit black carbon also emit several other pollutants: Cooling particles that reflect light away from the Earth and gases that warm the Earth by changing ozone and methane. You can think of each source like a bathroom faucet. The mixed water can be very warm if you turn on the black carbon or the gasses, very cold if you turn on the cooling particles, and the net result depends on the balance.

So sources with high emissions of warming pollutants are the most promising targets for reducing warming. Of the sources I listed above, diesel engines are the richest in warming pollutants by far, followed by residential cooking and heating, industrial sources, and, last, open burning of biomass.

Since the late 1800s, emissions in the United States have gradually transitioned from residential wood and coal to industry to diesel engines. This development track is common through much of the world. In countries at low levels of development, black carbon emissions come mainly from solid fuels for heating and cooking. In developed regions like the United States and Europe, the main sources are diesel engines.

There are three big drivers of cleaning up black carbon. First, technology. Our very first success was in the use of pulverized coal boilers to increase coal use and yet reduce black carbon emissions at the same time. Second, clean fuels. Introduction of natural gas, electricity, and liquified petroleum gas has played a large role in cleaning up residential emissions. That is just one example. And, finally, regulation and government participation in technology development, such as the initiative that Mr. Sensenbrenner mentioned. These have driven advanced technologies and retrofit programs for diesel, for example.

Now, to confirm that reducing sources rich in black carbon will benefit——

The CHAIRMAN. If you could just summarize, please.

Ms. BOND. I am on my last paragraph.

To confirm that reducing sources rich in black carbon will benefit climate, we have to estimate the net effect of cleaning up individual emission sources, our best estimate of cloud response to particle emissions, which is very important. I and three other scientists are leading a group of about 30 coauthors in a study to assess those questions, and we expect to have a product in June.

I don't think that all the questions about black carbon will be solved by June, but that report should be able to tell us which actions can be taken soon and what targeted research is needed to evaluate actions in the near future.

Thank you.

[The statement of Ms. Bond follows:]

Testimony for "Clearing the Smoke: Black Carbon Pollution"

House Committee on Energy Independence and Global Warming

United States House of Representatives

The Honorable Edward Markey, Chair

March 16, 2010

Tami C. Bond, Associate Professor

University of Illinois at Urbana-Champaign

Chairman Markey and Ranking Member Sensenbrenner, and members of the Committee, thank you for this opportunity to discuss black carbon, its origins, and its role in climate change. I am honored to participate in your committee's important discussions on climate change, energy use, and a wide variety of solutions.

I am Tami Bond, Associate Professor of Civil and Environmental Engineering at the University of Illinois, Urbana-Champaign. I began measuring black carbon 15 years ago, when I traveled to the former East Germany, an economy in transition, to measure a small coal boiler with few emission controls. Since that time, I've measured diesel engines and cookstoves, and created estimates of emission rates that are used in global atmospheric models. I am currently co-leading a group of about 30 scientists conducting a scientific assessment of the net impact of black carbon on the climate system. My comments to you are based on that experience.

1. Scope of testimony

In this document, I will discuss:

- the nature of black carbon
- black carbon's impact on the Earth's radiative balance
- reducing black carbon compared with reducing carbon dioxide
- sources that emit black carbon, both globally and in the United States
- research remaining to evaluate black carbon mitigation

2. What is black carbon?

Smoke has been intimately associated with civilization for millennia, with home heating for centuries, and with industrial production since the invention of the steam engine. Black carbon is a component of this smoke, responsible for its dark appearance. Upon inspection under an electron microscope, black carbon looks very different than other particles: it is a collection of tiny spheres, like a bunch of dark grapes.

Some of the unique physical properties of black carbon also give it interesting behavior in the environment. It has a high surface area: one ounce of black carbon dispersed in the atmosphere blocks the amount of sunlight that would fall on a tennis court. The "black" in the name of this substance means that it absorbs every color of light; it does so because it is chemically similar to graphite. This absorbed light is turned into heat and transferred to the atmosphere.

Because black carbon is so good at absorbing sunlight and turning it into heat, emitting one-third of an ounce to the atmosphere (about the weight of two nickels) is like adding a home furnace, running continuously, to the Earth system for one week. That amount would be emitted by burning about three gallons of fuel in a diesel engine without advanced controls.[i]

3. Black carbon is a strong climate warmer

The contribution of any pollutant to warming or cooling the climate is often expressed as "forcing," or the change in heat input caused by that pollutant at the top of the atmosphere. In 2007, the Intergovernmental Panel on Climate Change (IPCC) estimated the forcing of black carbon as +0.34 watts per square meter (W/m^2) [1]. This estimate was based on several models of the global atmosphere. It can be compared with the forcing of carbon dioxide, which was estimated as +1.66 W/m^2 in the same document. Black carbon's forcing is smaller but significant.

Criticisms could be made of the model results summarized in the IPCC report. Many of them did not include a well-understood change which would make the radiative forcing higher. Black carbon collides and interacts with other particles, so that each particle contains many chemicals, not just black carbon. This mixing increases the absorption of black carbon by about 50%. The change is not controversial; it has been measured both in laboratory tests and in field measurements [2,3]. This makes the forcing per emitted mass much higher than most models predict.

Including the mixing, my best guess of black carbon atmospheric radiative impact for an emission rate of 8.2 million tons (7.5 million metric tons, or the estimated emission rate in 2000) is about +0.46 watts per square meter[ii]. Forcing by black carbon on snow is an additional +0.05 W/m^2. This apparently small snow forcing is highly effective at producing warming [4].

The emission rate of black carbon is another important factor in determining its forcing. Forcing is directly proportional to emission rate, so if emission estimates are doubled, the forcing estimate will double as well. Atmospheric measurements suggest that our current estimate of year 2000 emissions is too low in some regions [5]. Forcing estimates as high

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[i] The values I used for this calculation are: normalized direct radiative forcing = 1800 watts per gram, resulting in a heat input of about 17 kW or 58000 Btu/hour. The diesel engine is assumed to have an emission rate of 1 gram BC per kg of fuel, similar to engines with early but not stringent regulations.

[ii] "Atmospheric radiative impact" is similar to forcing, except that it refers to all the material in the atmosphere, not the difference between present day and 1750. IPCC's estimate of atmospheric radiative impact would have been similar to this one. Because emissions in 1750 are poorly known, and because all present-day emissions could be considered for mitigation, I prefer to present the total impact rather than subtracting a pre-industrial baseline. Models summarized by IPCC did not include the mixing effect in some models, but did include some models with high emissions.

as 1 watt per square meter [6,7] have been published and are usually associated with models that assume more black carbon in the atmosphere than other models.

Besides the emission rate, there are other sources of uncertainty in the forcing estimate. Some of these factors include rainout rates and whether black carbon is suspended above or below clouds. These factors lead to an additional uncertainty of about 50% in forcing estimates.

Work to resolve the magnitude of emissions and the resulting forcing remains. Nevertheless, we have high confidence that **atmospheric and snow forcing by black carbon leads to warming and is significant in comparison with greenhouse gases.** (As discussed in Section 5, however, the impacts of individual emission sources may not be warming.)

4. The atmosphere responds rapidly to changes in black carbon emissions

Black carbon, and other particles, stay in the atmosphere for only about a week. They are rapidly removed by rainfall. Even during those few days, it can travel for thousands of kilometers, reaching other continents and traveling to sensitive regions such as the Arctic. However, the short lifetime gives it a very different character than carbon dioxide.

If emissions of black carbon are shut off, its warming will be stopped within a few days. This makes it a powerful tool to address warming quickly. This is also true of other short-lived climate forcers such as ozone.

Black carbon does not accumulate in the atmosphere, while carbon dioxide does. If both CO_2 and black carbon emissions remain constant, in a few decades, there will be a lot more CO_2 in the atmosphere than there is today, but the same amount of black carbon. This means that CO_2 requires long-term management, which your committee is discussing elsewhere. It also means that reducing black carbon emissions is not a long-term solution to climate change. It is, however, a component of our current toolbox.

Reducing black carbon and ozone in the atmosphere is like applying an emergency brake in a car out of control. It will slow the vehicle quickly and give you a little time to think. But the problem will continue if you don't take your foot off the gas pedal—that is, if CO_2 emissions are maintained.

One way to compare the warming of pollutants is to add up (integrate) the energy added to the atmosphere over some period of time and compare it with the energy added during the same period by CO_2. The ratio between the two is known as the *global warming potential.* In current discussions about climate mitigation, 100 years is the chosen integration time. For this time period, black carbon has a global warming potential of about 700. That is, even during its few days in the atmosphere, one pound of black carbon absorbs 700 times as much energy as one pound of emitted CO_2.

Although black carbon has a powerful impact, its emissions are over one thousand times smaller than the amount of fuel carbon turned into carbon dioxide each year. Thus, both are important-- black carbon due to its strong warming, and carbon dioxide due to its abundance and long lifetime.

5. Black carbon does not travel alone

Sources that emit black carbon also emit several other pollutants. These include sulfur dioxide, which leads to sulfate particles, and carbon particles that are not black, known as "organic" carbon. These pollutants generally reflect light away from the Earth; this causes them to cool the Earth system. Gases that affect ozone and methane are also emitted with the particles, usually adding some warming.

Any action to reduce black carbon will also affect any *co-emitted pollutants* from the same source. Any emission source produces warming pollutants (black carbon and some gases) and cooling pollutants (sulfates and organic carbon), and the result is like mixing hot and cold water in a faucet. The mixed water can be very warm, very cold, or in between depending on the amount of each flow. Sources with high emissions of warming pollutants are the most promising targets for reducing black carbon warming.

The warming by black carbon may also be offset by some other interactions in the atmosphere, especially those involving clouds. Removing particles from clouds may result in bigger droplets, clouds that are less bright, less reflected energy, and therefore a warmer Earth. This is one of the major uncertainties in quantifying the link between black carbon emissions and climate benefit.

6. Sources and magnitudes of black carbon emissions

Estimates of black carbon emissions in 2000, based on *bottom-up* calculations, were about 5.4 million tons (4.9 million metric tons) from energy-related sources including fossil and biofuel burning, and about 2.9 million tons (2.6 million metric tons) from open burning of biomass. The total of about 8.2 million tons is the one used for the forcing estimates in Section 3. Later, I'll explain some of the limitations of "bottom-up" emission estimates.

Figure 1 summarizes the main source categories: (1) diesel engines for transportation or industrial use; (2) residential solid fuels such as wood and coal, burned with traditional technologies; (3) open forest and savanna burning, both natural and initiated by humans for land clearing; and (4) industrial combustion, usually in smaller boilers. Although the estimates given here have some uncertainty, we have confidence that the major types of contributors to black carbon emissions have been identified. As estimates improve, the magnitude of each sectoral contribution may change somewhat.

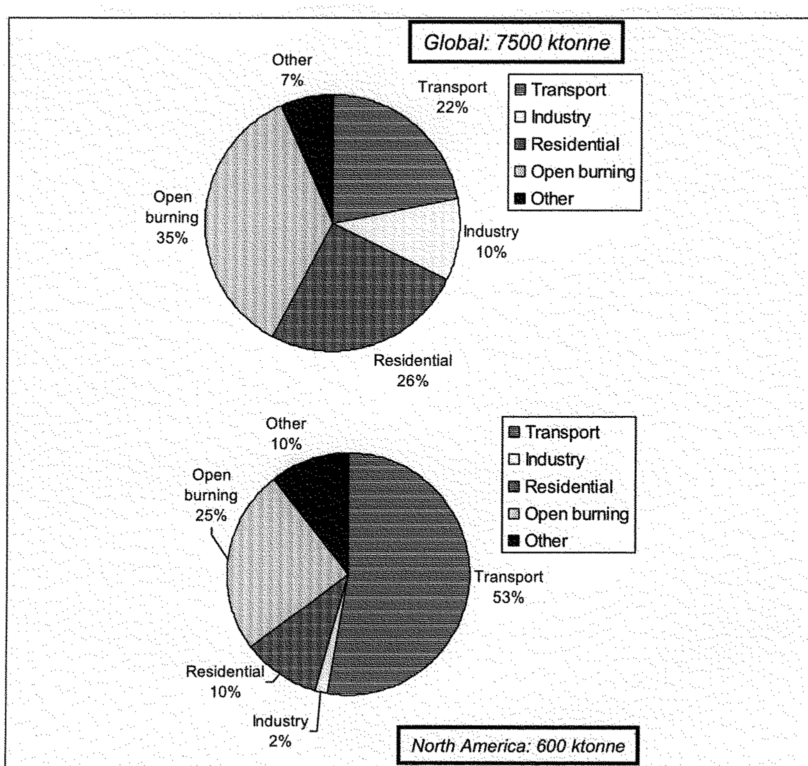

Figure 1. Global and North American sources of black carbon. Open burning is largely in the forests of Canada. 1 ktonne (metric)= 1100 tons.

Emissions in North America are quite different than the global average. Transportation contributes a much greater fraction, and residential fuels a much smaller fraction. Total emissions are also a small fraction of the global total, although per-capita emissions are within a factor of three for all regions.

The history of the United States illustrates how black carbon emitted from energy use changes with development [8]. In the late 1800s, U.S. black carbon emissions were dominated by residential solid fuel, especially coal. Industry was on the increase, too. Making the coke needed to feed the steel furnaces of Pittsburgh created a lot of black carbon,. Black carbon emissions decreased greatly when companies started capturing the gases from coke ovens. The invention of boilers that burned pulverized (powdered) coal rather than piling the fuel on a grate allowed black carbon emissions in the United States to decrease (Figure 2) despite phenomenal growth in coal use. Eventually, industrial pollution became relatively clean, in part due to regulations that come into play in a richer society, and in part due to technology. However, a wealthy society also has greater mechanization and transport of goods, leading to a greater use of diesel engines. This North American emission trend [2,9] is consistent with ice-core records in the Arctic [10].

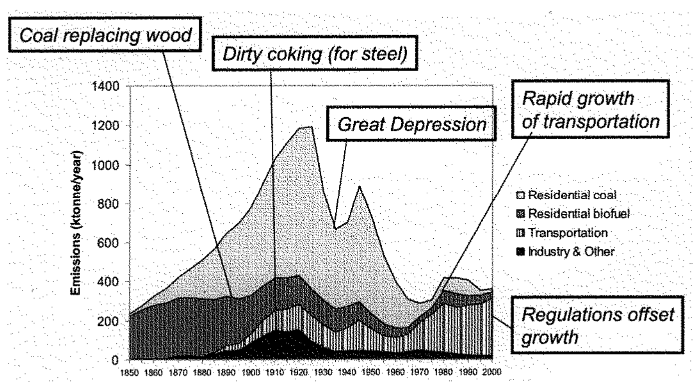

Figure 2. History of emissions for the United States, demonstrating transitions between fuels and dominant emitters (early 20th century), and the success of regulation at offsetting high growth due to emissions (late 20th century).

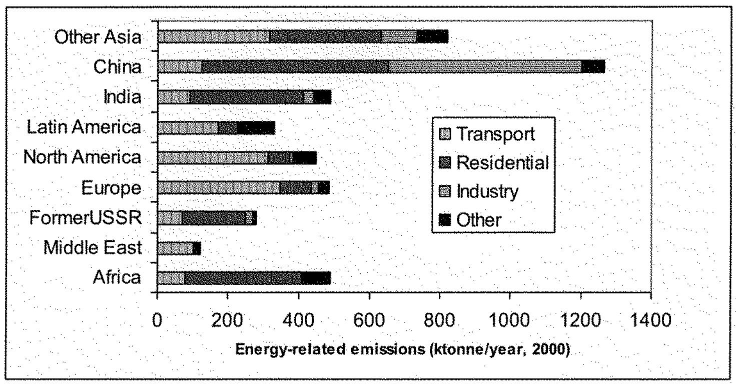

Figure 3. Black carbon emissions by type and world region, for energy-related emissions only (i.e. excluding open burning).

As development occurs, per-capita emissions of black carbon change a little, but the sources change quite a lot [11]. This source shift is apparent in emission differences between world regions, as well (Figure 3). In countries where infrastructure is limited and clean fuels are unavailable or unaffordable, black carbon emissions come mainly from solid fuels for heating and cooking. Regions with large populations and poor infrastructure have high black carbon emissions from residential fuels. These emissions have a large atmospheric impact, but also a large potential for cleaning up. In highly developed regions like the United States and Europe, the main sources are diesel engines.

Of the sources discussed above, **diesel engines** are the richest in warming black carbon pollutants, by far. **Residential cooking and heating** emissions have some organic carbon and, in some cases, sulfate precursors. Their net effect on sunlight is probably still warming, but their interaction with clouds is unknown. **Open burning of biomass** has the largest fraction of co-emitted organic carbon (cooling) pollutants. Finally, there is very little information on small industrial sources, and measurements of co-emitted pollutants are needed in order to determine whether they have more warming or more cooling pollutants.

While there are still substantial black carbon emissions in the U.S., it is not the major contributor to global BC emissions. New diesel regulations, retrofit programs, and implementation of advanced diesel technology will ensure that black carbon emissions decline even if fuel consumption grows.

The history of the United States also shows that given proper conditions and incentives, many polluting technologies can be quickly phased out. For domestic cooking, especially in developing countries, health and convenience will drive such a transition when affordable, reliable alternatives that are consistent with local cooking practices are available. For other sources, such as vehicles or coal boilers, regulations may be required to facilitate either the development of new technology or the transition to existing technology. Collaboration and technology transfer can assist in ameliorating black carbon emissions elsewhere in the world, and many regions can also benefit from the lessons learned in reducing road-transport emissions.

The discussion above focused on black carbon from energy consumption, not emissions from open burning of biomass. Open burning is a large contributor to emissions in regions with large forests or grasslands. Much of that open burning is natural, but some is generated by humans. Burning of farmland before or after harvest can also contribute to pollution in some regions. There are fewer acceptable alternatives for open burning than for energy-related burning.

7. Remaining research

My testimony has mentioned some of the uncertainties in the science surrounding black carbon. To confirm that mitigating sources rich in black carbon will in fact benefit climate, a few questions must be addressed:

- What is the net effect of cleaning up emission sources on the Earth's radiative balance, considering all co-emitted pollutants?
- How do clouds respond to changes in emissions of particles of different composition?
- How does atmospheric heating by black carbon affect clouds?
- How does black carbon deposition affect snow?
- How do these impacts vary among world regions?
- What is our best guess of uncertainty in all of these impacts?

Fortunately, a co-ordinated study, entitled "Bounding the Role of Black Carbon in Climate," is underway to assess the questions above. The study is sponsored by the Atmospheric Chemistry and Climate initiative, with support from the International Global Atmospheric Chemistry organization. I and three other scientists are leading the group of about thirty co-authors, and I expect a product in June, 2010 to be submitted as a peer-refereed journal paper.

Although we certainly do not expect the science of black carbon to be solved by June, the report will contain our best current guess of net black carbon impact on climate, with uncertainties. The report will also detail any key remaining uncertainties that must be addressed in order to fully evaluate the promise of black carbon mitigation.

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The CHAIRMAN. Thank you, Dr. Bond, very much.

Our second witness is Dr. V. Ramanathan. He is a distinguished professor of atmospheric sciences at the Scripps Institution of Oceanography at the University of California, San Diego, and the director of the Center for Atmospheric Sciences. He is the chair of the National Academy of Sciences panel that provides strategic advice to the U.S. Climate Change Science Program.

We welcome you, sir. Whenever you are ready, please begin.

STATEMENT OF VEERABHADRAN RAMANATHAN

Mr. RAMANATHAN. Chairman Markey, Ranking Member Sensenbrenner, and other honorable members of the committee, I am truly honored by this.

My own work is using autonomous——

The CHAIRMAN. Is your microphone on down there?

Mr. RAMANATHAN. I think so. Can you hear me now?

The CHAIRMAN. Yes.

Mr. RAMANATHAN. Can I start over or get 20 seconds?

The CHAIRMAN. All right.

Mr. RAMANATHAN. My own work is using autonomous, unmanned aerial vehicles to measure this absorption of sunlight by black carbon directly.

We also use instrumented aircraft like the Gulf aircraft, and we have followed black carbon transport all the way from China across the Pacific Ocean into the U.S. So these things travel long distances.

We also have stations in the Himalayas and in the Sierras to see how the black carbon settling on the snow darkens the snows and causes melting. And we have measurements for all of these phenomena.

And the first thing we have to recognize—first of all, I completely agree with the opening statement by both the chairman and the ranking member. The BC impact, impacts the air pollution and health at regional scales—and I will talk about that—and global scales, in terms of global warming.

At the regional scale, black carbon influences cloud formation and heats the air around it, disrupts rainfall patterns, such as a monsoon in India. And the deposition of black carbon on bright snow surfaces darkens ice and snow. And this, along with the warming of the air by BC, contributes to the warming of the Arctic—my colleague, Dr. Shindell, will talk about that—as well as the elevated regions of the Himalayan-Tibetan glaciers and snow packs. Thus, black carbon is directly linked with the water budget of the planet.

Relating to the global warming effort of BC, current estimates show the contribution of BC, black carbon, to the heat addition of the planet is as much as 20 percent to 60 percent of that due to carbon dioxide. The 60 percent value is my estimate with Professor Carmichael, in which we constrained the global network of instruments and aircraft data.

As has been mentioned, BC is an important fast-action tool in mitigating long-term warming due to greenhouse gases. To give an example, reducing black carbon emissions by 50 percent today will lead to a 50 percent reduction in the heat trapped by them within a few months so that policymakers will witness the success of their actions during their tenure. I think it would also be a great opportunity to test climate scientist theories and models. And it is instructive to compare the potential of BC as a mitigation tool with that of CO_2 reduction.

The manmade carbon dioxide blanket weighs a staggering 880 billion tons. The weight of black carbon in the blanket is a minuscule 250,000 tons, except it almost has half the effect of CO_2. However, we have to point out, CO_2 reductions are required to avert large warming. For example, we are currently adding about 35 gigatons every year, and it is growing at a rate of 2 to 3 percent. At this rate, we will be adding another 1,500 billion tons of CO_2 during this century. So black carbon reduction should be thought of as complementary and not as supplementing CO_2.

As has been pointed out, two important targets for reductions of black carbon are those generated by diesel and BC generated by cooking with biomass fuels. For example, I am working with a village in India, trying to understand replacing the cookstoves, the traditional cookstoves, with nearly smoke-free cookstoves, how much climate warming we would avoid.

So the last thing I want to conclude, the science of black-carbon-climate link we have to understand is relatively new, compared to what we have spent—over 4 or 5 decades—understanding the issue of CO_2. And, as a result, every month we are finding out yet another way in which black carbon impacts the environment. So this is the science in the making.

I just want to give you three major examples. The interaction of black carbon within clouds and the impact on precipitation and cloud extent—this might emerge as one of the bigger issues. The role the black carbon atmospheric heating and ice/snow darkening, its role on the observed warming and melting of the alpine glaciers and snow packs. It is an emerging science. Lastly, impact of black carbon on the Arctic warming and sea ice retreat, which I think will be covered by my colleague, Dr. Shindell.

Thank you so much.

[The statement of Mr. Ramanathan follows:]

Climate Impacts of Black Carbon

V. Ramanathan
Scripps Institution of Oceanography
University of California, San Diego

*Testimonial to the House Select Committee on Energy Independence and Global Warming
Chair: The Honorable Edward J. Markey
Ranking Member: The Honorable F. James Sensenbrenner, Jr

House Hearing entitled:
Clearing the Smoke: Understanding the Impacts of Black Carbon Pollution
March 16, 2010

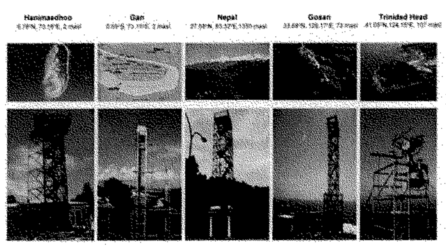
2175 Rayburn House Office Building
Washington D.C.

**The views expressed here are those of the author and do not necessarily represents the views of the author's institution or the funding agencies.*

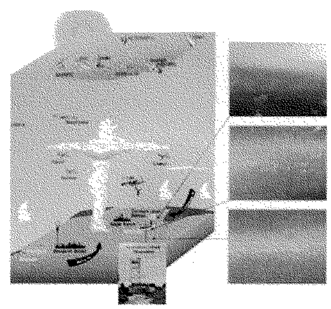
My Background

I am an atmospheric physicist. My work on black carbon and its radiative warming is largely based on experimental and observational studies. I Co-Chaired the Indian Ocean Experiment in the 1990s which looked at long range transport of black carbon from S Asia and its regional radiative forcing. I also chair the United Nations Environmental Program's Atmospheric Brown Clouds (ABC) project and set up regional observatories in the Arabian Sea, Nepal and western Pacific to observe long term variations in black carbon and other manmade particles. With researchers in my group, I have developed autonomous unmanned aerial observing systems (UAS) with miniaturized black carbon and radiometers instrumentation to measure directly how black carbon and other aerosols modify the heating of the atmosphere. UAS campaigns have been conducted in the Arabian Sea, in S California and in the western Pacific during the Beijing summer Olympics to examine the impact of the 'great pollution shutdown' in Beijing.

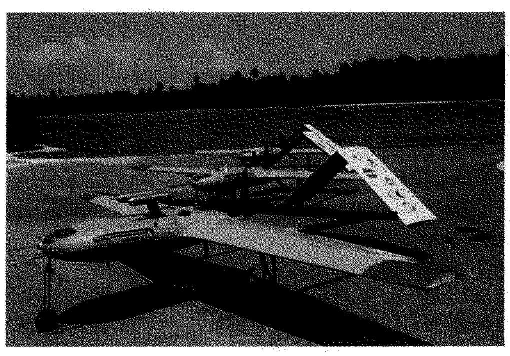
ABC Observatories



Indian Ocean Experiment



Unmanned Aerial Vehicle Observing Systems



I. SYNOPSIS

This testimony is largely based on a synthesis article published in 2008: Ramanathan, V. and G. Carmichael (2008).

What is Black Carbon(BC)?: Black carbon is the particle (also known as Aerosol) which gives the darker color to smoke from diesel vehicles or fires. BC is generated through cooking with solid fuels (wood, cow dung, crop residues), by bio mass burning (savanna burning, forest fires and crop residue burning) and fossil fuel combustion (diesel, solid coal and others).

Atmospheric Brown Clouds (ABCs): In the atmosphere, BC is mixed with other particles such as sulfates, nitrates, dust and other pollutants, and together, the mix of manmade particles are sometimes referred to as Atmospheric Brown Clouds (ABCs). The name "Brown Clouds" is due to the fact that the mixture of BC and other aerosols gives a brownish color to the sky.

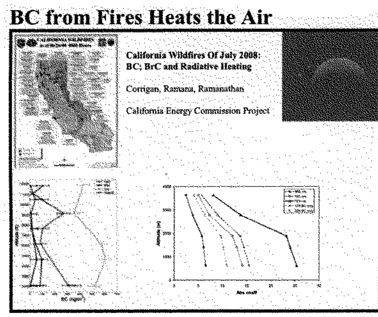
Physics of Climate Warming Effects by BC: BC is one of the strongest absorbers of solar radiation in the atmosphere and thus it is a source of global warming. In addition to BC, smoke also contains some organic aerosols which also absorb visible and UV solar radiation and such organic aerosols are called as Brown Carbon. Black carbon is removed from the atmosphere by precipitation. When BC is deposited on snow and ice, it darkens them which in turn increases absorption of sunlight by snow and ice. This darkening effect contributes to surface warming of the arctic and the alpine glaciers.

Observationally Constrained Estimate of Heating: The estimate of BC heating by this author's group is constrained by ground based, aircraft and satellite observations. We estimate that the current (2000-2003) global warming effect of BCs may be as much as 60% of the current (2005) CO_2 greenhouse warming effect. Most model based estimates of BC warming effect are smaller and are in the range of 20% to 50%.

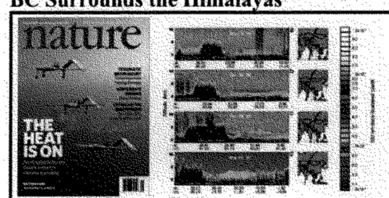
Global Water Budget: Digressing to all particles in ABCs, ABCs enhance scattering and absorption of solar radiation and also produce brighter clouds that are less efficient at releasing precipitation. The net result is a large reduction of sunlight at the surface, popularly known as dimming. The interception of sunlight in the atmosphere by BC and the surface dimming, along with the micro-physical effects can lead to a weaker hydrological cycle and drying of the planet. ABCs and black carbon are thus linked with the availability of fresh water, a major environmental issue of the 21st century.

Regional Climate Impacts: The regional effects of BC are estimated to be particularly large over Asia, Africa and the Arctic. Since the dimming and atmospheric heating are non-uniform in space and time, BC leads to changes in north-south and land-ocean contrast in surface temperatures, in turn disrupting rainfall patterns. For example, the Sahelian drought, the decrease in the monsoon rainfall over India and the drying of northern China are attributed by models to BC and other aerosols in ABCs. Recent studies employing unmanned aerial vehicles showed that BC enhances atmospheric solar heating by about 25% to 50% in S.Asia, E. Asia and in California. Model studies suggest this heating to have contributed as much as greenhouse warming to the large warming observed over elevated regions of the Himalayan-Tibetan glacier region. In addition, the deposition of BC over the bright snow and ice surfaces darkens these

BC from Fires Heats the Air

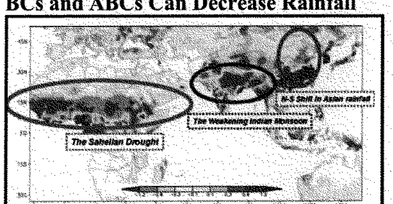


BC Surrounds the Himalayas



Color-coded profiles of 532nm backscatter return signal from the CALIPSO satellite lidar showing the vertical distribution of ABCs. The image shows ABCs surrounding the Himalayas from both the S and SE Asian side (Source: *Ramanathan et al.*, 2007b)

BCs and ABCs Can Decrease Rainfall



Trend in observed rainfall from 1950 to 2002. The figure shows the change in rainfall between 1950 and 2002; It was obtained by multiplying the year linear trend in mm/day/year by 52 years. The precipitation data is the Hadley center CRU data (Source: *Mitchell and Jones*, 2005)

surfaces. The resulting increase in absorption of solar radiation is estimated to be a major source of warming and melting of the arctic sea ice and the eurasian snow mass including the Himalayas and the Tibetan regions.

Status of Current Understanding: It is important to distinguish issues that are well understood from those that require confirmation. The first definitive study on the global warming magnitude of CO_2 increase was published 45 years ago and it required hundreds of model studies by numerous groups since then to reach the current level of consensus on the importance of CO_2 to climate change. In comparison, observational studies on climate effects of BC were begun in earnest about 15 years ago. There is reasonable consensus on the following issues:

- Life time of black carbon in the air is of the order of several days to few weeks.
- Fossil fuel combustion, bio fuel cooking and biomass burning are the sources of BC.
- BC adds solar heating to the atmosphere and causes dimming at the surface. The atmospheric solar heating is much larger than the surface dimming, and as a result, BC leads to a net warming of the surface and the atmosphere.
- Deposition of BC on sea ice and snow darkens the surface and leads to more solar absorption and melting of sea ice and snow.
- Atmospheric Brown Clouds (i.e., BC and other manmade particles) lead to dimming at the surface and the global average effect of this is to decrease rainfall.
- Globally, BC has a net warming effect on the climate system. The magnitude of its current warming effect is subject to a large uncertainty, ranging from about

20% to as much as 60% of the warming effect of CO2 increase since the 1850s.

Rationale for Mitigating BC Emissions: BC offers an opportunity to reduce the projected global warming trends in the short term. The life time of BC in the air is of the order of days to several weeks. The BC concentration and its solar warming effect will decrease almost immediately after reduction of its emission. Policy makers will have a unique opportunity to witness the success of their mitigation efforts during their tenure. Reductions of BC emissions are also warranted from considerations of public health, air quality and regional climate change.

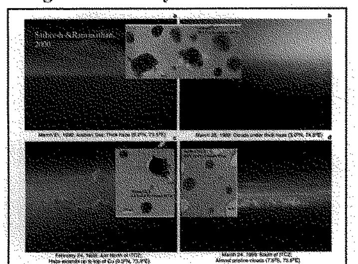
Other Considerations for Policy Makers:

- ***Unmasking of the Greenhouse Effect:*** A blanket keeps us warm on a cold winter night by trapping the heat from our body. Likewise, the greenhouse gases surround the planet like a blanket and trap the infrared heat generated by the planet's surface and the atmosphere. Black carbon particles enter this blanket and heats it by trapping sunlight. Sources that generate BC also co-emit other particles made of organics, which act like mirrors on the blanket and cool the surface by reflecting sunlight. In addition, some fossil fuels also generate other mirror like particles such as sulfates and nitrates. Because of the concern over sulfate pollution, emission of SO_2 has come down by 30% to 50% in developed nations since the 1980s, thus eliminating their cooling effect. This unmasking has been observed as increased sunlight in most of Europe and USA during the last few decades, and needs to be offset by corresponding decreases in BC.
- ***Complementing CO_2 Emission Reductions:*** CO_2 is the major factor (as much as 55%) contributing to the enhancement of the greenhouse effect. At current rate of emission (35 billion tons per year) and the current growth rate of 2% to 3%, the manmade greenhouse effect can double during this century. BC reductions, even at 50%, cannot offset the CO_2 effect. However, BC reductions when combined with reductions in other short lived climate warming gases, can delay large warming by few decades and complement CO_2 mitigation efforts.

Diesel and Cook stoves are Prime Targets for Mitigation: BC generated by diesel combustion has greater warming potential than bio-fuel cooking or biomass burning. This is because diesel generates less of the cooling organic aerosols. With respect to biomass fuel cooking, limited studies suggest that this source is also a net climate warmer but we need to conduct a careful and well documented scientific study of the impact of biomass cookstoves. Towards this goal, this author along with a team of NGOs and public health experts, has proposed Project Surya (http://www-ramanathan.ucsd.edu/ProjectSurya.html). Cooking with solid fuels (wood and cow dung) is a major source of BCs over S Asia and has major health impacts on women and children. Surya will adopt a large rural area of about 50,000 population, in India, and provide alternate cooking with biogas plants, smoke free cookers and solar cookers.

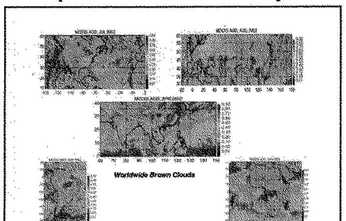
Major Source of Uncertainties: The basic input data for most models is the inventory of emissions of BC from various parts of the world. This has about a three-fold uncertainty, particularly for Asia, Africa and S America. The second major uncertainty is the inter-action of BC and organics aerosols in clouds. Relying on just observational work, BC-Cloud interactions seem to have a net warming effect.

Images of Internally Mixed BC



Ramanathan, et al 2001a

Atmospheric Brown Cloud: Hot Spots



Monthly mean aerosol optical depths derived from MODIS aerosol instrument on NASA's TERRA satellite. The optical depth is a good index for the product of the aerosol number concentration and their surface area from the surface through the depth of the atmosphere. The color shading is dark blue for AODs smaller than 0.05 (clean marine background); green for 0.2 (visible brown clouds), yellow for 0.4 to 0.5 (very hazy)and red for AODs>0.6 (heavily polluted).

Ramanathan et al, 2007c

II. Black Carbon, Atmospheric Brown Clouds and Greenhouse Effect: Background

1. ***Origin of Black Carbon:*** Black carbon (BC), a major component of soot, is emitted through cooking with solid fuels (coal, wood, cow dung and crop residues), by biomass burning and fossil fuel combustion (solid coal or combustion of diesel fuel). These sources also emit organic aerosols and the mix of BC and organics is popularly referred to as soot. In the atmosphere, BC is mixed (*Moffet and Prather, 2009*) with other particles such as sulfates, nitrates, dust and other pollutants. A single particle can contain a mixture of BC and one or more of these other chemical species, in which case, the particle is referred to as internally mixed. BC can also exist as a separate particle, coexisting with other aerosols side by side, and in this instance BC is referred to as externally mixed. BC and these other particles remain in the atmosphere for several days to few weeks, during which they can be transported thousands of kilometers away from their source.

2. ***Atmospheric Brown Clouds and BC Hotspots***: Such vast plumes of pollution aerosols containing BC are sometimes referred to as Atmospheric Brown Clouds (ABCs). Hot spots of ABCs with large concentrations of BC as well as other man-made aerosols such as sulfates, organics, nitrates and others have been identified by synthesizing satellite observations with ground base and aircraft observations: The following regions fall under the hot spot category: (1) east Asia (eastern China, Thailand, Vietnam and Cambodia), (2) Indo-Gangetic Plains in south Asia (the northwest to northeast region extending from eastern Pakistan, across India to Bangladesh and Myanmar), (3) Indonesian region, (4) southern Africa extending southward from sub-Saharan Africa into Angola and Zambia and Zimbabwe, and (5) the Amazon basin in South America. However, ABCs are a world wide problem, including developed nations. For example, per capita emissions of black carbon in US is comparable to that in E. Asia.

3. ***Policy Implications of the Regional Nature of BC Effects***: The regionally concentrated nature of BC concentrations is a potential advantage for policy makers. While one of BC's major effect is on global and regional climate change, the immediate effect of BC reductions will be felt locally (wherever mitigation actions are taken) as an improvement in air quality and visibility accompanied by mitigation of the impacts of BC on human health, agriculture, and local precipitation.

4. ***Black and Brown Carbon Terminology***: *Black carbon is not a 'greenhouse gas'*. It is a particle and it is the strongest absorber of solar radiation in the atmosphere. It also absorbs and emits infra red or heat radiation and contributes to the greenhouse effect. However, the latter effect is much smaller than the solar warming effect. The term "black carbon" is not rigorously defined. Climate models have largely assumed black carbon is the same as elemental carbon. All man-made sources of black carbon also emit hundreds of organic aerosols and gases (which later become aerosols). Most climate models treat these organic aerosols as purely reflecting (and not absorbing) aerosols, i.e., they have a cooling effect. Recent experimental work has given compelling evidence that some of these organic aerosols also absorb sunlight in UV and visible wavelengths and thus enhance the warming effects of BC (*Magi, 2009*). These absorbing organic aerosols are popularly referred to as 'Brown Carbon' (*Andreae and Gelencser, 2007*). For the purpose of this report, absorption of solar radiation by BC and brown carbon are treated together, since they occur in the same wavelength region.

5. ***How Does BC contribute to Global Climate Change?***
BC warms the climate in at least 5 different ways (*Jacobson, 2010*): i) It traps (absorbs) solar radiation in the atmosphere, directly heats the air and thus contributes to climate warming. There is now strong experimental evidence that internally mixed BC absorbs significantly more solar radiation than externally mixed BC (*Moffet and Prather, 2009*). ii) When BC is deposited on sea ice, snow packs and glaciers, it darkens the snow and ice surfaces, enhances absorption of sunlight and contributes to melting of snow and ice. iii) BC also absorbs and emits heat radiation (Infra red radiation) and adds to the atmospheric greenhouse effect. This effect, although much less than the warming from the solar heating effect, can be important in the arctic and during nights. iv) BC gets into cloud droplets (by nucleation or scavenging) and enhances absorption of solar radiation by drops. v) The day time warming of the lower layers of the atmosphere, first few kilometers, by BC can suppress the relative humidity and evaporate low level clouds, which will allow more solar radiation to reach the ground and amplify the warming.

BC has also a potential cooling effect. When aged and mixed with other aerosols such as sulfates and oxidized organics, BC can also be efficient cloud nuclei. Formation of new cloud drops through BC nucleation, in low level stratus and cumulus clouds, can make the clouds brighter and shield the surface from solar radiation and cause surface cooling.

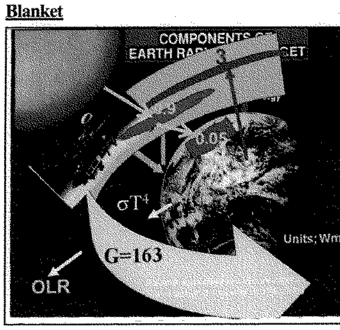
6. ***Recent Estimates of BC Forcing***: Compared with the climate forcing due to carbon dioxide which has been studied intensely for several decades, the science of BC and its climate effects is relatively new. Our understanding of the impact of black carbon (BC) aerosols has undergone major improvements and revisions during the last 10 years. The major contributing factors are listed below: i) Experimental findings from field and aircraft observations (e.g. INDOEX, ACE-Asia and others) in Asia, Africa, Arctic, Europe, and N America. ii) new satellite observations [e.g., MODIS, CALIPSO]. iii) surface observatories such as the IMPROVE network in USA; worldwide AERONET network by NASA and Atmospheric Brown Cloud observatories for the Indo-Asian-Pacific region by UNEP, NOAA and others; iv) Scripps' Unmanned Aircraft Observing systems funded by NSF and NOAA; v) UCSD's Time of flight mass spectrometer single particle measurements; vi) observationally constrained emission inventories; vii) aerosol chemical-transport models developed at Stanford, Caltech, NASA, NOAA and NCAR laboratories. We now have direct UAV measurements for the large enhancement of atmospheric solar heating by BC (*Ramanathan et al, 2007b*).

Black Carbon Global Radiative Forcing

	SOLAR EFFECT				GREENHOUSE EFFECT
	Direct Atmospheric Heating			Ice/Snow Heating	
	Externally Mixed	Internally Mixed	Observationally Constrained		
STANFORD STUDY (Jacobson, 2001)	0.31	0.55 to 0.62		0.05	0.03 to 0.04
CAL TECH STUDY (Chung & Seinfeld 2002)	0.5	0.8			
NOAA_GFDL STUDY (in Forster et al, 2007)	0.5				
IPCC – AR4 (Forster et al, 2007)	0.34			0.1	
NASA STUDY (Sato, 2003)			1		
SCRIPPS STUDY (Ramanathan & Carmichael)			0.9 (±30%)		

Global averaged estimates for the radiative heating (or radiative forcing) of the surface-atmosphere system by BC as of now (year 2005) is in the range of 0.3 Wm^{-2} to 0.9 Wm^{-2} for the direct solar absorption by atmospheric BC; 0.05(± 50%) Wm^{-2} for the BC solar heating of ice and snow; 0.03 (±50%) Wm^{-2} for the greenhouse effect of BC. The combination of these three warming effects of BC is referred to as direct radiative forcing. The direct radiative forcing of BC (0.4 to 1 Wm^{-2}) is about 20% to 60% of the pre-industrial to year 2005, CO_2 greenhouse forcing. We have adopted *Forster et al's (2007)* IPCC estimates of 1.66 Wm^{-2} for the pre-industrial to year 2005, CO_2 radiative forcing. The heating due to BC in clouds (items iv and v above) and the cooling effect due to BC nucleation of cloud drops are not yet firmly established.

BC forcing in the context of the Greenhouse Blanket



7. ***BC forcing in the context of the Greenhouse Blanket***: The greenhouse gases (water vapor, carbon dioxide, ozone and others) surround the planet like a blanket. A blanket keeps us warm on a cold winter night by retaining (or trapping) our body heat. Similarly, the GHGs retain much of the infra red radiation (or heat radiation) given off by the surface and the atmosphere (including clouds) within the planet. The energy retained (thickness of the blanket) by the atmosphere has been determined from satellite radiation budget data and other correlative surface temperature data, to be about 163 Wm^{-2} (5%) for the 1985 to 1989 period. H_2O in the form of

Non-CO_2 Climate Warmers

Contribution to 2005 forcing relative to CO_2 (1.66 Wm^{-2})	
Greenhouse Gases	
Ozone (troposphere)	: 20%
Methane	: 30%
Halocarbons	: 20%
Particles (Aerosols)	
Black Carbon (soot/smoke)	: 27% to 55%*
Total Non-CO_2	: 97% to 125%

All numbers except the red are IPCC values; Long lived N_2O not included

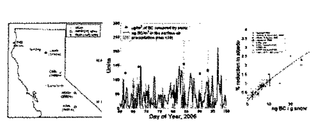
* Ramanathan & Carmichael; 2008

Deposition of BC on Snow in California: Direct Measurements

Measured Black Carbon Deposition on the Sierra Nevada Snow Pack

O Hadley, C. Corrigan, T W Kirchstetter, C. S. Davis, V. Ramanathan

California CEC Project

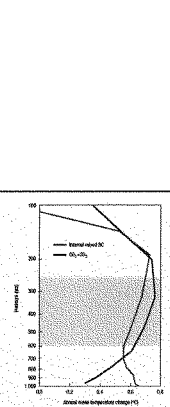


	2006 BC (ng/m³)	2009 BC (ng/m³)
Lassen	5.0 (±2.3)	0.9 (±1.1)
CSSL	6.7 (±3.1)	6.3 (±4.9)

vapor, cloud drops and ice crystals provide about 2/3 of the total effect, CO_2 about 20% and the balance is due to other GHGs including ozone, methane, nitrous oxide.

Since pre-industrial times, the increase in GHGs (CO_2; methane; CFCs; nitrous oxide; and others) by human activities have thickened the blanket and retained more energy. CO_2 alone has increased from 280 ppm to 387 ppm. This increase as well as increase in the other anthropogenic GHGs has retained additional energy of about 3 (15%) Wm^{-2} or thickened the blanket by about 1.8% (3 Wm^{-2} out of 163 Wm^{-2}). The 1.8% may seem small, but it should be noted that, the increase in global mean surface temperature from glacial to the current interglacial period is about 5° K (5°C) and in the absolute Kelvin temperature scale, 5°C is only 1.7 % of the global mean temperature of 289° K (15.5°C). Reverting back to the effect of BC, we can think of BC as smoke in the blanket that traps sunlight (0.3 to 0.9 Wm^{-2}) directly into the blanket and into snow and sea ice (0.05 Wm^{-2}) as well as retaining infra-red radiation (0.03 Wm^{-2}) in the blanket.

8. ***Role of Non-CO2 Climate Warmers in Mitigation***: BC is but one of several non-CO_2 climate warmers. Human activities have added several other GHGs. These include, methane, nitrous oxide, halocarbons and tropospheric ozone. Compared with the centuries to millennial time scales of CO_2, the life times of several non-CO_2 warmers are much shorter. BC's life time is less than few weeks; Ozone molecule's life time is few months, methane less than 15 years and halocarbons range from a year to a decade. Because of their shorter life times, reductions in the emissions of short lived warmers will lead to quicker reductions in the concentrations and their radiative warming of climate. In fact, such a mitigation action, will also help the science of climate change test its model predictions of cause and effect. Several studies have estimated that, with continuation of current trends in GHGs emissions, there is more than a 50% probability of surpassing the 2°C warming threshold during this century. A IIASA study estimates that with currently available technology and stringent implementation of current air pollution laws, it is possible to achieve about 30% reductions in methane, ozone, HFCs and more than 30% for BC. Such reductions in non-CO_2 warmers, can postpone the time for crossing the 2°C threshold by few decades or more.



Simulated effects of BC and CO_2 on atmospheric temperatures over India. (*Ramanathan and Carmichael, 2008*)

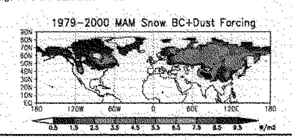
BC and Eurasian Snow Cover

Springtime warming and reduced snow cover from carbonaceous particles

M. G. Flanner1, C. S. Zender2, P. G. Hess1,3, N. M. Mahowald1,3, T. H. Painter4, V. Ramanathan5, and P. J. Rasch1

ACPD 8, 19819–19859, 2008

Equilibrium climate experiments suggest that fossil fuel and biofuel emissions of BC+OM induce 95% as much springtime snow cover loss over Eurasia as anthropogenic carbon dioxide, a consequence of strong snow-albedo feedback and large BC+OM emissions from Asia.



9. ***Regional Climate Effects of BC:*** The regional effects of BC are estimated to be particularly large over Asia, Africa and the Arctic. In these regions its effects include alteration of surface and atmospheric temperatures, disrupting monsoon circulation and rainfall patterns (*Menon et al, 2002; Ramanathan et al, 2005; Lau et al, 2008*). The interaction of the regional climate effects of greenhouse gases and ABCs deserve more attention. For example, a recent study (*Ramanathan et al, 2007b*) employing unmanned aerial vehicles suggests that BC enhances atmospheric solar heating by as much as 50%. When these data are combined with CALIPSO and other satellite data over S, SE Asia and the Indian Ocean and employed in a climate model, the simulations suggest that the elevated atmospheric warming over the S and SE Asian region, (including the elevated Himalayan regions) by ABCs is as much as that due to the greenhouse warming. Thus the atmospheric solar heating by BC may be intensifying the effects of greenhouse gases on the Himalayan-Tibetan glacier region. Climate model studies also suggest that fossil fuel and biofuel BC emissions in Asia and Europe induce as much springtime snow cover loss over Eurasia as anthropogenic carbon dioxide, a consequence of the darkening of the snow by deposition of snow and strong snow-albedo feedback. (*Flanner et al, 2009*). We now have direct measurements of efficient removal of BC by snow over the Sierras in California.

10. ***Effects of BC and ABCs on Regional Water Budget:*** Reverting to the general effects of all aerosols (and not just BC), ABCs enhance scattering and absorption of solar radiation and also produce brighter clouds (*IPCC, 2007*) that are less efficient at releasing precipitation (*Rosenfeld et al, 2000*). These in turn lead to large reductions in the amount of solar radiation reaching the surface (also known as dimming), a corresponding increase in atmospheric solar heating, changes in atmospheric thermal structure, surface cooling, atmospheric warming, alterations of north-south and land-ocean contrast in surface temperatures, disruption of regional circulation systems such as the monsoons, suppression of rainfall, and less efficient removal of pollutants (*Ramanathan et al, 2001b, 2005, 2007a; Menon et al, 2002*). Together the aerosol radiation and microphysical effects can lead to a weaker hydrological cycle and drying of the planet. This connects aerosols directly to availability of fresh water, a major environmental issue of the 21st century (*Ramanathan et al, 2001b*). For example, the Sahelian drought during the last century is attributed by some models to the north-south asymmetry in aerosol forcing (*Rotstayn and Lohman, 2002*). In addition, new coupled-ocean atmosphere model studies suggest that aerosol radiative forcing may be

the major source for some of the observed drying of the land regions of the planet (e.g. India&northern China) during the last 50 years (*Ramanathan et al, 2005 and Meehl et al, 2008*). Regionally aerosol induced radiative changes (forcing) are an order of magnitude larger than that of the greenhouse gases, but because of the global nature of the greenhouse forcing, its global climate effects are still more important. However there is one important distinction to be made. While the warming due to the greenhouse gases is projected to increase global average rainfall, the large reduction in surface solar radiation due to absorbing aerosols would offset it.

11. Challenges and Opportunities for Mitigation:
BC's warming effect presents an opportunity to reduce projected warming in the short term (as also suggested by others, e.g. *Hansen and Sato, 2001; Jacobson, 2002; Bond and Sun, 2005*). My thesis is that, BC reductions have the potential to forestall the onset of the so-called dangerous climate change. For example, a reduction of BC emissions by about 50%, may reduce the radiative forcing by about 0.2 Wm^{-2} to 0.5 Wm^{-2}. In comparison, if CO_2 continues to increase at the current rate of increase, it will add about 0.2 to 0.3 Wm^{-2} per decade. Thus a drastic reduction in BC has the potential to offset CO_2-induced warming for a decade or two. Effectively, BC reduction may provide a possible mechanism for buying time to develop and implement effective steps for reducing CO_2 emissions. The following issues need to be factored in further consideration of this proposal:

i) The life time of BC is of the order of days to several weeks, depending on the location. Thus the BC concentration and its global heating will decrease almost immediately after reduction of its emission;
ii) Inhalation of soot is a major public health issue. For example, in India, alone it is estimated inhalation of indoor smoke is responsible for over 400,000 deaths annually (mostly among women and children; *Smith, 2000*). Air pollution related fatalities for Asia is estimated (*Pachauri and Sridharan, 1998*) to be over one million (indoor smoke inhalation and outdoor brown clouds). Thus reduction of BC emissions may be warranted from public health considerations alone.
iii) The developed nations have reduced their BC emissions from fossil fuel sources significantly since the 1960s. Thus the technology exists for a drastic reduction of fossil fuel related BC. With respect to biofuel cooking, it can be reduced if not eliminated, by providing alternate cooking methods in rural areas in Asia and Africa. But we need to conduct a careful and well documented scientific study of the impact of BC reduction on radiative forcing and its cost effectiveness. Towards this goal, this author along with a team of NGOs, public health experts and alternate energy experts, has proposed Project Surya (http://www-ramanathan.ucsd.edu/ProjectSurya.html), that will adopt a large rural area of about 50,000 population, in India, and provide alternate cooking with biogas plants, smoke free cookers and solar cookers. The objective of this experiment is to estimate from observations the warming potential of BC. Surya will also assess the impact of BC reduction on human health and the cost of reducing BC emissions from biofuels. Results from this pilot experiment will be used to scale up similar efforts throughout the subcontinent.
iv) Long range transport of BC is an important factor for policy discussion of BC mitigation. For example, studies have shown that transport of BC from E. Asia across the pacific is a major source of BC above one km in altitude over California (*Hadley et al, 2007*). Likewise, BC from N. America and Europe deposits on snow and sea ice in the Arctic. BC from S. Asia and E. Asia surrounds the Himalayan-Tibetan mountain ranges.
v) The notion that we may reach a level of dangerous climate change during this century is increasingly perceived as a possibility. Given this development, options for mitigating such dangerous climate changes are being explored worldwide. The present BC reduction proposal should also be considered in this context, and by no means is BC reduction being proposed by this author as an alternative to CO_2 reduction. At best, it is a short term measure, to buy a decade or two time for implementing CO_2 emission reduction.

Major Uncertainties: Our ability to model the effects of BC in climate models is severely limited. One of the main reasons is the large uncertainty (factor of 2 or more) in the current estimates of the emission of organic (OC) and elemental carbon (EC) (See *Bond et al, 2004; 2007*). Furthermore, biomass burning contributes significantly to the emissions of OC and EC and the historical trends (during the last 100 years) in these emissions are unknown. Models currently resort to adhoc methods such as scaling the present day emissions with past trends in population.

BC has two competing effects inside clouds. Mixtures of BC with sulfates or organics can become cloud nuclei and in turn enhance the number of cloud drops. This in turn can lead to a decrease in drop size, an increase in cloud lifetime followed by an increase in reflection of solar radiation. In addition, the a decrease in drop size can suppress rain formation. On the other hand, the large solar heating of the cloudy skies by BC can decrease relative humidity and evaporate clouds, which can lead to increased penetration of sunlight to the ground and warming of the surface. These two competing effects have been examined with surface data (*Kaufman and Koren, 2006*) over several continental and marine locations. These data suggest that the warming effect of BC dominates the cooling effect of BC-Organic-Sulfate mixtures. Satellite data over Amazon have been used to examine the net interaction of BC laden biomass burning smoke with clouds. This study (*Koren et al, 2004*) also showed that the smoke lead to dissipation of low clouds. Similarly, cloud coverage in highly polluted E Asia exhibited a long term declining trend (Qian et al, 2006).

Acknowledgements

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The CHAIRMAN. Thank you, Doctor, very much.

Our next witness is Dr. Drew Shindell, a senior scientist at NASA's Goddard Institute for Space Studies. He is also a lecturer in the earth and environment sciences at Columbia University. Of his many distinctions, he received a National Science Foundation Antarctic Service Medal and a Scientific American Top 50 Scientists award.

We welcome you, sir. Whenever you are ready, please begin.

STATEMENT OF DREW T. SHINDELL

Mr. SHINDELL. I would like to first thank the committee for the opportunity to testify this morning.

Direct observations of climate seldom reveal cause and effect, so that the influence of black carbon on surface temperature must be estimated using models as well as data. Several independent methods find broadly similar results, with an overall global mean warming due to black carbon that is about 15 to 55 percent of the warming due to carbon dioxide, as we have heard. Black carbon has likely had even larger regional effects, especially in areas such as the Arctic, due to its strong impact on snow and ice.

Black carbon affects other aspects of climate in addition to surface temperature. Several studies have indicated that the large amounts of smoke and haze observed near Asia can cause shifts in a monsoon.

The physical mechanism linking black carbon to changes in precipitation is clear and operates worldwide. Unlike temperature changes, shifts in precipitation nearly always have negative net economic impacts, as long-term infrastructure has quite sensibly been designed for norms over past decades.

Actual policies will usually impact emissions of many compounds simultaneously, since incomplete combustion produces substantial amounts of other particulates and gases in addition to black carbon. Hence, it is necessary to examine the net impacts of all emissions from a particular activity on climate. Furthermore, emissions of pollutants also affect the quality of the air we breathe. Policies typically treat the air quality and climate effects separately, however.

Encouragingly, research has shown that the optimal strategies to reduce black carbon and the ozone precursors carbon monoxide, volatile organic compounds, and methane are similar whether the goal is improving air quality or limiting global warming. This argues for a stronger emphasis on reduction in emissions of these pollutants in air quality policies, for which there would be a climate co-benefit, and in climate policies, for which there would be an air quality co-benefit.

Research suggests that strategies to simultaneously improve air quality and mitigate global warming differ from region to region. In the U.S., reductions in overall emissions from diesel vehicles appear to achieve both goals, with the substantial part of the benefits coming from reduced black carbon. More generally, increases in fuel efficiency coupled with reductions in emissions from both gasoline- and diesel-fueled vehicles show the most positive results for climate and air quality.

In contrast, many countries in the developing world use fuel with high sulfur content, as the U.S. did years ago. Hence, in developing Asia, where particulate emissions are larger than in any part of the world, reductions in emissions from both industrial processes and residential cooking stoves offer ways to simultaneously improve air quality and mitigate warming.

The health benefits that would be gained from reductions in particulate and ozone concentrations are clear from epidemiological studies. While these benefits are most strongly felt in nearby population, long-range transport of air pollution can also be substantial. And, hence, the health impacts of air pollution are not simply a local issue. Climate impacts extend even more broadly.

Particulates also impair visibility, with detrimental impacts on tourism and recreation. Elevated levels of ozone cause damage to plants, leading to economic losses from reduced agricultural and forestry yields and decreased food security. Many projects to control black carbon, carbon monoxide, volatile organics, and methane emissions may therefore have higher benefits than costs, even without including any value from reducing warming. For example, both State and Federal diesel emissions regulations have shown human health benefits five times or more than the cost of implementing the regulations.

Air pollution leads to $70 billion to $270 billion in damages per year in the United States alone. So there is clearly a great deal of potential for co-benefits, including health care cost savings.

Though further research is clearly needed to reduce uncertainties, we can already conclude that reductions in emissions of black carbon are likely to be a useful component of strategies to mitigate climate change. Realistic emissions reductions would affect several types of particles and gasses and, thus, require a careful analysis of their net impact.

In summary, while there is more to learn, several things are already clear: Reductions in emissions of products of incomplete combustion will virtually always improve health. And by targeting emissions rich in black carbon, carbon monoxide, volatile organic compounds, and methane, many options are available that will simultaneously mitigate climate change.

Thank you.

[The statement of Mr. Shindell follows:]

HOLD FOR RELEASE
UNTIL PRESENTED
BY WITNESS
March 16, 2010

Statement of
Dr. Drew T. Shindell
Senior Scientist
NASA Goddard Institute for Space Studies
before the

Select Committee on Energy Independence and Global Warming
United States House of Representatives

I thank the committee for the opportunity to testify on the impacts of black carbon. I have been a researcher at NASA's Goddard Institute for Space Studies since 1995, and have taught the graduate level course on atmospheric chemistry and pollution at Columbia University since 1997.

Black carbon is one of many products of incomplete burning (combustion). It is not produced in large amounts from very high temperature combustion such as that which takes place in power plants, but in numerous types of much less efficient burning such as in diesel engines, agricultural and forest fires, and residential cooking stoves. Most of these emission sources are a direct result of human activities, while emissions from fires can be thought of as natural activities that are influenced by humans. The largest sources of black carbon emissions from human activities in the US (and Europe) are diesel engines while residential stoves (use for cooking and heating, and fueled by agricultural waste, wood, coal, dung, etc) and industrial processes are typically most important in developing countries and for the global total [1, 2].

Black carbon influences climate in multiple ways. It absorbs sunlight, leading to large-scale surface warming (though locally there may be cooling as less sunlight reaches the surface). It can also influence clouds in numerous, complex ways that are not fully understood at present. Hence the overall impact of those effects is not known. When black carbon falls on snow and ice surfaces it darkens them, reducing their ability to reflect sunlight away from the Earth's surface, and thus causing warming [3, 4]. Furthermore, the absorption of sunlight by black carbon particles on or in snow and ice leads to melting, creating a positive feedback that enhances the original warming effect substantially. A broad assessment of current scientific knowledge leads to a best estimate that black carbon causes substantial global mean warming, but with a very large uncertainty [5-12]. Near snow or ice covered regions, emissions of black carbon are almost certain to have an overall warming impact [3, 6].

Direct observations of the climate seldom reveal cause and effect, so that the influence of black carbon on surface temperature must be estimated by models. The models are continually tested against observations, however. NASA provides many useful measurements of atmospheric particulate (aerosols), including satellite observations, surface-based radiation detection networks, and airborne field campaigns in collaboration with other agencies such as the Department of Energy, the National Oceanic and Atmospheric Administration (NOAA), and the National Science Foundation, as well as carrying out research and analysis, and modeling and data assimilation. Earth observing satellites with a direct role in observing aerosols include NASA's

Terra, Aura, Aqua and Calipso satellites (which include instruments from other US agencies and foreign partners) and NOAA's polar orbiting and geostationary environmental satellites. New missions in development are expected to make a direct contribution to the investigation of atmospheric aerosols, including the Glory satellite that should provide much more detail on aerosol properties than previously available, and longer range planning includes important follow-on capabilities. NASA ground based networks include the Aerosol Robotic Network (Aeronet) and the Micro-Pulse Lidar Network with sites located around the world. Developed primarily for satellite calibration and validation, these networks have proven to be useful and productive data sources for aerosol research as well. Annual NASA investment in aerosol missions and science has historically been approximately $130 million per year. As is described below, black carbon's role in climate cannot be understood in isolation, making it fitting that this research is embedded in a broader, multi-agency effort to understand the Earth's climate.

Multiple techniques have been used to investigate the effect of black carbon on surface temperature. In one type of study, emissions are put into a model of atmospheric chemistry and climate, and the results analyzed to isolate the effect of black carbon [6, 8, 9, 11]. The model is evaluated against observations both of particulate in the atmosphere and of climate. How well the model is able to reproduce measured particulate amounts and locations and observed temperatures gives us a sense of its accuracy and the credibility of its future projections. In addition to this type of study, changes in atmospheric energy fluxes that are due to particulate have been measured by aircraft and satellite and then put into climate models, and the response evaluated [10, 13]. Still another line of enquiry has used statistical comparisons between time-variations in climate model results and in observations to isolate the influence of black carbon in the surface temperature measurements [14]. A fourth, related technique has used regional temperature changes derived from the NASA Goddard Institute climate model and the observed regional temperature trends to calculate the influence of particulate on climate during the 20th century in comparison with other agents driving climate change [7]. Encouragingly, all these studies find results that are generally fairly similar, with an overall global mean warming due to black carbon that is about 15-55 percent of the warming due to carbon dioxide. These studies clearly still present a substantial range of values, and are further limited by our incomplete knowledge of interactions between black carbon and clouds but nevertheless all suggest a substantial warming impact from black carbon. It is important to keep in mind that while carbon dioxide increases have contributed more than any other single factor to warming, emissions of long-lived greenhouse gases other than carbon dioxide have in total contributed nearly as much to warming as has carbon dioxide itself [15]. At the same time, reflective aerosol particles such as organics, sulfates, and nitrates have offset a substantial portion of the warming from greenhouse gases [15]. This means that the percentage contribution of any individual factor to the total forcing of climate change depends upon how the comparison is made (against net forcing, or total positive forcing, for example). In terms of percent contribution to net warming since the mid-18th Century, the above estimate implies 15-55 percent of that warming may have been driven by increased black carbon (the contribution from carbon dioxide alone and the net warming from all climate change drivers has been approximately the same, so that comparison with either of these leads to comparable values). If the comparison is against the impact of all the greenhouse gases contributing to warming, then black carbon has added 10-35 percent to the greenhouse-gas induced warming, some of which has been offset by reflective aerosols and aerosol-induced cloud changes.

Black carbon has likely had even larger regional effects, especially due to its strong impact on snow and ice. In the Arctic, so called 'Arctic Haze' has been observed by pilots for decades, and results largely from transport of pollution from lower latitude industrialized areas. Though it is difficult to separate the effects of black carbon on Arctic temperatures from the effects of other factors, several results suggest that black carbon has contributed a larger share of warming in that region than it has globally [3, 6-8, 11]. In other words, more than 15-55 percent of Arctic warming since the mid 18th century might be attributable to black carbon. It may have had an especially large effect in the early 20th Century, when coal burning was commonly used in the Northeast US for residential heating, and along with reductions in sulfur emissions, may have also helped drive the very rapid Arctic warming of the past several decades [7]. In the Himalayan region, located very close to the world's largest emissions of black carbon, detailed observations of glaciers covering large areas and long periods of time are unfortunately quite sparse. While it seems that glaciers in this region are retreating overall [16], the role of black carbon in that retreat remains difficult to quantify, though it is likely to have played some role, especially in glaciers on the southern flank of the Tibetan plateau [17].

Since black carbon absorbs sunlight in the atmosphere much as it does in snow and ice, it can also affect other aspects of climate in addition to surface temperature. When sunlight is absorbed by the dark particles, the air a few kilometers above the surface containing the particles warms. This alters the temperature differences that create winds, which affects both regional temperatures and precipitation. Several studies have indicated that the large amounts of smoke and haze (so-called atmospheric brown clouds) observed near Asia can cause shifts in the timing and intensity of the monsoon, with large impacts for rainfall in India and China [18-20]. As with most aspects of climate change, it is difficult to verify this link exclusively with observations as many other factors also influence the monsoon, and other types of particles such as windblown desert dust contribute to the brown clouds. However, the physical mechanism linking black carbon to changes in precipitation is clear and operates worldwide. Unlike temperature changes, shifts in precipitation nearly always have negative net economic impacts as long-term infrastructure has quite sensibly been designed for norms over past decades.

Emissions of black carbon may affect the quality of the air we breathe as well as our climate. Policies are typically designed with the goal of limiting damage to one or the other, but largely treat the air quality and climate effects separately. For example, US regulations on the emissions of air pollutants including particulate matter (of which black carbon is a component) primarily consider their adverse effects on air quality public health, and the environment [21]. In most of the world, air quality regulations are created at local, state, or national levels, and do not consider climate impacts, while international climate change mitigation efforts (e.g. the Kyoto Protocol, the Copenhagen Accord) generally address greenhouse gases such as carbon dioxide but do not include shorter-lived pollutants such as lower atmospheric ozone or black carbon and does not consider the effects of the greenhouse gases on air quality. This separation is driven by policy rather than science, however, as the emissions of many pollutants affect both aspects of our environment. Encouragingly, research has shown that the optimal strategies to reduce black carbon and some ozone precursors are similar whether the goal is improving air quality or limiting global warming [22]. This is not the case for all pollutants that influence air quality, such as sulfur dioxide. However, for black carbon, carbon monoxide, volatile organic compounds and methane in particular, these two goals align. Even in the absence of a broad strategy encompassing both goals this argues for a stronger emphasis on reductions in emissions of these pollutants in air quality policies, for which there would be a climate co-benefit, and in climate policies, for which there would be an air quality co-benefit.

Actual policies will usually impact many species simultaneously, since, as discussed previously, black carbon is a product of incomplete combustion and this also produces substantial amounts of other particulates and gases. The amount of sunlight absorbed by black carbon can be substantially altered by interactions with these other compounds, and they themselves also affect climate. This means that it's necessary to examine the net effect of all emissions from a particular activity on climate rather than the effect of black carbon alone. Research suggests that strategies to simultaneously improve air quality and mitigate global warming differ from region to region. Preliminary results from ongoing work at my institute suggest that in the United States, reductions in overall emissions from diesel vehicles appears to be a method to achieve both goals, with a substantial part of the climate benefits coming from reduced black carbon. This could result from a shift from trucks to rail for cargo transport, for example. Imposition of diesel particulate filters on diesel vehicles, another method to reduce emissions, would in practice have different effects on emissions of different compounds. For example, these filters reduce particulate matter by about 90% but could result in a slight increase in carbon dioxide emissions due to decreased engine efficiency. Proper vehicle operation and maintenance practices optimize the air quality benefits of filters and other emission reduction technologies. The overall conclusion that such emissions reductions represent a win-win for air quality and climate does not change, however. More generally, increases in fuel efficiency coupled with reductions in emissions (carbon monoxide and volatile organic compounds) from both gasoline and diesel fueled vehicles show the most positive results for both climate and air quality [23, 24].

In contrast, many countries in the developing world use fuel with high sulfur content (as the US did years ago). Reductions in across-the-board emissions from those areas would improve air quality, but could actually increase near-term warming because these reductions would reduce reflective particles in the atmosphere that produce a cooling effect and increase atmospheric methane [24]. However, most of the developing nations are expected to follow the pattern of the developed nations and switch to low-sulfur fuels (to both directly reduce emissions that lead to particulate formation and to enable advanced emission controls) as their populations become more affluent and demand better air quality. While the transition to low-sulfur fuels may lead to near-term warming, simultaneous use of particulate filters would reduce that warming and may even lead to an overall cooling. In other words, policies that consider both air quality and climate, and hence strongly reduce emissions of black carbon, carbon monoxide and volatile organic compounds (as diesel filters do) as well as sulfur, are considerably more climate-friendly. In developing Asia, where particulate emissions are larger than in any other part of the world, reductions in emissions from both industrial processes and residential cooking stoves offer ways to simultaneously improve air quality and mitigate warming [24, 25]. Additional work is ongoing to characterize the effects of emissions from other activities, including aviation and shipping which may increase substantially and/or change location in the future. While there is more to learn, several things are already clear. Reductions in emissions of products of incomplete combustion will virtually always improve health. By targeting emissions rich in black carbon, carbon monoxide and volatile organic compounds relative to sulfur dioxide and nitrogen oxides, many options are available that will simultaneously benefit climate change.

It is worth noting that these options are by no means the default choices, and to date air quality regulations made for the sake of public health in the US, Europe and Japan have often been much more successful in reducing pollutants that cool climate (sulfur dioxide and nitrogen oxides) than those which lead to warming (for example, methane and black carbon). Changes in emissions of short-lived pollutants resulting from air quality policies along with the continued growth in Northern Hemispheric emissions of some warming pollutants such as black carbon have been linked to the accelerated warming of the Northern Hemisphere since the 1970s and the very rapid heating of the Arctic during recent decades (they may account for more than half the 1970-2007 warming trends, which have been nearly two degrees F (1 C) for the Northern Hemisphere and 3 F (1.5 C) for the Arctic)[7]. This highlights the substantial impact of these pollutants on climate change, especially at regional scales. It also emphasizes the importance of coordinated air quality and climate policies to achieve progress in both areas simultaneously rather than continuing our record of improvement in one at the expense of the other.

The health benefits that could be gained from particulate and ozone precursor emissions reductions are clear from epidemiological studies. These studies span both long periods of time and wide areas and also short, local changes due to events such as temporary industrial strikes [26-30]. Both particulate matter and tropospheric (lower atmospheric) ozone, a gas produced from carbon monoxide, volatile organic compounds and methane (in the presence of nitrogen oxides), contribute to a variety of adverse health effects. Reductions of emissions directly into living spaces are likely to yield substantial health benefits. One recent study estimated that roughly 2 million deaths could be prevented in India by bringing advanced biomass stoves to 15 million homes per year over the next 10 years [31]. While the health benefits of emissions reductions are most strongly felt in the nearby population, long-range transport of air pollution can also be substantial: one recent study found that ozone levels a few kilometers above the Western US can be significantly influenced by emissions from East Asia [32]. Another recent study estimates that the difference between Chinese emissions of particulate following a 'high-end' or 'low-end' projected trend would be several hundred premature deaths annually in the US in 2030 [33]. Though small compared with the hundreds of thousands of additional premature deaths within China itself, this nonetheless shows that the health impact of air pollution is not simply a local issue. Climate impacts extend even more broadly, with most of the Northern Hemisphere north of the tropics responding strongly to emissions from anywhere within that region, for example [7]. In a study of the projected climate during the 21st Century, substantial warming and drying of the continental interior of the US was seen, and much of this was driven by changes in air quality pollutant emissions from East Asia [34].

There are other co-benefits from control of air pollution in addition to improved public health. Particulate matter and tropospheric ozone precursors both impair visibility, with potential detrimental economic impacts on tourism and recreation. Elevated levels of tropospheric ozone also causes damage to plants, leading to economic losses from reduced agricultural and forestry yields [35]. Air pollution can also degrade many types of materials used in buildings, such as stonework and metalwork. In economic analyses developed by the EPA and others, the valuation of human health impacts tend to dominate, however [35]. Economic analyses including the benefits of reduced pollution of course show vastly different net economic impacts of controlling emissions from incomplete combustion than estimates based simply on the cost of implementing the controls. This is true even without including any monetary value for reduced damages due to climate change. A compelling example of the use of co-benefits to motivate a strategy to mitigate emissions that lead to warming is the international 'Methane to Markets' program led by the United States. This program has provided funding and expertise to advance projects that capture methane from farms, landfills, pipelines and coal mines. The projects then use the captured methane to produce energy at a net profit while also mitigating warming. When the economic benefits from avoided health impacts are included, many projects to control black carbon and carbon monoxide may have higher benefits than costs even without including the value of reduced warming. For example, recently proposed emissions regulations for diesel vehicles in California were estimated to lead to a reduction in human health damages of approximately five times the cost of implementing the particulate reductions[36]. Numerous federal diesel rules have shown similar and even greater ratios of health benefits to costs. Policies that consider both human health and climate change mitigation simultaneously are likely to provide substantial health benefits in associated health care cost savings[37]. In the US alone, air pollution has been calculated to lead to 70-270 billion dollars in damages per year [35], so that there is a great deal of potential for co-benefits that should be considered when evaluating the costs of emissions reduction.

Reducing emissions of the short-lived warming agents is unlikely to eliminate global warming even in the near-term, and reductions in carbon dioxide emissions are clearly required to mitigate long-term warming. However, the combined influence of all the short-lived warming agents, black carbon, carbon monoxide, volatile organic compounds, methane and hydrofluorocarbons, is quite large, so that reductions in all these together could achieve a substantial reduction in near-term warming. With the exception of the hydrofluorocarbons, all these reductions would lead to significant improvements in air quality as well, making them attractive options from many perspectives. And for all these short-lived forcing agents, technology to reduce emissions is already readily available for deployment, with the primary barriers being structural rather than technological (unlike, for example, carbon dioxide produced from burning fossil fuels).

Further research is needed to provide a clearer understanding of how much black carbon is emitted by different types of burning, how it interacts with other types of particulate and with clouds, and how to improve the ability of models to simulate black carbon in the atmosphere and cryosphere (snow and ice). Such research would lead to more reliable estimates of black carbon's role in climate change. However, taking into account the current range of estimates for black carbon's global impact, along with its known ability to substantially influence snow and ice covered regions and to shift precipitation, emissions reductions are likely to be a useful component of strategies to mitigate climate change. Realistic emissions reductions would affect several types of particles and gases, and thus require careful analysis of their net impact. This type of research, that integrates knowledge of many different aspects of the climate system, is needed to compliment federal programs that are typically focused on single components of climate research. Ideally, future research should provide policy makers a menu of mitigation options covering technological, structural and behavioral, and regulatory approaches for individual emission sources in different regions of the world. As stated earlier, reductions in emissions from incomplete burning are virtually always good for health. Reductions of emissions rich in black carbon, carbon monoxide, volatile organic compounds and methane are typically good for climate as well, allowing many 'no regrets' options to be identified already. Further work can allow much better optimization of emission reduction strategies to simultaneously provide clean air and limit climate change.

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The CHAIRMAN. Thank you, Doctor.

And our final witness is Conrad Schneider. He is the advocacy director of the Clear Air Task Force, a nonprofit environmental research, education, and legal advocacy organization.

We welcome you, sir.

STATEMENT OF CONRAD SCHNEIDER

Mr. SCHNEIDER. Thank you, Mr. Chairman, Ranking Member Sensenbrenner, and members of the committee. My name is Conrad Schneider, advocacy director of the Clear Air Task Force. And I want to thank you personally for the leadership that you and this committee have shown on the issue of climate change and for the work done in passing the Waxman-Markey bill. I appreciate the opportunity to speak with you today regarding policy options for reducing black carbon emissions.

The Waxman-Markey bill made an excellent start in dealing with this issue, and we appreciate you revisiting it today because it represents a promising approach that deserves immediate attention, both in the climate bill and in other legislation currently before Congress.

At the outset of today's hearing, I just want to make one thing very clear: Addressing black carbon and the other short-lived climate forcing agents, such as methane and ozone, is not a substitute for enacting comprehensive climate change legislation to deal with carbon dioxide emissions. We are going to need both and then some in order to address the climate crisis.

I want to try to give a sense of urgency to this hearing, as well, and these solutions. Imagine a world in which the Arctic is literally melting; that the Arctic Ocean is about to become ice-free, we are told; that permafrost is melting, potential releasing millennial stores of carbon dioxide and methane. And we are searching, globally, we are searching for strategies that can counteract this situation almost immediately. And we find a strategy that not only can act immediately to do so, but it could save hundreds of thousands of lives globally.

We don't have to imagine very much. That is the situation we face today. And reducing black carbon is a strategy that can deliver those immediate benefits. In fact, some experts estimate that black carbon emissions to reduce global warming could deliver as much as one to two of the Socolow wedges that you all are familiar with—the goals of trying to use a variety of different steps to meet the Carbon Mitigation Initiative's 200-billion-ton goal.

And, as you have heard, black carbon is not only a climate forcing agent, it is a potent, deadly air pollutant. In the U.S., we have estimated that diesel particulate emissions alone will cause over 21,000 premature deaths this year.

So black carbon is a win-win for climate and public health, but given the tremendous environmental and health benefits of reducing it, relatively little is being done in the U.S. or globally to actually attack this problem. The previous panelists identified diesel engines, cookstoves, and agriculture burning as the most controllable sources of black carbon. So I am going to focus there today on the policies that we can use to attack them.

Now, last year, due in part to the leadership of Representative Inslee, Congress directed the U.S. EPA to study the issue of black carbon and report back early next year, about a year from now. It is supposed to inventory the sources, assess the potential metrics, and identify the most cost-effective approaches for reductions.

Now, on one level, the solutions for these source categories are pretty simple. For diesel engines, there are filters available to trap up to 90 percent of this pollution. For cookstoves, the key is replacing existing smoking cookstoves with more efficient cookstoves. And for agriculture burning, it involves shifting the burning away from the spring season and using pyrolysis to turn waste into biochar that sequesters carbon and increases agricultural productivity.

However, all of this is easier said than done. There are over 11 million diesel engines in use today without filters, tens of millions globally. Half the people on Earth use inefficient cookstoves, and unnecessary agriculture burning persists in many places.

For diesels, the debated policies boil down to two things, and the kind of things that you don't want to hear, necessarily: mandates and money. The U.S. and the EU have adopted new engine standards that are going to reduce these emissions by 90 percent, but it will take decades before they are fully effective. In the meantime, we really need to focus on retrofitting the existing diesel fleet with these filters.

Now, the Waxman-Markey bill directed EPA to exercise its existing authority over black carbon. And the lion's share, as you have heard, in the United States comes from diesels. But, unfortunately, the EPA, under the Clean Air Act, has the authority to regulate only 1 million out of those 11 million diesel engines. An analysis by MJ Bradley Associates estimated that targeting just that million could achieve the climate benefits of removing 21 million cars from the road and would save approximately 7,500 lives, yet EPA has failed to act.

On the money side, the Kerry-Boxer bill that passed the Senate committee devoted a portion of that bill's allowance allocation proceeds to fund the Diesel Emission Reduction Act, DERA. DERA passed in 2005 and authorized a billion dollars over 5 years to clean up diesel. However, it has been chronically underfunded. The Recovery Act provided $300 million for DERA, but EPA received $2 billion worth of applications for that money and is sitting on $1.7 billion worth of project applications that could cut black carbon emissions significantly today. Additional funding for DERA should be included in any jobs bill that passes this year. And since DERA expires next year, it should be reauthorized and fully funded.

In addition, the upcoming transportation bill reauthorization offers the opportunity to reduce black carbon from diesel construction equipment. We believe that work on federally funded transportation infrastructure projects should be accomplished with clean diesel equipment paid for through the transportation bill funds.

And Associated General Contractors, the people who own that equipment, they agree. Last year, we negotiated a set of joint clean construction principles with AGC. Now Representative Hall of this committee, with the support of several Members here, is championing the effort to see that those principles are included in the transportation bill.

For cookstoves, the Waxman-Markey bill calls for providing assistance in foreign countries to reduce black carbon emissions and specifically outlines actions to provide affordable stoves for developing countries. It notably also provides a set of performance standards, which are excellent.

However, the bill did not allocate any allowances or auction proceeds to fund the program. The U.S. should lead in the creation of jointly funded international programs to develop regionally appropriate strategies to deploy these stoves. But they face many other challenges, as well, including cultural acceptance of the stoves, the need for on-site verification and mitigation, and cheaper stoves that can be deployed at scale.

And, lastly, stemming agricultural fires in the spring when Arctic ice and snow is most affected by the deposition of black carbon requires overcoming cultural resistance to long-held agriculture practices. Black carbon emissions from spring agricultural burning in the northern latitudes are highest in Eurasia and in North America, in the grain belt. Black carbon emissions can transport directly from there into the Arctic, darkening the surfaces there and accelerating melting. So these fires present a clear target for mitigation.

So, in conclusion, policies targeting black carbon emissions offer a viable climate strategy that can be implemented without delay, that will deliver immediate climate benefits, using technology that is available today. And, moreover, they can deliver important public health protections from one of the most potent and widespread air-pollution-related public health threats.

Winning these policies will not be easy, but their significant benefits make them extremely cost beneficial, and they may constitute our best hedge against near-term climate impacts.

Thank you.

[The statement of Mr. Schneider follows:]

BEFORE THE SELECT COMMITTEE ON ENERGY INDEPENDENCE AND GLOBAL WARMING UNITED STATES HOUSE OF REPRESENTATIVES

REDUCING BLACK CARBON OFFERS IMMEDIATE OPPORTUNITY FOR CLIMATE AND PUBLIC HEALTH BENEFITS

**TESTIMONY OF CONRAD SCHNEIDER
ADVOCACY DIRECTOR
CLEAN AIR TASK FORCE**

March 16, 2010

Summary of Testimony

Mr. Chairman, members of the Select Committee, good morning. My name is Conrad Schneider, and I am the Advocacy Director of the Clean Air Task Force. I want to thank you for the leadership that you and this Committee have shown on the issue of climate change and for the work that went into passage of the Waxman-Markey climate bill. I appreciate the opportunity to speak with you today regarding policy options for reducing black carbon emissions. The Waxman-Markey bill made an excellent start in dealing with this issue and we appreciate you revisiting it today because it represents a promising approach that deserves immediate attention both in the climate bill and in other legislation that is before Congress. At the outset of today's hearing I want to make one thing very clear: addressing black carbon and the other short-lived climate forcing pollutants such as methane and ozone is not a substitute for enacting comprehensive climate change legislation to deal with carbon dioxide emissions. We are going to need both and then some in order to address the climate crisis.

So please let me thank you for shining the spotlight today on black carbon as a critical part of the solution. Adopting policies to reduce black carbon offers us a "no regrets" strategy. Leading experts say that addressing black carbon emissions globally can deliver between 1 and 2 Socolow climate mitigation "wedges", each wedge equivalent to a cumulative reduction of 25 billion carbon equivalent tons over 50 years, and representing the major steps required to reverse the growth of greenhouse gases in the atmosphere. A global black carbon reduction strategy could also avoid hundreds of thousands of premature deaths from exposure to particulate matter. That's a "win-win" for climate and public health.

To avoid the worst impacts of global warming, many scientists say we must guard against two related but different risks on different timescales: (1) we need to counter the cumulative warming due to increasing concentrations of greenhouse gases in the atmosphere; and (2) we need to counter the threat of near-term effects of climate change and feedbacks from such changes, which could plunge the earth into a cycle of rising seas and an abrupt shift to a much warmer climate regime.

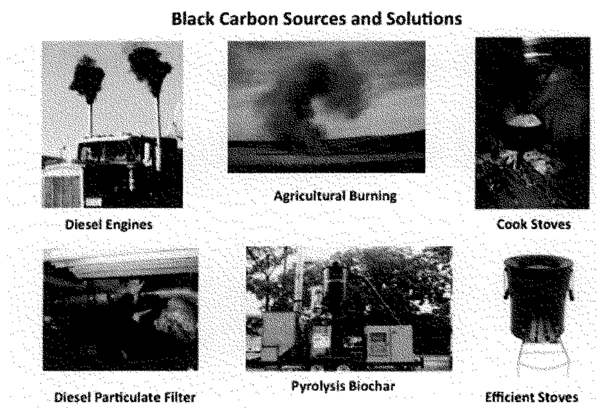
While the focus of mitigation to date has been on limiting emissions of carbon dioxide (CO_2) and other greenhouse gases into the atmosphere, even rapid action on this front may not be fast enough to avoid dangerous changes. Some climate scientists argue that even if we are able institute policies which will return CO_2 concentration to 350 parts per million by 2100, irreversible changes and feedback loops such as melting of Arctic summer ice and collapse of ice sheets may still occur during this century. An ice-free and therefore darker Arctic Ocean will absorb and trap more heat. Melting permafrost could release millennial stores of methane and carbon dioxide. These developments ultimately could contribute to the disintegration of the Greenland ice sheet triggering rapid and catastrophic sea level rise.

So not only must we take action to reduce global greenhouse gas (GHG) emissions significantly by mid-century, we must quickly reduce several short-lived pollutants, such as black carbon, which can have an immediate impact and slow the rate of warming.

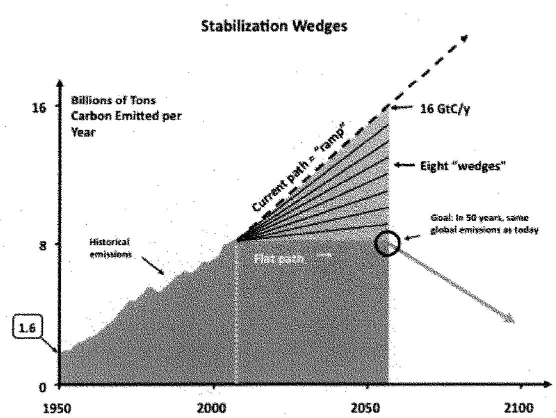
Black carbon is an important component of airborne particulate matter, and not only represents a potent climate-forcing agent, but also is a deadly air pollutant. In the U.S., the Clean Air Task Force, using U.S. EPA methodology approved by the National Academy of Sciences, has estimated that diesel particulate emissions will cause over 21,000 premature deaths this year. Globally, the World Health Organization estimates that ambient particulate matter is responsible for 865,000 premature deaths each year. A recent *Lancet* article finds that over 2 million deaths can be avoided over a ten-year period through reductions in exposure to pollutants from cook stoves.

The previous panelists have identified diesel engines, cook stoves, and agricultural burning as the major controllable sources of black carbon, so my testimony will focus on domestic and international policies to deal with them. Programs to address these pollution sources have been underway for years, mainly to reduce health impacts and deforestation. Only recently have these strategies been understood to offer climate benefits as well. Last year, due in part to the leadership of Rep. Inslee, Congress directed U.S. EPA to study the issue of black carbon and report back early next year. The study requires EPA to inventory major sources of black carbon, assess its impacts on global and regional climate, assess potential metrics and approaches for quantifying the climatic effects, identify the most cost-effective approaches for reductions, and analyze the climatic effects and other environmental and public health benefits from the identified approaches.

At one level, the solutions for each of these source categories are simple. For diesel engines, filters that are available today can trap up to 90 percent of the black carbon emissions. For cook stoves, the key is replacing existing, smoking stoves with clean, efficient stoves. For agricultural burning, it involves shifting the burning away from the spring season and using pyrolysis to turn waste into "biochar" that sequesters carbon and increases agricultural productivity. However, all of this is easier said than done. There are over 11 million diesel engines in the U.S. without filters, tens of millions globally. Half the people on earth rely on inefficient cook stoves. And unnecessary agricultural burning occurs in virtually every country on earth.



For diesels, the needed policies boil down to mandates and money. The U.S. and European Union have adopted emissions standards for new engines that, in essence, require filters on all new engines and that eventually will reduce particulate matter (and black carbon) emissions by 90 percent. Michael Walsh, board chair of the International Council on Clean Transportation (ICCT), estimates that adoption of these standards in China, India, and Brazil with lesser standards elsewhere could deliver between 1 and 1 ½ Socolow climate stabilization "wedges". However, because diesels are so durable, it will take decades before the fleet turns over completely to these new, cleaner engines. In the meantime, the focus must be on retrofitting existing engines and accelerating fleet turnover.



Domestically, the Clean Air Act gives U.S EPA the authority to regulate only 1 million of the 11 million diesel engines in use today. An analysis by M.J. Bradley & Associates estimated that targeting this fleet for retrofit could achieve the same climate benefits as removing 21 million cars from the road and would save approximately 7500 lives through reduced particulate matter pollution. The Waxman-Markey bill directed EPA to exercise this authority, but it did not expand that authority to reach the other 10 million engines. We were pleased that, in addition, the Kerry-Boxer bill that passed the Senate Environment and Public Works Committee devoted a significant portion of the bill's allowance auction proceeds to fund the Diesel Emissions Reduction Act (DERA).

In 2005, Congress passed DERA, which authorized $1 billion over five years to a grant and loan program for diesel clean up. However, DERA has been chronically underfunded. Although the American Reinvestment and Recovery Act (ARRA) did provide $300 million for DERA, EPA has received $2 billion in project applications and so is sitting on $1.7 billion in unfunded project applications that could cut black carbon significantly. Additional funding for DERA should be included in any "Jobs Bill" Congress passes this year. DERA expires next year, so it should be reauthorized and fully funded. Language in the Waxman-Markey bill reauthorized DERA but did not fund it.

In addition, the upcoming Transportation Bill offers the opportunity to reduce black carbon from diesel construction equipment. We believe that work on federally funded transportation infrastructure projects should be accomplished with clean diesel equipment paid for through transportation funds and the Associated General Contractors (AGC), which represents the construction firms that own the equipment, agrees. Last year, the Clean Air Task Force negotiated a set of joint "clean construction" legislative principles with AGC. Now, Rep. Hall, with the support of several members of this Committee, is championing the effort to see that these principles are included in the Transportation bill reauthorization.

For cook stoves, the Waxman-Markey bill calls for providing assistance to foreign countries to reduce, mitigate, and otherwise abate black carbon emissions, and specifically outlines action to provide affordable stoves, fuels, or both stoves and fuels to residents of developing countries. Notably, the bill also prescribes a set of environmental performance standards for stoves including: reduces fuel by more than fifty percent, reduces black carbon by more than sixty percent, and reduces childhood pneumonia by more than thirty percent. However, the bill did not allocate any allowances or auction proceeds for this program.

The U.S. should lead in the creation of jointly funded international programs in the public, private, and non-profit sectors that will develop regionally appropriate strategies to deploy cleaner cook stoves globally. These programs should include financing plans, identification of local manufacturers and service providers, and training and testing. As part of the black carbon study, EPA is charged with investigating the question of whether projects such as stove replacement programs should qualify for "offsets" under cap and trade and, if so, what credit they should be given. But, we face many other challenges as well, including cultural acceptance of these stoves in developing countries, the need for on-site verification of mitigation, and cheap stoves that can be produced at scale.

Similarly, stemming agricultural fires in spring, when arctic ice and snow is most affected by black carbon, requires overcoming cultural resistance to changing long held practices. Black carbon emissions from spring agricultural burning in northern latitudes are highest in areas across Eurasia—from Eastern Europe, through southern and Siberian Russia, into Northeastern China—and in the northern part of North America's grain belt. Black carbon emissions can transport directly from these areas to the Arctic, and when they do they can be deposited on ice and snow, darkening the cover and absorbing more solar radiation. Accordingly, fires in these countries present a clear target for mitigation. However, change will require education, engagement by the international community, and enforcement of existing no-burn laws by these countries.

Pyrolysis, which involves turning agricultural waste into "biochar", similar to charcoal, holds out the promise of a more productive use of this waste. Biochar is a soil amendment that can increase productivity while sequestering the carbon from the plant waste – another "win-win" strategy. The challenge is developing and providing low-cost pyrolysis units to the farmers burning crop wastes and the education necessary for them to understand the economic, as well as environmental, advantages of biochar. A program to produce and deploy this technology should be a priority.

In conclusion, policies targeting black carbon emissions offer a viable climate strategy that can be implemented without delay and will deliver immediate climate benefits using technology available today. Moreover, black carbon reduction policies can deliver important public health protection from particulate matter pollution, one of the most potent and widespread air pollution-related public health threats. Winning these policies domestically and globally will be challenging, but their significant health benefits make them extremely cost-beneficial and they may constitute our best hedge against near-term climate impacts.

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THE CLIMATE CHALLENGE

To avoid the worst impacts of global warming, many scientists say we must guard against two related but different risks on different timescales: (1) we need to counter the cumulative warming due to increasing concentrations of greenhouse gases in the atmosphere; and (2) we need to counter the threat of near-term effects of climate change, which could plunge the earth into a cycle of rising seas, feedbacks from such changes, and an abrupt shift to a much warmer climate regime.

While the focus of mitigation to date has been on limiting emissions of carbon dioxide (CO_2) and other greenhouse gases into the atmosphere, even rapid action on this front may not be fast enough to avoid dangerous changes. Some climate scientists argue that even if we are able institute policies which will return the CO_2 concentration to 350 parts per million by 2100, irreversible changes and feedback loops such as melting of Arctic summer ice and collapse of ice sheets may still occur during this century.[1] An ice-free and therefore darker Arctic Ocean will absorb and trap more heat. Melting permafrost could release millennial stores of methane and carbon dioxide.[2] These developments ultimately could contribute to the disintegration of the Greenland ice sheet and trigger rapid sea level rise.[3]

Not only must we take action to reduce global greenhouse gas (GHG) emissions significantly by mid-century, we must quickly reduce several short-lived pollutants, such as black carbon, which can have an immediate impact and slow the rate of warming.

A FOCUS ON SHORT-LIVED CLIMATE FORCING AGENTS CAN HELP BUY TIME FOR FURTHER CLIMATE MITIGATION MEASURES TO BE EFFECTIVE

A key mitigation strategy with a fast climate response is reducing short-lived climate forcing agents such as black carbon, tropospheric ozone, and methane. While carbon dioxide emissions persist in the atmosphere for centuries or even millennia, black carbon and ozone reside in the atmosphere for days or weeks and methane persists for just a decade. Their relatively short atmospheric lifetimes mean that reductions in these

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[1] Solomon, S, G. Plattner, R. Knutti, and P. Friedlingstein (2009) Irreversible climate change due to carbon dioxide emissions, *Proc. Natl. Acad. Sci.*, 106, 1704–1709. Available at: http://www.pnas.org/content/106/6/1704.abstract

[2] Quinn, P.K, T.S. Bates, E. Baum, N. Doubleday, A.M. Fiore, M. Flanner, A. Fridlind, T.J. Garrett, D. Koch, S. Menon, D. Shindell, A. Stohl, and S.G. Warren (2008) Short lived pollutants in the Arctic: their climate impact and possible mitigation strategies, *Atmos. Chem. Phys.*, 8, 1723-1735. Available at: http://www.atmos-chem-phys.net/8/1723/2008/

[3] Lenton, T., H. Held, E. Kriegler, J. Hall, W. Lucht, S. Rahmstorf, and H. Schellnhuber (2008) Tipping elements in the Earth's climate system, *Proc. Natl. Acad. Sci.*, 105, 1786-1793. Available at: http://www.pnas.org/content/105/6/1786.abstract

pollutants could result in rapid reduction in their atmospheric concentrations and therefore their radiative forcing.[4]

One of these pollutants, black carbon, has been estimated to be responsible for up to 50 percent of the anthropogenic warming experienced to date.[5] Because of its dark color, black carbon contributes to global warming by absorption of sunlight, in two distinct ways: First, it absorbs light in the atmosphere and then radiates it as heat, thereby warming the surrounding air. Second, the black particles deposit on and darken the surfaces of snow, ice, and glaciers, accelerating their melting. Over a 20-year period, pound for pound, black carbon may trap 2000 times more heat than carbon dioxide.[6]

Globally, the major anthropogenic sources of black carbon include agricultural burning, biomass and coal burning for residential cooking and heating, diesel engines, brick kilns, and coke ovens.[7]

Black carbon is an important component of airborne particulate matter, and not only represents a potent climate-forcing agent, but also is a deadly air pollutant. In the U.S., the Clean Air Task Force, using U.S. EPA methodology approved by the National Academy of Sciences, has estimated that diesel particulate emissions will cause over 21,000 premature deaths in 2010.[8] Globally, the World Health Organization estimates that outdoor particulate matter is responsible for 865,000 premature deaths each year.[9] A recent *Lancet* article found that over 2 million deaths could be avoided over a ten-year period through reductions in exposure from pollutants from cook stoves.[10]

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[4] Jacobson, M. (2002) Control of fossil-fuel particulate black carbon plus organic matter, possibly the most effective method of slowing global warming. *J. Geophys. Res.*, 107, 4410.
[5] Ramanathan, V. and Y. Feng (2008) On avoiding dangerous interference with the climate system: Formidable challenges ahead. *Proc. Natl. Acad. Sci.*, 105, 14245-14250. Available at: http://www.pnas.org/content/105/38/14245.abstract
[6] Bond, T.C. (2007) Can warming particles enter global climate discussions? *Environ. Res. Lett.* 2 045030. Available at: http://www.iop.org/EJ/article/-search=68386981.1/1748-9326/2/4/045030/erl7_4_045030.html; Bond, T.C. and H. Sun (2005). Can reducing black carbon emissions counteract global warming? *Environ. Sci. Technol.* 39, 5921-5926; Hansen, J., M. Sato, P. Kharecha, G. Russell, D.W. Lea, and M. Sidall (2007). Climate change and trace gases. *Phil. Trans. R. Soc. A*, 365, 1925-1954, Available at: http://rsta.royalsocietypublishing.org/content/365/1856/1925.abstract; Jacobson, M. (2001). Strong radiative heating due to the mixing state of black carbon in atmospheric aerosols. *Nature*, 409, 695-697.
[7] Bond, T.C, D.G. Streets, K.F. Yarber, S.M. Nelson, J.H. Woo, and Z. Klimont (2004) A technology-based global inventory of black and organic carbon emissions from combustion. *J. Geophys. Res.*, 109, p. D14203.
[8] Clean Air Task Force (2005) Diesel and Health in America, the Lingering Threat. Available at: http://www.catf.us/publications/reports/Diesel_Health_in_America.pdf
[9] See: http://www.who.int/entity/quantifying_ehimpacts/countryprofilesebd.xls
[10] Wilkinson, P., K.R. Smith, M. Davies, H. Adair, B.G. Armstrong, M. Barrett, N. Bruce, A. Haines, I. Hamilton, T. Oreszczyn, I. Ridley, C. Tonne, Z. Chalabi (2009) Public health benefits of strategies to reduce greenhouse-gas emissions: Household energy. *Lancet*, 374, 1917-1929.

Sources and Policy Responses

Drs. Bond, Ramanathan, and Shindell have described sources that are rich in black carbon emissions and what we understand about how controlling these sources could benefit climate. I will focus my testimony on the relevant emissions control strategies, the domestic and international black carbon abatement efforts that are underway, and what additional policies should be pursued.

It is important to note that the U.S. Congress recently directed U.S. EPA to study the sources of black carbon and provide recommendations for action by early next year.[11] The study requires EPA to inventory major sources of black carbon, assess the impacts of on global and regional climate, assess potential metrics and approaches for quantifying the climatic effects, identify the most cost-effective approaches for reductions, and analyze the climatic effects and other environmental and public health benefits from the identified approaches.

Transportation

On- and off-road diesel engines represent one of the largest sources of black carbon[12] and offer one of the greatest opportunities for controlling the climate impact of black carbon. In the U.S. and European Union (EU) nearly 60 percent of the black carbon emissions come from diesels.[13] U.S. per capita emissions of black carbon are higher than those from other regions of the world, including Asia.[14] In the developing world, diesel emissions likely represent the fastest growing source of black carbon.[15]

Control options

One promising strategy for reducing black carbon emissions involves fitting as many diesel engines as possible with diesel particulate filters (DPFs). DPFs, which physically trap black carbon particles, can reduce black carbon emissions by more than 90 percent relative to an uncontrolled engine.[16] Requiring DPFs on new diesel engines and requiring, and funding, filter retrofits on existing in-use diesel engines represent key black carbon control strategies.

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[11] SA 2505, Senate Report 111-058 – Black Carbon Research Bill to accompany S. 849 (July 22, 2009).

[12] Bond, T.C., et al. (2004) Op.Cit.

[13] Ibid.

[14] See: http://www.yaleclimatemediaforum.org/2009/07/black-carbon-and-global-warming/

[15] Streets, D. G., T. C. Bond, T. Lee, and C. Jang (2004) On the future of carbonaceous aerosol emissions, *J. Geophys. Res.*, 109, D2421, doi:10.1029/2004JD004902

[16] Frank, B., S. Tang, T. Lanni, G. Rideout, C. Beregszaszy, N. Meyer, S. Chatterjee, R. Conway, H. Windawi, D. Lowell, C. Bush, J. Evans (2004) *A Study of the Effects of Fuel Type and Emission Control Systems on Regulated Gaseous Emissions from Heavy-Duty Diesel Engines.* SAE paper 2004-01-1085, 18p.

Domestic Policies

The U.S. has adopted standards for new engines that the U.S. EPA estimates will reduce particulate matter and black carbon emissions from diesel 90 percent by the year 2030.[17] However, the current economic downturn has brought the rate of fleet turnover to a standstill and, even if the economy comes roaring back, two decades may be too late to avoid triggering dramatic near-term climate impacts. Both to protect the climate and to continue our leadership in reducing health impacts from particulate matter, the U.S. should expeditiously address emissions from our in-use diesel fleet. In the U.S. and the EU, the best opportunity to reduce diesel black carbon reductions consists of retrofitting existing diesel engines with DPFs and adopting policies to accelerate fleet turnover to new engines already fitted with filter technology.

The State of California, through the California Air Resources Board, has led the way in this regard, setting emissions standards and timetables that are targeted to achieve a 85 percent reduction in diesel particulate emissions by 2020 in that state.[18] At the federal level, U.S. EPA so far has declined to exercise its existing regulatory authority under the Clean Air Act to require filters on all on-road diesel engines whenever they are rebuilt. Under the Bush Administration, EPA preferred a "voluntary" approach funded largely through the Diesel Emission Reduction Act (DERA), which authorized $1 billion over five years to subsidize a variety of diesel clean up measures. In assessing its benefits, the EPA has estimated that for every dollar spent in the DERA program, more than $13 of economic and health benefits are generated.[19] However, because the program has never been fully funded,[20] diesel particulate filters have barely penetrated the existing fleet and therefore represent an immediate opportunity to address positive climate forcing with available technology.

The U.S. can lead by adopting a suite of policies to deal with the problem of in-use diesel black carbon emissions including:

1. U.S. EPA issuing a "Engine Rebuild" rule under its existing Clean Air Act authority governing rebuilt engines
2. Expanding EPA's regulatory authority and providing funding for diesel retrofits in the Climate Bill
3. Requiring and funding clean construction equipment on all federal transportation infrastructure projects in the reauthorization of the Transportation Bill
4. Reauthorizing and fully funding DERA.

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[17] EPA (2004) *Final Regulatory Analysis: Control of Emissions from Nonroad Diesel Engines*, EPA420-R-04-007; EPA (2000) *Regulatory Impact Analysis: Heavy-Duty Engine and Vehicle Standards and Highway Diesel Fuel Sulfur Control Requirements*, EPA420-R-00-026.

[18] California Air Resources Board (2000) *Risk Reduction Plan to Reduce Particulate Matter Emissions from Diesel-Fueled Engines and Vehicles*. The CARB website lists CARB diesel regulations, at: http://www.arb.ca.gov/diesel/mobile.htm.

[19] Lisa P. Jackson, EPA Administrator, remarks on Ohio Recovery Act DERA Grant, June 3, 2009.

[20] http://www.epa.gov/diesel/grantfund.htm.

1. U.S. EPA Engine Rebuild Rule

EPA should exercise its existing regulatory authority under the Clean Air Act and issue a rule requiring all Class 8 trucks built between 1998 and 2006 (after which the new engine standards took effect) to meet emissions standards commensurate with the installation of a filter whenever their engines are rebuilt.[21] Class 8 trucks, which comprise long-haul tractor-trailer trucks, dump trucks, and transit buses, consume nearly 75 percent of the diesel fuel used by on-road trucks in the U.S. and thus are responsible for a commensurate share of black carbon emissions. M.J. Bradley & Associates has estimated that targeting this fleet of approximately 1 million engines for retrofit could achieve the same climate benefits as removing 21 million cars from the road and would save approximately 7500 lives through reduced particulate matter.[22] Incentives from the Diesel Emission Reduction Act, Transportation bill, and other sources could facilitate and accelerated compliance with such a regulation. See discussion infra.

2. U.S. Climate Legislation Should Expand EPA Authority Over and Fund Retrofits on Existing Diesel Engines

In the current session, the U.S. Congress has taken up the issue of climate legislation in earnest. The U.S. House of Representatives passed the American Clean Energy and Security Act of 2009, which directs U.S. EPA to use its existing regulatory authority to cut black carbon emissions (i.e., to issue a rebuild rule), but it did not expand EPA's authority to cover the other 10 million engines in use today.[23] It should. In addition, the bill orders U.S. EPA to study the options for reducing black carbon both domestically and internationally and to report a set of recommended policy actions to Congress.[24] The Clean Energy Jobs and Power Act (Kerry-Boxer bill) that passed the Senate Environment and Pubic Works Committee included all of those provisions, but took the significant additional step of allocating a percentage of the proceeds from the auction of allowances to fund diesel retrofits targeted at reducing black carbon.[25] To do the job, final comprehensive climate legislation should devote at least 1 percent of allowances of any economy wide cap and trade bill to fund diesel retrofits for the first 10 years with a sustained but lesser amount thereafter. Because diesel particulate filters confer no economic benefit on fleet owners (such as fuel economy savings), to ensure their use, regulatory mandates will be needed and should be part of any final climate legislation.

3. Transportation Bill Reauthorization Presents An Opportunity for Cleaning Up Construction Equipment

According to the U.S. EPA's Clean Air Act Advisory Committee (CAAAC), off-road

[21] Clean Air Act Sec. 202(a)(3)(D) [42 U.S.C. Sec. 7521(a)(3)(D)].
[22] See CATF Report: *The Carbon Dioxide-Equivalent Benefits of Reducing Black Carbon Emissions from U.S. Class 8 Class 8 Trucks Using Diesel Particulate Filters: A Preliminary Analysis.* http://www.catf.us/projects/diesel/
[23] H.R. 2454 Sec. 851 (2009).
[24] H.R. 2454 Sec. 333 (2009).
[25] S. 1733 Secs. 201(g) and 771(b)(3) (2009).

construction equipment is responsible for 37 percent of land-based particulate matter emissions in the U.S.[26] However, U.S. EPA lacks the regulatory authority under the Clean Air Act to require emission reductions from in-use equipment. To help address the emissions from this sector, Congress in the Transportation Bill reauthorization should require and fund the use of "clean construction" equipment on all federally funded transportation infrastructure projects. The Associated General Contractors agrees. The Clean Air Task Force negotiated a set of joint "clean construction" legislative principles with AGC[27] and Rep. Hall, with the support of several members of this Committee, is championing the effort to see that this policy is included in the Transportation bill reauthorization.[28] Optimally, this would involve prioritizing the use of diesel particulate filters where possible.

4. Fully Funding the Diesel Emission Reduction Act

The Diesel Emission Reduction Act (DERA), which authorized $1 billion for a variety of diesel clean up strategies over 5 years beginning in 2008, expires in 2011.[29] Language in the Waxman-Markey bill reauthorized DERA but did not fund it. Congress should reauthorize DERA, increase the authorized funding amount, and commit to fully fund the program each year. U.S. EPA received applications totaling requests for over $2 billion in funding for the $300 million appropriated to DERA as part of the U.S. American Recovery and Reinvestment Act, so the demand for the program is well-established.[30] Additional funding for DERA should be included in any "Jobs Bill" that Congress passes this year. KeyBridge Research, a reputable economics consulting firm, found that a $1 billion investment in DERA would generate 19,000 jobs.[31]

International Policies

The European Union has adopted the EURO VI particulate matter emission standards for new on-road heavy-duty diesel engines and Stage III and IV standards for new non-road diesel engines, which will drive similar market penetration of the DPF technology in the EU as the EPA new engine standards will in the U.S.[32] Globally, adoption of these new

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[26] U.S. Clean Air Act Advisory Committee (2006) *Recommendations for Reducing Emissions from the Legacy Diesel Fleet: A Report from the Clean Air Act Advisory Committee* p. 48.
[27] http://www.catf.us/projects/diesel/20090929-AGC_CATF_Principles.pdf
[28] Letter from 55 Members of the House of Representatives to Reps. Oberstar, DeFazio, Mica, and Duncan dated August 10 2009.
[29] Subtitle G of Title VII of the Energy Policy Act of 2005 (42 U.S.C. 16131 et seq.)
[30] Public Law 111-05 - American Recovery and Reinvestment Act of 2009.
[31] KeyBridge Research (2008).
[32] Regulation (EC) No 595/2009 of the European Parliament and of the Council of 18 June 2009 on type-approval of motor vehicles and engines with respect to emissions from heavy duty vehicles (Euro VI); and Directive 2004/26/EC of the European Parliament and of the Council of 21 April 2004 amending Directive 97/68/EC on the approximation of the laws of the Member States relating to measures against the emission of gaseous and particulate pollutants from internal combustion engines to be installed on mobile non-road machinery. Directive 2005/55/EC introduced by Regulation (EC) No 715/2007 of the European Parliament and of the Council of 20 June 2007 on type approval of motor vehicles with respect to emissions from light passenger and commercial vehicles (Euro 5 and Euro 6).

vehicle and engine particulate and/or black carbon emission standards holds great potential to achieve meaningful near-term climate benefits. A preliminary estimate by Michael Walsh, an internationally recognized transportation expert and the current board chair of the International Council on Clean Transportation (ICCT), found that extending by 2015 the EURO 6 and VI particulate standards for new engines to China, India, and Brazil plus adoption of less stringent EURO 4 standards in the rest of Latin America and the Middle East and EURO 3 in Africa by the year 2015, could achieve an additional 38 billion CO_2-equivalent tons reduction by 2050. [33] This level of reduction constitutes nearly 20 percent of the Princeton Carbon Mitigation Initiative's 200 billion-ton goal i.e., the equivalent of about one and a half Pacala and Socolow "wedges."[34]

A crucial and challenging precondition for widespread use of DPFs involves reducing sulfur content in diesel fuel to very low levels - at a minimum to levels below 50 ppm, with levels as low as 10 ppm preferred, especially in cold climates. Low fuel sulfur levels are required to ensure that these devices can regenerate passively, and to preclude the production of sulfate particulate.[35] As part of its new engine standards, the U.S., for example, has adopted 15 ppm sulfur in fuel standards that should be available nationwide for on- and off-road use during 2010.[36]

Another strategy is to retire older diesel engines. In 2009, China retrofitted 8000 vehicles, scrapped 104,000 light and heavy duty vehicles in, and is aiming to scrap 40,000 more by May 2010. China's Ministry of Environmental Protection of the People's Republic has stated that it wants to scrap all pre Euro III diesels by 2015.[37]

Marine Shipping

Closely related to diesel, international shipping is a significant emitter of black carbon,

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[33] Walsh, Michael, Presentation: "What is the World Doing to Reduce Black Carbon?" Briefing for European Commission staff, Brussels (October 7, 2009).

[34] http://cmi.princeton.edu. Pacala and Socolow identified an overall carbon emissions reduction stabilization target of 200 billion tons divided into 8 "wedges" each representing 25 billion tons of carbon emissions that could avoided by 2050 through implementation of different reduction technologies. See Pacala, S. and R. Socolow (2004) Stabilization wedges: Solving the climate problem for the next 50 years with current technologies, *Science,* 305, 968-972. See also: Grieshop, A.P, C.C.O. Reynolds, M. Kandlikar and H. Dowlatabadi (2009) A black-carbon mitigation wedge, *Nature Geoscience* 2, 533–534.

[35] USDOE, NREL (2002) *Diesel Emission Control – Sulfur Effects Project (DECSE), Summary of Reports*, NREL/TP-540-31600. Available at: http://www.nrel.gov/docs/fy02osti/31600.pdf Manufacturers of Emissions Controls Association (2000). *Catalyst-Based Diesel Particulate Filters and NOx Adsorbers: A Summary of the Technologies and the Effects of Fuel Sulfur.* Available at: http://www.meca.org/galleries/default-file/cbdpf-noxadwp.pdf

[36] EPA (2001), "Control of Air Pollution from New Motor Vehicles: Heavy-Duty Engine and Vehicle Standards and Highway Diesel Sulfur Control Requirements," 66 Fed. Reg. 5002 (January 18, 2001). EPA (2004), "Control of Emission of Air Pollution From Nonroad Diesel Engines and Fuel; Final Rule," 69 Fed. Reg. 38957 (June 29, 2004).

[37] Walsh, Michael, Presentation: "Clean Diesels: An Important Strategy to Reduce Black Carbon," Arctic Council Meeting, San Francisco (February, 2010).

emitting between 71,000 and 160,000 metric tons annually,[38,39] and constituting between 5 percent and 15 percent of world shipping emissions of particulate matter.[40] Currently marine vessels emit an estimated 2 percent of total global black carbon (and about 3 percent of CO_2). An estimated 85 percent of shipping emissions occur in the northern hemisphere, and the release of black carbon emissions in northern shipping routes close to the Arctic is particularly damaging to that region. Furthermore, as sea ice melts, more Arctic sea lanes will open up. Although shipping emissions of black carbon in the Arctic region are relatively small at present, some estimates project they will increase by two to three times the global rate between now and year 2050. International shipping is a larger relative source of black carbon emissions – by more than 50 percent – north of 40° latitude, where most international shipping traffic occurs and emissions are more likely to reach the Arctic.[41]

As a product of incomplete combustion, black carbon emissions from marine engines vary, depending on engine type and combustion efficiency. A recent study found that medium speed marine engines typically used on tugboats, fishing vessels and ferries emit black carbon at more than twice the rate of slow speed engines used on large ocean-going ships (excepting containerships) and high speed engines used on passenger ships.[42]

Control options

- In-engine measures to reduce smoke include improved fuel injection systems (e.g., common rail) and modified turbochargers.
- Diesel particulate filters (DPF) are after-treatment devices that are effective at controlling black carbon, reducing emissions by up to 95 percent (with 70-95 percent reductions in total particulate matter).[43] This technology is suitable only use with for high grade (ideally ultra-low sulfur fuel) distillate fuels and cannot be used with residual/bunker fuels.
- Water mixing and injection technologies, where water is emulsified into the fuel or separately injected into the fuel-air mixture, have been shown to reduce particulate matter (PM) and black carbon emissions by over 50 percent. Water injection also

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[38] Green, E., J. Winebrake, and J. Corbett (2007) Opportunities for reducing greenhouse gas emissions from ships, annex to document MEPC 58/INF.21.
[39] Lack, D., B. Lerner, C. Granier, T. Baynard, E. Lovejoy, P. Massoli, A.R. Ravishankara, and E. Williams (2008) Light absorbing carbon emissions from commercial shipping. *Geophys. Res. Lett.*, 35, L13815.
[40] Lack, D., *et al.* (2009) Particulate emissions from commercial shipping; Chemical, physical and optical properties. *J. Geophys. Res.*, 114, D00F04, doi:10.1029/2008JD011300.

[41] Preliminary calculations by Corbett and Koch for Clean Air Task Force, 2009.
[42] Lack, D. *et al.* (2009) Op.Cit. Although higher black carbon emissions were found in ships burning lower sulfur fuel, these ships had predominantly medium speed engines, and the engines rather than the fuel likely produced the higher black carbon emission rates.
[43] See, e.g., annex to document MEPC 58/INF.21. Other technologies such as oxidation catalysts reduce some PM constituents, but do not reduce black carbon.

reduces emissions of nitrogen oxides (NOx).[44]

- Slide valves produce more complete combustion than conventional valves, reducing PM and black carbon by 25 percent or more. NOx is also reduced, by about 10-25 percent. Slide valve replacement is extremely cost-effective, having a total incremental installation cost of less than $700 per valve.[45] Slide valves cannot be used on all engines.

Domestic/international Policies

Air emissions from ships sailing in international waters are subject to international regulations set by the International Maritime Organization (IMO).[46] On January 15, 2010, Norway, Sweden, and the U.S. filed a joint paper to the Marine Environment Protection Committee (MEPC) of the IMO requesting that "the Committee discuss how to address [black carbon] by examining potential measures to be recommended or required to significantly reduce black carbon emissions from shipping having an impact in the Arctic."[47] A companion submission describes a recent report and analysis of inventories of emissions of black carbon, organic carbon, and sulfur dioxide emissions from international shipping activity in the Arctic (north of 60 degrees North latitude) for the years 2004, 2020, and 2030.[48]

Solid Fuel Stoves

Use of inefficient cookstoves in the developing world contributes to a range of serious health and environmental problems that dramatically reduce the life span of millions of women and children,[49] threaten the security of women as they forage for fuel, exacerbate global climate change through inefficient burning and production of black carbon,[50] and degrade forests and ecosystems. Globally, there are 500 million biomass-fueled cook stoves in use, supporting more than three billion people, or nearly half of the world's population. Worldwide, cookstoves are the second largest source of human generated black carbon emissions.[51]

[44] Winebrake, J., J. Corbett, and E. Green (2009) *Black carbon control costs in shipping*, prepared for ClimateWorks Foundation.

[45] Entec UK Ltd. (2005) *Final Report for European Commission Directorate-General-Environment, "Service Contract of Ship Emissions: Assignment, Abatement and Market-based Instruments."* Available at: http://ec.europa.eu/environment/air/pdf/task2_nox.pdf

[46] Any country has jurisdiction to regulate harmful emissions from ships sailing to their ports within their waters, subject to any applicable international right of innocent passage.

[47] Marine Environment Protection Committee, 60th session, Agenda item 4, Prevention Of Air Pollution From Ships, "Reduction of emissions of black carbon from shipping in the Arctic," Submitted by Norway, Sweden and the United States.

[48] Marine Environment Protection Committee, 60th session, Agenda item 4, Prevention Of Air Pollution From Ships, "New Inventory of short-lived climate forcing aerosols from international shipping activity in the Arctic."

[49] Wilkinson, P. *et al.* (2009), Op.Cit.

[50] Venkataraman, C., G. Habib, A. Eiguren-Fernandez, A.H. Miguel, and S.K. Friedlander (2005) Residential biofuels in South Asia: Carbonaceous aerosol emissions and climate impacts, *Science*, 307, 1454-1456.

[51] Bond, T.C. *et al.* (2004), Op.Cit.

Control options

The dominant black carbon control option is stove replacement to more efficient and cleaner burning stoves. The first priority of stove improvements is better health, but several stove designs have been advanced which, at least in tests, reduce black carbon emissions and increase fuel efficiency (decreasing CO_2 emission) in addition to dramatic decreases in total PM. Confirming these reduced emissions requires careful sampling of emissions of black carbon and other pollutants from improved and traditional stoves, both in the laboratory and in the homes where the stoves are to be used. Stove replacement efforts include many critical steps – financing mechanisms, distribution, program coordination, performance methodologies, and scrappage of the stoves being replaced – and all are important to achieve goals related to health, climate, sustainability, or security. However, to understand (and claim) climate benefits from improved stoves, standards and field and lab testing are particularly essential elements.

Domestic Policies

The U.S. should lead in the creation of jointly funded international programs in the public, private, and non-profit sectors that will develop regionally appropriate strategies to deploy cleaner cook stoves globally. These programs should include financing plans, identification of local manufacturers and service providers, training, and testing. As part of the black carbon study, EPA is charged with investigating the question of whether projects such as cook stove replacement programs should qualify for "offsets" under cap and trade and, if so, what credit they should be given. However, there are many other challenges, including cultural acceptance of these stoves in developing countries the need for on-site verification of mitigation and cheap stoves that can be produced at scale.

Provisions in H.R. 2454: American Clean Energy and Security Act of 2009[52] call for providing assistance to foreign countries to reduce, mitigate, and otherwise abate black carbon emissions, and specifically outlines action to provide affordable stoves, fuels, or both stoves and fuels to residents of developing countries. Notably, the bill also prescribes a set of environmental performance standards for stoves including: reduces fuel by more than fifty percent, reduces black carbon by more than sixty percent, and reduces childhood pneumonia by more than thirty percent. However, the bill failed to allocate any allowances or auction proceeds for this program. The Kerry-Boxer bill does not contain similar cook stove provisions, but does include language requiring EPA to report on cost-effective opportunities for reducing black carbon domestically and internationally.

International Policies

While myriad international and country-specific programs exist to promote the use of cleaner cookstoves, few have reached the commercial scale needed to meaningfully address the nature of this global problem, and many projects fail to achieve measurable

[52] H.R. 2454 Sec. 851 (2009).

improvements in health and safety, combustion efficiency, or reduced emissions of black carbon and other pollutants.

That said, some specific program initiatives include:

- The UN Foundation seeks to build a Global Alliance for Clean Cookstoves with the United Nations, the U.S. Government, and other international private sector, non-profit, foundation, and government partners to develop an effective program that would dramatically scale up the development, distribution, and utilization of clean cookstoves, with the goal of deploying millions of stoves in target countries by 2015.
- EPA's Partnership for Clean Indoor Air (PCIA) has over 330 partners operating in 115 countries and is growing.
- In December 2009, India announced a major national initiative on biomass cookstoves, with a goal of scaling up to replacing over 150 million cookstoves.

Successful programs will likely combine strong bottom-up policies and actions that include stove and program development; protocols design, testing and dissemination with top down strategies that engage governments and donors at the highest level.

Agricultural Burning

Agricultural fires are used to remove crop residues, prepare fields for planting, and clear brush for grazing. Emissions from these fires, especially when they occur in the spring, can result in transport and deposition of black carbon to the Arctic during the most vulnerable period for ice and snow melt.[53] Moreover, field burning frequently ignites larger forest fires, which, in addition to increasing burn area and emissions, cause property and health damage.[54] Black carbon emissions from spring agricultural burning in northern latitudes are highest in areas across Eurasia – from Eastern Europe, through southern and Siberian Russia, into Northeastern China – and in the northern part of North America's grain belt. Accordingly, these fires present a clear target for mitigation.[55]

Control Options

Like the issue of cook stove replacement, stemming spring agricultural fires will include overcoming cultural resistance to changing long-held practices. Change will require education, engagement by the international community, and better enforcement of existing and future regulations and laws.

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[53] Warneke, C., K.D. Froyd, J. Brioude, R. Bahreini, C.A. Brock, J. Cozic, J.A. de Gouw, D.W. Fahey, R. Ferrare, J.S. Holloway, A.M. Middlebrook, L. Miller, S. Montzka, J.P. Schwarz, H. Sodemann, J.R. Spackman, A. Stohl (2010) An important contribution to springtime Arctic aerosol from biomass burning in Russia, *Geophys. Res. Lett.*, 37, L01801.

[54] Warneke, C., R. Bahreini, J. Brioude, C.A. Brock, J.A. de Gouw, D.W. Fahey, K.D. Froyd, J.S. Holloway, A. Middlebrook, L. Miller, S. Montzka, D.M. Murphy, J. Peischl, T.B Ryerson, J.P. Schwarz, J.R. Spackman, and P. Veres (2009) Biomass burning in Siberia and Kazakhstan as an important source for haze over the Alaskan Arctic in April 2008, *Geophys. Res. Lett.*, 36, L02813.

[55] Pettus, A. (2009) *Agricultural Fires and Arctic Climate Change*, Report for the Clean Air Task Force, available at: http://www.catf.us/publications/view/99

These include:

1. banning spring time burning
2. expanding uses for crop waste, including biochar production *via* pyrolysis.
3. timing and permitting fires, based on meteorological conditions and forecasts to avoid transport of black carbon to the Arctic

Domestic policies

In the United States, field burning is regulated at the state level, with requirements varying by state. Many states require permits for open-field burning, and state officials post "no-burn" periods during exceptionally dry conditions. Both U.S. EPA and USDA collect fire data, although there is no standard database of fire events or area burned for any year.[56] Federal fire statistics in the U.S. have limited spatial accuracy, tend to be aggregated at the county level, and may exclude fires outside of public lands.[57]

Selected International Policies

Russia is the largest contributor of emissions to the Arctic from springtime agricultural burning, with fires representing over 80 percent of the springtime black carbon emissions that reach the Arctic, followed by Kazakhstan, China, and the U.S.[58] Since the collapse of the USSR, Russia's centralized fire management system has steadily weakened. This has diminished the government's once strong capacity to detect, monitor and fight fires, allowing increasingly severe blazes to burn unchecked.[59] Our understanding is that while broad laws generally ban agricultural burning in Russia, this law is not enforced, nor are penalties or jurisdictions spelled out to enable enforcement.[60,61]

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[56] For instance, to estimate forest and wildfire emissions for the 1999 emissions year, the EPA used fire activity data for the years 1985-1998 obtained from the U.S. Department of Interior and the USFS for Non-Grand Canyon States. After the emissions estimates were produced, they were often distributed from an aggregated state level to a county level using data from a prior year(s). This often led to large errors and inaccuracies when comparing where emissions were shown to occur and where actual biomass burning occurred. Recently, in a large part as a result of this work, the EPA had begun to include satellite data in the National Emissions Inventory (Soja et al. 2009)

[57] Soja, A.J., J.A. Al-Saadi, L. Giglio, D. Randall, C. Kittaka, G.A. Pouliot, J.J. Kordzi, S.M. Raffuse, T.G. Pace, T. Pierce, T. Moore, B. Roy, B. Pierce, J.J. Szykman (2009) Assessing satellite-based fire data for use in the National Emissions Inventory, *J. Appl. Remote Sens.*, 3, 031504.

[58] Pettus, A. (2009), Op. Cit.

[59] Ibid.

[60] According to Burenin Nikolaj Sergeevich, paragraph 327, section X of the Russian Federation Prevention of Fire Regulation 01-03, states that: "the burning of stub land and crop residues, as well as bonfires in the fields, are prohibited" (personal communication). Mr. Sergeevich identifies himself as "head of the department for scientific-metholodological grounds in the field of environmental impact, transboundary transfer, and state accounting."

[61] Evdokimova, N. and E. Kobets (2009) *Legal regulation on air protection connected with waste burning and transport pollution in Russia*, Report for Bellona Foundation.

Agricultural fires have been suggested as a topic for inclusion in the Clinton-Lavrov bi-lateral commission, dedicated to pursuing joint projects that strengthen strategic stability, international security, economic well being, and the development of ties between the Russian and American people.

Although China's government officially prohibits open-field burning (and has even used satellite technology to monitor burning in rural areas), public compliance has been weak.[62]

Agricultural burning has been significantly reduced in recent decades in Europe, suggesting that mitigation efforts can greatly reduce this important source of black carbon, which particularly affects the Arctic.

Pyrolysis, which involves turning agricultural waste into biochar, similar to charcoal, holds out the promise of a productive use of field wastes that are often burned off. Biochar is a soil amendment that can increase productivity while sequestering the carbon from the plant waste – another "win-win" strategy. The challenge is to provide low-cost pyrolysis units in areas where agricultural burning occurs and to inform farmers of the advantages of biochar.[63] A program to produce and deploy this technology should be a priority.

Industrial Sources

Industrial sources are estimated to produce a significant fraction, 18 percent, of global black carbon emissions. Brick making is the largest single industrial source of black carbon, followed by coke ovens and commercial boilers.[64]

Brick kilns

Bricks are one of the oldest and most important building materials in the world. Over 98 percent of bricks are made in developing countries, using very basic tools and techniques. The majority – 55 percent – are produced in China, followed by India – 11 percent. The balance is made in thousands of small brickworks scattered throughout Southeast Asia and, to a lesser extent, Africa and South America. Primitive brick kilns have been recognized in several developing countries as having large environmental, health, and a range of social problems.[65]

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[62] Cao, G.L., X.Y. Zhang, Y.Q. Wang, F.C. Zheng (2008) Estimation of emissions from field burning of crop straw in China, *Chin. Sci. Bull.* 53, 784-790. Available at: http://www.springerlink.com/content/x545112257l13um1/fulltext.pdf

[63] For more information, see: http://www.biochar-international.org/

[64] Bond, T.C. *et al.* (2004), Op.Cit.

[65] Heierli, U., and S. Maithel, (2008) *Brick by brick: the Herculean task of cleaning up the Asian brick industry*. Swiss Agency for Development and Cooperation, Natural Resources and Environment Division. Available at: http://www.poverty.ch/asian-brick-industry.html.

Control options

Improved kiln designs, which have been widely adopted in some regions, offer substantial improvements over primitive designs in energy efficiency and air pollution. Although systematic measurements of black carbon from the various kilns have not been made, improved kiln designs very likely offer an opportunity to reduce black carbon pollution (improved kilns almost certainly produce less air pollution in general, improving human health). Additionally, anecdotal observations indicate that primitive kilns produce substantial black smoke plumes, which disappear with some improved kiln designs. This is corroborated by measurements of total particulate emissions, which decrease from more primitive to the more advanced kilns.[66]

In most cases, replacing relatively primitive with more modern brick kilns will have considerable co-benefits – substantially lower operating costs, fuel consumption, emissions of harmful pollutants (particulates, SO_2 and NO_X), and CO_2 emissions, and improved brick quality.

There are potentially four ways to reduce black carbon emissions from brick kilns:

1. use more energy efficient kilns
2. install pollution control technologies on existing kilns
3. use cleaner fuels
4. switch to making hollow bricks

Measurement of climate-relevant emissions is needed to quantify the climate mitigation opportunity from improving brick kilns.

International Policy

Low fuel efficiency, high polluting continuous kilns have been banned by law in China since at least the mid 1990's because of their low fuel efficiency.[67] We have no information regarding the level of enforcement of this ban.

Some highly polluting kiln designs, while widely used in South Asia, have been banned in India since 2002[68] and in Nepal, in the Kathmandu Valley, since 2004.[69] In January 2009, the Environmental Protection Agency of Pakistan (Pak-EPA) ordered brick makers in and around the capital to close their operation or switch to alternative technology

[66] Co, H.X., N.T. Dung, H.A. Le, D.D. An, K.V. Chinh, and N.T.K. Oanh (2009) Integrated management strategies for brick kiln emission reduction in Vietnam: a case stud. *Int. J. Environ. Stud.* 66, 113-124.

[67] Zhang, Z. (1996) Energy efficiency and environmental pollution of brickmaking in China. *Energy,* 22, 33-42.

[68] Damle Clay Structurals, Ltd. "Indian Clay Brick Industry – On the Threshold of Mechanisation," Available at: http://www.damleclaystructurals.com/Article6.htm Accessed 12 February 2010.

[69] Nepal Ministry of Environment, Science and Technology (2007) *Ambient Air Quality of Kathmandu Valley 2007*. Kathmandu, Nepal.

because of the high level of pollution produced by primitive kilns.[70] We have no additional information on the success of this order.

Coke Production

Coke production is concentrated in a relatively small number of coke making facilities (about 1500 worldwide) and is dominated by China, which produced 60 percent of global coke in 2008 and accounted for 96 percent of global production growth since 2000.[71]

A coke making technology is comprised of coke ovens, auxiliary equipment, and by-product recovery system. Three major types of coke ovens dominate current coke production.[72]

- **Beehive** – "Primitive" technology in limited use – probably primarily in China. Emissions from this technology are high – with black plumes suggesting large black carbon emissions. These ovens are also called "pile" or "kiln" ovens and in China they are called "indigenous" or "modified indigenous" ovens.
- **"Slot Oven"** – Modern technology ovens that recover a wide range of chemicals from coke oven gas. These coke ovens have many potential air emissions points. With proper maintenance practices and appropriate air emissions controls, black carbon emissions can potentially be reduced to very low levels. These ovens are also called "recovery" or "machinery" ovens.
- **"Non-recovery"** – Modern technology ovens that combust coke oven gas and may recover heat but not chemicals. These coke ovens have fewer potential air emissions points and thus tend to have lower air emissions than recovery ovens. These ovens are also called "heat-recovery" ovens.

Air pollution emissions vary by major coke oven type and appear high for the more primitive coke ovens – with black plumes often reported. Except in the non-recovery coke ovens, air pollution is very high compared with production of other commodities.[73]

Control Options

Upgrading from the more primitive coke ovens and installing appropriate emissions control technology can potentially reduce black carbon emissions to very low levels. A wide range of emissions capture technologies and equipment maintenance measures can be employed at different processing stages, which should yield particulate matter

[70] Rehman, F. (2009) 12 brick kilns directed to stop functioning. *The Nation (Pakistan)*. March 18, 2009.

[71] Polenske, K.R., Ed. (2006) *The Technology-Energy-Environment-Health (TEEH) chain in China: A case study of cokemaking*, Dordrecht, Netherlands: Springer.

[72] Ibid.

[73] Polenske, K.R, X. Zhang, S. Li, J. Li, and H. Liu (2009) *Cokemaking Report to the Clean Air Task Force.*

reductions and will likely result in reductions in black carbon. Modern coke ovens also have a combustion stack, which allows installation of pollution control technologies.[74]

Again, as with brick kilns, the lack of measurements of climate-relevant emissions constrain efforts to advocate for upgrading facilities, which likely can improve climate and air quality by reducing global coke oven black carbon emissions to much lower levels over one or two decades. Field measurements will be necessary to determine which actions reduce black carbon emissions and by how much.

Domestic Policy

The U.S. coke industry has been subjected to technology-based regulation of fugitive emissions for over 30 years. U.S. and European environmental regulation has demonstrated that air emissions – likely including black carbon emissions – can be reduced to very low levels through proper maintenance practices and installation of appropriate air emissions control technology. But, even in the U.S., the emissions from one coke oven are largely responsible for the surrounding area failing to meet national ambient air quality standards for particulate matter.[75]

International Policy

A significant fraction of China's primitive coke ovens have been phased out, with current estimates of such production ranging from ~5 percent to 20 percent of the total. Elimination of nearly all primitive coke oven production in China and replacement with modern kilns may occur within the next several years.[76]

Funding Options for International Black Carbon Reductions

The major obstacle to widespread replacement of cook stoves and availability of mobile pyrolysis units is money. Several funding options, probably implemented in combination, will be needed to help make the needed equipment available. These could include:

1. Set aside of carbon allowances or use of auction proceeds under the Climate Bill

In the Waxman-Markey bill, various climate mitigation technologies and programs are funded via the set aside of allowance value or through the use of auction proceeds. The Kerry-Boxer bill devoted a portion of the auction proceeds under the bill to fund diesel black carbon reductions, but nothing to international black carbon projects. Domestic and international programs to reduce black carbon emissions could receive allowance set asides and/or auction proceeds because they offer significant, immediate climate mitigation benefits.

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[74] Ibid.

[75] Weitkamp, E.A, E.M. Lipsky, P.J. Pancras, J.M. Ondov, A. Polidori, B.J. Turpin and A.L. Robinson (2005) Fine particulate emission profile for a large coke production facility based on highly time-resolved fence line measurements, *Atmos. Environ.* 39, 6719-6733.

[76] Polenske, K.R. *et al.* (2009), Op.Cit.

2. Offsets

A climate bill could recognize black carbon reductions as eligible for international offsets under a cap and trade program. Doing so, however, would not be as straightforward for projects that reduce the suite of six recognized greenhouse gases, which have an internationally accepted carbon dioxide equivalency factor. As part of the black carbon study, EPA is charged with investigating the question of whether projects such as cook stove replacement programs should qualify for "offsets" under a cap and trade program and, if so, what credit they should be given.

3. Global black carbon mitigation fund

One possibility for international black carbon reductions would be a financial mechanism that would provide "black carbon credits" funded via public or private participation. Current international climate negotiations in the "Bali track" encourage voluntary mitigation actions with near-term impacts; and black carbon provides one means to do this that has a significant health and environmental co-benefits. Interested countries could agree to pay for black carbon reductions at a fixed price. Moreover, since some of these black carbon reductions projects might arise via investments that provide other carbon and development benefits (such as vehicle filters reducing PM, agricultural burning reducing CO2, and displacement of high carbon and black carbon cook stoves with captured methane-fueled stoves), these separate revenue streams could backstop and be leveraged by a black carbon fund's base price guarantee.

International and National Venues for Black Carbon Mitigation

In the past two years, there have been a number of venues committed to: 1) better understanding the role of black carbon; and 2) recommending and developing abatement strategies. These include:

The Arctic Council was the first to consider early mitigation actions through its Arctic Monitoring and Assessment Program in September 2008. The eight Arctic Foreign Ministers issued the Tromsø Declaration of the Arctic Council during their April 2009 meeting, in which they highlighted the role of "short-lived climate forcers" such as black carbon, methane, and tropospheric ozone in Arctic climate change. They stated that reducing emissions of these forcers has "*the potential to slow the rate of Arctic snow, sea ice and sheet ice melting in the near-term.*" The Arctic Council has created two internal task forces to solidify the science and draft policy action steps to report out in 2011.

The UN Convention on Long Range Transboundary Pollution (CLRTAP), a "decision-making" body aimed at creating or revising binding international agreements, has been ratified by the EU, the U.S., Canada, and Russia. The convention establishes binding authority to impose specific pollution reduction measures on treaty signatories. In part in response to the Arctic Council's action, at its December 2009 meeting, the Executive Body of Convention decided to take up short-lived climate forcing pollution by establishing an ad hoc Expert Group on Black Carbon, with the mandate of completing its work and providing a report for consideration by the Executive Body at its twenty-eighth session in December 2010. The report is expected to identify options for potential revisions to the Gothenburg Protocol, which would enable the Parties to mitigate black carbon as a component of PM for health purposes while also achieving climate co-benefits.

The United Nations Environment Programme (UNEP) is undertaking a black carbon and tropospheric ozone assessment, addressing the climate change, public health and ecosystem impacts of measures to decrease concentrations of black carbon and tropospheric ozone. A final report to the UNEP Governing Council is anticipated in early 2011 and is expected to summarize the state of science and identify technological and policy options for different regions of the world, including mechanisms for international action.

US Strategic Initiative was announced at COP-15 by the U.S. State Department and signaled the Administration's intention to commit $5 million towards international cooperation to reduce black carbon emissions in and around the Arctic. This effort will seek to fill information gaps and develop and implement mitigation efforts that could help reduce Arctic warming while yielding significant direct public health and ecosystem benefits. The U.S. anticipates these funds will be matched by other nations. Federal agencies currently are submitting proposals for spending these funds.

United Nations Framework Convention on Climate Change (UNFCCC) At COP-15, treaty language requesting governments and the UNFCCC to begin taking into account the impact of short-lived climate forcers was successfully negotiated and agreed to in one of the texts, the "LCA" (Long-term Cooperative Action) or "Bali track" text. The section refers to the need to address near-term and mid-term climate change and was spearheaded by Micronesia, actively supported by Norway, the EU and the U.S. Although this section is now non-bracketed or "agreed to", the status of the LCA text in relation to the Copenhagen Accord remains unclear, and it will be important to track this issue closely in the upcoming negotiating sessions. The Accord contains no such reference.

The Department of the Interior, Environment, and Related Agencies Appropriations Act, 2010 directed the EPA Administrator to carry out and submit to Congress the results of a study on domestic and international black carbon emissions. The report, due in April 2011, will inventory major sources of black carbon, assess the impacts of on global and regional climate, assess potential metrics and approaches for quantifying the climatic effects, identify the most cost-effective approaches for reductions, and analyze the climatic effects and other environmental and public health benefits to the identified approaches.

Bounding the Role of Black Carbon in Climate. This scientific assessment, sponsored by National Oceanographic and Atmospheric Administration's (NOAA) Atmospheric Chemistry and Climate Initiative[77] draws on over 30 authors worldwide with deep black carbon scientific expertise. The team will address a broad suite of critical questions

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[77] See: http://www.igac.noaa.gov/ACandC.php

associated with sources, climate responses and key uncertainties of black carbon. A final paper, slated for completion in June 2010 for submission to a peer-refereed journal, will derive the best estimate for radiative forcing from black carbon.

CONCLUSION

Policies targeting black carbon emissions offer a viable climate strategy that can be implemented without delay and will deliver immediate climate benefits using technology available today. Moreover, black carbon reduction policies can deliver important public health protection from particulate matter pollution, one of the most potent and widespread air pollution-related public health threats. Winning these policies domestically and globally will be challenging, but their significant health benefits make them extremely cost-beneficial and they may constitute our best hedge against near-term climate impacts.

The CHAIRMAN. I recognize the gentleman from Washington State, Mr. Inslee.

Mr. INSLEE. Thank you.

This is really an excellent panel. Dr. Bond, if I had had someone like you in college, I would have fulfilled my fantasies of becoming a physicist. So, thanks for your educational work here.

First question: Is black carbon a proxy for the health benefits of reduction of other emissions associated with fossil fuels? If we reduce black carbon, do we get the benefits, almost by necessity, of reductions of other emissions? Or are they different?

Ms. BOND. There is a lot of similarity, and there are some differences.

Black carbon is just a component of particulate matter, which has severe health impacts. And so you can reduce particulate matter and also reduce black carbon, or you can reduce particulate matter and if you don't target black carbon sources, then don't get the black carbon reductions.

Now, your question was the other way around. If you reduce black carbon, do you always get the health benefits? In fact, the health benefits are more clear for black carbon reductions than the climate benefits. The climate benefits have some uncertainty. There are sources for which we are confident in the climate benefit. But the health benefits are always existing.

Mr. INSLEE. So let me ask a little different question. If we made an investment in our diesel transportation fleet of X dollars right now and our interest was on the health impacts, would the best investment to be, at least in the short term, the filtration systems to capture black carbon and then get health benefits associated with that, or would there be a better investment for better health impacts?

Mr. Schneider.

Mr. SCHNEIDER. I will try to take that one.

The Clean Air Task Force has analyzed the benefits of looking at power plant pollution cleanup, diesel pollution cleanup, car pollution cleanup from both a health perspective and from a climate perspective. And if you factor in, if you take into a combination both the health and the climate benefits, there is no better investment than in a particle filtration system.

Particulates are the most deadly air pollutant. Black carbon may deliver the fastest climate benefits. So, taken together—and when you have a technology that can deliver a 90 percent reduction in the particulate/black carbon, you have a real winner for a technology.

Mr. INSLEE. I introduced this black carbon bill, I don't know, about a year, year and a half ago, and it seemed to me the right thing to do. But since then I have seen a documentary showing that the soot on the surface, it was either the Arctic or Greenland, and I can't recall which it was, but it showed these depressions. The whole sheet of ice I saw had these depressions. And at the bottom of the depression, there would be this patch of black soot, and I mean black soot, against the white ice. And it looked like the entire cap was covered with this stuff, at least at the bottom of each one of these little melt pools. It caught my attention.

And I guess the question is, is the albedo effect of black carbon, how does that compare to the general climate change when it is in the atmosphere? Is it just a small part of the problem or a big part of the problem?

Mr. RAMANATHAN. Maybe I can answer part of that question.

If you look at global warming effect of black carbon, this albedo effect contributes about 10 percent of the total black carbon effect. But if you look in the Arctic or in Alpine glaciers, then the darkening effect may be the dominant effect. Because black carbon warming comes from trapping sunlight in the air. But, locally, in the sea ice and the glaciers and the ice sheets, the darkening effect may very well be the dominant effect.

Dr. Shindell.

Mr. SHINDELL. Thank you.

We believe that anywhere where there is snow and ice, the effect you have been describing occurs. In places like the Himalayas, the results are somewhat more ambiguous because you have a fair amount of wind-blown dust and other types of pollutants that are already deposited on those glaciers. So it almost certainly contributes, but how much it contributes there is more ambiguous.

In the Arctic, which tends to be very far from, say, dust sources, the snow is very clean, so the effect is extremely large. And there we believe that it is quite possible that black carbon is responsible for over half of the accelerated melting we have seen in the last few decades, or at least over, say, the 20th century.

Mr. INSLEE. Do you mean the albedo effect from the black carbon?

Mr. SHINDELL. Well, it is both the effect of black carbon in the atmosphere and the albedo effect. And the effect on albedo is obviously very local, but even the effect in the atmosphere has an extra powerful impact on the Arctic because most of the sources are from the Northern Hemisphere industrialized or developing nations, which means that their emissions are closer.

So, unlike CO_2, which just drifts around uniformly everywhere, the black carbon being physically emitted in the Northern Hemisphere, fairly close to the Arctic, allows it to have an even stronger impact on the Arctic than it does on the global average.

Mr. INSLEE. Mr. Schneider, you pointed out what sounded like a potential imperfection of the Waxman-Markey bill, which we don't believe there could ever be an imperfection on that work of art. But you did make reference to, I thought that the provision that would implement a regulation on black carbon would apply only to 1 million of the 11 million units. Could you explain that?

Mr. SCHNEIDER. I will. And thank you very much. And let me just offer another opportunity to thank and commend the committee and the people who worked so hard on that bill. And I appreciate you all revisiting the issue today, hopefully to maybe strengthen the black carbon provisions, which are already the best in any bill.

Mr. INSLEE. And, by the way, if there is an imperfection, it is not those two gentlemen's responsibility. I will take full responsibility.

Mr. SCHNEIDER. I suspect that when——

The Chairman. I actually praised Congressman Inslee in my opening statement for the provisions. So I think he deserves full credit for everything that is——

Mr. INSLEE. Including the imperfections.

Mr. SCHNEIDER. The bill basically directs EPA to exercise its existing authority over all sources of black carbon, the largest, nearly 60 percent of that in the U.S. being diesel. So it is sort of directing EPA to deal with diesel.

And the imperfection, if there is one, is not in the Waxman-Markey bill. It is in the Clean Air Act, which gives EPA only the authority, in terms of in-use diesels, to deal with a very small slice of those engines. The only provision in the Clean Air Act that allows that is one called—it is a rebuild provision. Whenever any truck engines are rebuilt—that is, taken from an old, rebuilt to be in a new—EPA has the authority to issue more stringent emissions standards for those rebuilt engines.

And in this country, over the next decade, we project that only about 1 million vehicles will rebuild in that way. So if EPA exercised, as you directed them, to use the full extent of their authority, they could only cover that 1 million set of rebuilding engines over that period of time, whereas the in-use fleet is 11 million. That would include all the other trucks that don't get rebuilt and would include all the off-road engines: The construction equipment and other engines. EPA right now has no authority over those, and the courts have said so. I mean, it is very clear that that is constrained.

So one of the first things we would say that needs to be fixed in that regard is to give EPA broader regulatory authority to require filters and after-treatment devices on the existing fleet. And we promote the idea of doing that in conjunction with incentives to turn over the fleet faster and potentially economic incentives, like in the Diesel Emission Reduction Act, to pay for some of that.

But one of the things that is holdings us back right now is we have this golden opportunity to deal with these sources, which are public health threats and climate forcers, but EPA really can't go much further.

I don't mean to be overly critical, but I would point out also that, even with respect to the engine rebuild rule, EPA is aware that that authority exists and is studying the question, looking at the question of whether to exercise that authority. And we hope they will shortly, but to date they have not.

Mr. INSLEE. What is the best assessment of the costs associated with that that has been done already?

Mr. SCHNEIDER. In terms of the rebuild rule itself?

Mr. INSLEE. Yes.

Mr. SCHNEIDER. I believe that to deal with those million engines, depending on what—not every engine can take the most advanced type of filter, so that you have a mixture of solutions. It is several billion dollars, with a "B," to comply with that.

Mr. INSLEE. All right.

So, next question: To what extent is black carbon an issue on our coal-fired utility plants? We have talked about diesel. Is black carbon an issue at all with coal-fired utility plants?

Ms. BOND. Not to the best of our knowledge. The combustion in a coal plant is good enough that it burns out all the black carbon. And that has changed in the last hundred years, but that has been one of our successes. So there may be particulate matter, but most of it isn't black.

Mr. INSLEE. And I just was reading a little blurb today about a U.N. program to improve residential stoves, essentially, in the sub-Saharan African area, to try to get the more efficient stoves. Is this a viable strategy? On an international basis, what would it take to really have a meaningful system to improve the efficiency of these?

Open question.

Ms. BOND. I will say something. I am sure Dr. Ramanathan will want to speak, as well.

Two answers, as any good scientist would give you, or any good economist. First, yes, it is, because people want new technologies, people want clean cooking. And of course there are some cultural barriers, but it is definitely a potential solution.

The second answer is that you have to be careful how you do it. We have learned quite a lot about how to improve residential combustion. That includes both what to do and what not to do. What not to do is to parachute in, drop a bunch of improved stoves, and hope that people accept them.

But there is a lot of history in that field. And, as mentioned, you need to work with the communities, follow up, and, above all, think big-scale. And that involves both technological and implementation innovation.

Mr. RAMANATHAN. I will just follow that for India and South Asia. In India alone, 150 million households use mud stoves, using firewood. There has been a long history of trying to replace this, and, by and large, they have failed.

And we got into this just since last year. We have taken a small village, and the first thing we found was that technologies were not ready. I mean, they were sort of built in a laboratory and really didn't adapt to village conditions. And just in the last year or two, there are several companies, Shell and British Petroleum have come with improved stoves. There are also some U.S.-based companies. And they, we find now—we have tried five of them. And I am not allowed to give the names yet because we will publish the data.

At least one of them seems to do the job. The women are happy with it. I am happy with it because it cuts down the black carbon emissions. So it is a convergence of the scientific interest of reducing and cooking with something which is adaptable to local taste. So I think the technology is almost there.

The last thing I want to mention is that India has now started on a major cookstove program nationwide. And it is not clear which way that program is going.

Mr. INSLEE. You mean not clear whether it is going clean or unclean?

Mr. RAMANATHAN. No, I mean to cleaner cookstoves, India's program towards cleaner cookstoves.

Mr. INSLEE. Got it.

I am going to ask one more. This question is a little farther afield of this hearing, but I will ask Dr. Bond.

I have experienced a lot of frustration at the lack of understanding in a lot of places, including the U.S. Congress, about science associated with climate change, ocean acidification, black carbon, and the like. And one of the sources of frustration is that the information the scientific community has does not get shared with Members of the U.S. Congress. They just don't have an appreciation, for one reason or another, because they haven't heard from scientists enough, frankly.

I am surprised that—you know, we have people walking around here today, the U.S. Capitol, who are aggrieved, and they are petitioning their government for redress of grievances in a certain sort of direction. But I haven't seen scientists up here demanding action from the U.S. Congress, except in the most restrained, polite, academic, almost silent ways.

If I was a scientist and I knew what, frankly, a lot of scientists know in this country is going on out there in the planet, in the climatic systems, and in the oceans, I would be in somebody's grill about that, telling them that we need action. And yet you just don't see that from the scientific community, with very few exceptions.

We got a letter from, I think, 250 scientists last week I read, saying, "Wake up and smell the roses. This problem is still there, even though there were some nasty e-mails out of England." But that is about it—a letter, not a person laying down on the tracks.

Why doesn't that happen? Should it happen? And how do we engage the scientific community to be more sharing of the information they have when it needs to be shared?

I am focusing on you, Dr. Bond, because you are an educator and you are responsible for the future crop of scientists that we are going to depend upon.

Ms. BOND. Thank you, Mr. Inslee.

I think it was just Monday when I told my air quality modeling class that some of them should run for office. So I hope that helps.

Mr. INSLEE. That would be great, just not against me.

Ms. BOND. You are well-established enough. I think I voted for you when I was at University of Washington.

Mr. INSLEE. Well, I appreciate that.

Ms. BOND. At any rate, this is a difficult question, and it has to do with the nature of scientists and how they approach science.

If you have an action outcome, one is almost afraid that you will affect the science, because you are supposed to look at it dispassionately. And so, how we conduct our business, 99.9 percent of the time we must step back from what we want the outcome to be. We are not allowed to want an outcome.

And perhaps that leads to a disconnect between us and the people like you and like the rest of the committee who are able to put that science into action so wonderfully, to think of so many measures, as Mr. Schneider outlined, to implement action in society.

Ms. BOND. I don't have a good answer for you. I can't advise the scientific community to become more passionate because they want to be very careful, and that is a very important component of the scientific method. But I can say that if you perhaps had discussions like this one, or even more informal discussions in which there was mixing between the committee, like yourself, and a group of scientists, that that communication might flow a little more easily.

Mr. INSLEE. Well, I will just take this one opportunity to encourage the scientific community to figure out a way to be dispassionate objectively, but passionate about sharing the information they do have with the people who can give effect to those policies. And I think that is possible in the human intellect to do both of those things.

And if we don't have the scientific community doing that right now, we are not going to solve this problem because people, frankly, won't know about it. And this is great to have our committee doing this, but if we don't have scientists getting people and shaking them by the collars to get them to understand how significant this problem is, people are sleepwalking over a cliff. And frankly, the scientific community are the people vested with the intellect and knowledge who have the ability to get people to wake up. So I am just pleading with you, as members of the scientific community, to try to engage your members and colleagues in an effort to educate the U.S. Congress, because I think the moment demands it, and we don't have a lot of time.

Thank you.

The CHAIRMAN. I thank the gentleman very much.

Let me ask this question: The temperatures in Alaska have warmed six degrees Fahrenheit since 1950. Could any of you comment on the role that black carbon has played in terms of the changes that are occurring in Alaska or in the Arctic?

Mr. SHINDELL. That is something that, as I mentioned in my statement, cause and effect is very difficult to understand simply from observations because you only have one way that the real world happened to behave. So what has been happening that is distinct since the 1950's, while concentrations of CO_2 have been rising steadily, concentrations of different types of particulate have been changing, with time—after the Clean Air Act some have gone down—and in different locations. So we can identify the pattern and try to attribute cause and effect to those. The difficulty there is that the effect of sulfate, which is something we have controlled well because of acid rain, looks very similar to the pattern of black carbon.

So what we can see is that, in these kind of studies, more than half of the rapid warming in the Arctic is attributable to particulate, but some of that is due to a reduction in sulfate and some due to increases in black carbon, both of which have been taking place largely in the last 30 years. So it is very hard to really separate the two. Probably a third to a half, or slightly more, is the best number.

The CHAIRMAN. Dr. Ramanathan.

Mr. RAMANATHAN. I think just to echo what was said, we have been doing this air pollution reduction almost to speed up the warming. We talked about the smoke in the blanket, the sulfates and other aerosols act like mirrors on the blanket reflecting sunlight and shielding the greenhouse warming.

So since 1975, we have decreased the sulfate pollution quite a bit, almost 25 percent globally, but just in the Arctic nations, the reductions in North America and Europe is almost 50 percent. So the unmasking of the warming is definitely contributing to the Arctic warming.

The second thing that has been contributing to the warming is that fossil fuel black carbon has increased. Not all black carbon is the same. The biomass black carbon cools a lot less compared to fossil fuel black carbon. So there are three things which are happening at the same time to contribute to the Arctic and the Alaska warming: One is the increase in the greenhouse gases; reduction of sulfur pollution and unmasking the warming; and the third is increasing the fossil fuel black carbon. So what fraction that is I have to leave it to modeling scientists like Dr. Shindell.

The CHAIRMAN. Any other comments?

The Congress, Mr. Schneider, is moving towards the encouragement of all electric vehicles, plug in hybrids. Could you talk a little bit about that trend and the role that that could play in reducing black carbon?

Mr. SCHNEIDER. Sure. First of all, a lot of the discussion in this country around electric vehicles and plug in hybrids is in the light-duty sector. We don't have a lot of diesel vehicles in the light-duty sector here as in other countries, and particularly EU. So a conversion of the light-duty fleet to more electric vehicles and more plug in hybrids is critical with respect to the reduction of greenhouse gases, but probably won't make much of a difference with respect to black carbon reductions.

Representative Sensenbrenner has a bill—it passed the House—that talks about hybridizing more heavy-duty vehicles, and that is a strategy that over a long period of time, if it was able to be successful and all the R&D and so forth worked, could have a benefit. But the technology immediately that could be implemented on heavy-duty diesels where most of the black carbon is coming from in this country really is the installation of the filters that I described.

So these are all complimentary strategies, and it is important to look at which sector and what problem you are trying to address, but I think primarily the electrics and plug hybrids would be addressing greenhouse gasses from the light-duty automotive sector.

The CHAIRMAN. The Recovery Act, the stimulus package from last February, included $300 million for projects to reduce diesel exhaust resulting in replacement of old dirty engines with new cleaner ones and in retrofitting engines to capture black carbon and other pollutants. There is still more to do.

Could you outline the remaining needs in the United States and what we can do to reduce black carbon quickly and effectively?

Mr. SCHNEIDER. Well, first of all, let me commend everyone who supported those provisions in the Recovery Act. That is probably the biggest breakthrough in terms of diesel retrofit money that there has been since DERA was passed. DERA was authorized at $1 billion. It has typically been funded in the annual appropriation of EPA at around $50 million to $60 million, but in the Recovery Act, as you said, it got $300 million. And as I said in my testimony, for that $300 million, the EPA received $2 billion worth of applications. So that really demonstrates that the demand is out there, that people want to participate in the program, both in terms of replacement and retrofits, but EPA is sitting on about $1.7 billion worth of applications. And their internal review suggests that about $1 billion of those are very high quality.

So we have suggested that in any jobs packages that move that include spending, that perhaps, like the Recovery Act, more money could be devoted to the Diesel Emission Reduction Act. And EPA's message is, we can move $1 billion worth of these immediately because we have the applications sitting at our desk. And that would be probably be the fastest thing because the idea of the Recovery Act and the Jobs Act is to get the money out quickly to create the jobs. This type of DERA investment was estimated by Key Bridge Research to generate about 19,000 jobs per $1 billion invested, which is very favorable when you look at the average of the Recovery Act. So this is a win-win-win: It is a climate win. It is a public health win. It is a jobs win. So probably the most immediate thing that could be done is more funding.

The CHAIRMAN. Who won the $300 million, Mr. Schneider?

Mr. SCHNEIDER. How do you mean?

The CHAIRMAN. In terms of the $300 million, you said there was $1 billion worth of applications, who were the winners?

Mr. SCHNEIDER. First of all, there were a diverse set of winners. Applicants included public entities, included public-private entities. So, for example, a public entity, that might be a school district that wanted to retrofit school buses and not only protect the community, but protect the kids on the bus from the fumes on the bus. It would include municipalities that wanted to retrofit their transit buses. It included contractors who wanted to retrofit their construction fleets, and there was some success in terms of those types of awards.

There were other awards in which the people used the DERA money almost as a Cash-for-Clunkers type of situation where they were able to replace existing older vehicles, scrap the older ones and bring in ones with a new, cleaner technology. So that would include some private fleets, some State government fleets, and some fleets that work on contracts for State governments. So there was a whole variety of folks in every State of the Union I believe that were able to——

The CHAIRMAN. What has been the results in terms of the implementation of the programs that the $300 million have incentivized?

Mr. SCHNEIDER. Well, first of all, I think EPA is trying to calculate right now what the emissions benefits have been from that, and they can do that because the applications are quite detailed. But that money was able to be awarded very quickly. It is a reimbursement program, so it will take a little time to get the money out, but the orders came in and those fleets were transformed. I think that is the good news, is that many of those fleets were able to take advantage of that. And there have been announcements around the country where kids are riding cleaner buses to school, people are riding cleaner transit buses to work. Ferries have been retrofitted so that when they pull into their dock, the black smoke doesn't infiltrate the shore. All of these things have been accomplished through the Recovery Act.

The CHAIRMAN. So I should ask the EPA then to give me their——

Mr. SCHNEIDER. Their assessment of that, yes.

The CHAIRMAN [continuing]. Report in terms of how successful the $300 million has been. You said that for $1 billion, it would create how many thousands of jobs?

Mr. SCHNEIDER. Nineteen thousand.

The CHAIRMAN. So, theoretically, then 6,000 jobs were created with the $300 million.

Mr. SCHNEIDER. Correct.

The CHAIRMAN. So I think it is important for us to get the information on that as well because, as you said, it is win, win and win. Thank you.

Again, you each, I think, made some reference to the fact that acting on this black carbon sector should not in any way reduce our activities to reduce CO_2 in general. So could each one of you take 30 seconds to succinctly make your own point on that subject?

Let me go to you, Dr. Bond.

Ms. BOND. The fact that we should not reduce CO_2 endeavors because of black carbon? We have——

The CHAIRMAN. No, that we should not reduce our efforts to reduce the CO_2 because we are also working on the carbon issue.

Ms. BOND. Correct. I think Mr. Schneider said it best; we need both and everything else that we can think of.

Right now, we are in a position where we need to act quickly. We don't have the 50 years it will take to come up with new technologies to reduce atmospheric forcing. And so black carbon is a quick solution, but we will still be left with the bill after putting CO_2 into the atmosphere. We can't afford to miss either opportunity.

The CHAIRMAN. Dr. Ramanathan.

Mr. RAMANATHAN. It is important to recognize that black carbon reduction is not supplementing our prevention efforts to reduce CO_2 simply because we are adding 35 billion tons of carbon dioxide every year, and it is increasing at the rate of 2 to 3 percent. If we don't do anything about CO_2 emissions, the CO_2 concentration alone in this century can be double, and the warming from that added CO_2 can exceed 2 degrees. So there is nothing BC reductions is going to stop this. The BC reduction is more a short-term gain to slow down the climate change. Ultimately, that climate change is from CO_2, and we have to reduce it. Thank you.

The CHAIRMAN. Dr. Shindell.

Mr. SHINDELL. Well, in the nineties, the U.K. introduced a public health law that said that anybody emitting black smoke could be deemed a public nuisance, meaning legally actionable. So this led to the City of London suing the London Underground over a power plant emitting black smoke, which they got out of by claiming it was brown.

And I bring this up because the interesting thing about this, as well as being amusing, is this was the 1890s, not the 1990s. And we have known for a long time about the public health impact, and black carbon should be dealt with because it is a public health impact, whether or not it had any climate impact. There is an extra impetus now because climate is such a severe problem. And I don't even like the expression that this buys us time because we really don't have any time on the CO_2 issue either. That problem is coming down the road; it is simply a different time scale.

That problem, since CO_2 accumulates in the atmosphere and lasts in the atmosphere for centuries, that problem will be with us for a long time, even if we begin to address it right away. And so addressing black carbon and the other short-lived pollutants can help, but really has to be side by side with already immediate action on CO_2.

The CHAIRMAN. Thank you.

Mr. Schneider.

Mr. SCHNEIDER. Mr. Chairman, I like your metaphor about the house payments, down payment and monthly payments. We have a lot of experience in this particular area right now; if you make a down payment and fail to make the monthly payments, you know what happens. You get a foreclosure. And if we act on black carbon and make that down payment but we fail to make the monthly payments we need on greenhouse gases, our project will fail. And maybe we theoretically have bought ourselves a few years, but we will have squandered that opportunity, that down payment, if we don't follow through and make the necessary reductions in greenhouse gases. It will take, as I said, both—and in order to reach the target levels that people say will avoid the worst effects of global warming.

The CHAIRMAN. By the way, I wanted to tell you, Dr. Ramanathan, the reason we are having this hearing is I read this brilliant article that you had in Foreign Affairs. And from a public education perspective, if I could have 435 Members of Congress read it, I think that we would have a different reaction to the actions that we have to take and the recommendations for actions that we have to take to solve the problem but also why it is a smart way to go because it is something that can happen relatively quickly and have a big payoff as well.

If I could go to India for a second, and maybe you could expand a little bit more, Dr. Ramanathan, talk a little bit more about India and other countries and their cooking devices and what strategy you would recommend to be implemented. And what percentage of all black carbon comes just from those cooking mechanisms that are used in third-world countries?

Mr. RAMANATHAN. In fact, some of the statistics I am going to give you come from the pioneering studies of my colleague sitting to my right. But we have verified it with observations collecting isotope data of black carbon. It turns out at least two-thirds of the black carbon over South Asia, which includes India, Pakistan, Bangladesh, Nepal, comes from biomass burning in terms of cooking stoves.

The CHAIRMAN. Did you say two-thirds from those countries or two-thirds for the whole world?

Mr. RAMANATHAN. Two-thirds from those countries. If you look at the total emissions from India, about two-thirds is from biomass burning. I know my own grandmother cooked with these cook stoves. And they do that because the food from that is the most delicious at least I have ever eaten, just like the smoked salmon here. So that is the reason for the difficulty changing that to LPG stoves and others.

But that was the reasons given by all of the nonprofits with which I have interacted. But our experience based on this 1 year in this selected village is that the women are tired of cooking with these traditional mud stoves. It simply takes a long time to collect the fuel, and it is a lot of work.

And so I think the communities, at least the communities I have worked with, are ready. We are working with the most densely populated part of India. It is called the Indo-Gangetic Plain. Over 600 million live there.

And the other beautiful thing which is happening is the Indian Government has realized this is a development issue, a health issue. And now I have teamed up with some economists at Berkeley and Duke to show that it is also contributing to agriculture decrease of the yield. So all of this is coming together. And also the realization it may be impacting the glaciers is also bringing in a lot of communities together.

So my personal feeling is the timing is really perfect for a major bilateral collaboration between U.S. and India to take it to the next stage.

The CHAIRMAN. And what is the next stage? How can Americans change Indian cooking habits?

Mr. RAMANATHAN. I think the change can happen, my feeling, is through technology, transfer of the stoves, and there are various ways to do that. And there are also ways we can remove the black carbon from the chimneys, and so let them use. And the third is, of course, funding. Those three.

And the fourth I want to mention, the key thing is what we are doing; we have to document how much of the health we are saving, exposure studies. And we have to document how much global warming benefit will you get. My personal calculation suggests removing 1 ton of black carbon in those villages will have the same effect as removing thousands of tons of carbon dioxide, in terms of global warming. And these are theoretical calculations. So there are a number of scientific engineering, and just the question of giving loans to 150 million. So there are a variety of ways in which bilateral collaboration could just push it to the front page.

The CHAIRMAN. Thank you.

The Chair now recognizes the gentleman from Missouri, Mr. Cleaver.

Mr. CLEAVER. Thank you, Mr. Chairman.

I apologize, I am running between committees. I always like this committee and try to get here under almost any circumstances because of how significant it is.

I walked in on this conversation. My family is in Tanzania, Arusha, about 400 miles south of Nairobi and at the foot of Mount Kilimanjaro. I stood out one evening with one of my relatives, and we looked up at the moon. And we could actually see the outline of craters. And I said to him, you are fortunate in many ways over the Western World because there is no pollution. I think, in Arusha, average income is $1,500 a year; there may be 10 cars. I mean, if I am underestimating, let's say 100 cars on the high side, and yet I get on this committee and start learning about the soot that is there because my cousins cook outside. I mean, everybody is cooking outside. In fact, my cousin, believe it or not, in Africa is running a barbecue business, and so people line up outside, and nobody is thinking about what is going on.

But the concern I have is, it is low-hanging fruit. We can probably eliminate that intrusion into the atmosphere, black carbon, but how do we do it? It is something that we know we can do if we can just change the culture and also provide some kind of way for cooking that does not pollute, but it is going to cost money. I am thinking about my cousin or any of my relatives, they would easily probably go to another form of cooking if they could afford it.

And so, in the absence of having the money, what do we do? I mean, is it something that the United States and the polluters, the big polluters—India, China, Europe—is that our responsibility, or are there any suggestions? I will go tell them. You tell me what to do, and I will go tell them. I know the mayor. Anybody.

Ms. BOND. First of all, this is a big problem, of course. This is about half the people in the world. And there are places to target first to move rapidly. One of those areas is high-population density where that kind of cooking leads to high concentrations and impacts on quite a lot of people. And so it is easier to deliver to those groups of people than it would be to deliver to your cousin, who has a barbecue at the foot of Mount Kilimanjaro—forgive me if I have gotten your geography a bit wrong.

Mr. CLEAVER. No, you are right.

Ms. BOND. Now, Mr. Markey asked about the role of the United States. There is some funding needed, but we are also in a really good position to develop enabling technologies. For example, we find that a better stove can be made not by making a great stove here and delivering it there or by paying them to make a stove, but by developing capability to build mass production for a combustion chamber so that people there can build their own stoves, but the critical piece is made possible.

And so if you think of this as a large-scale problem and we have to solve every single household, it seems big and almost undoable. I think the role of the United States can be in identifying targeted research and targeted studies and targeted development for those things that are keeping new, clean, better technologies from spreading. And I don't want to underestimate the role of clean fuels as well as clean technology; clean fuel means not only modern fuels, but also methods for working on crop waste and creating pellets and that sort of thing. So I think we have the vision and we have the capability and we have a history of identifying those trigger points that make a big difference.

Mr. RAMANATHAN. May I add to that, Mr. Chairman?

Mr. CLEAVER. Yes, please, Doctor.

Mr. RAMANATHAN. First thing to recognize is that they are using the most environmental friendly fuel because it is not adding carbon dioxide to the air if you are cooking with crop residues and cow dung mixture.

And the cost of these stoves is such that, I think of, for example, India, 750 million depend on this, 150 million households. It is a $4 billion problem. So to me, I think it is a solvable problem. You are not talking about trillions. We are not talking about hundreds of billions; with clever micro credits and others, we could distribute this.

One thing I want to talk to you about is the brown clouds or the haze you saw covering Kilimanjaro. In Africa, part of the source of this black carbon is savanna burning.

Mr. CLEAVER. Is what?

Mr. RAMANATHAN. Savanna burning, so that contributes quite a bit to that Africa-wide haze, plus the cooking, both those sources.

Mr. CLEAVER. Let me follow up.

When I used to have knees, I could go up to the top of Kilimanjaro, and if any of you have done it, you know you start at the bottom, and you are in very tropical clothing because the temperature is going to be at the century mark. The higher you go, the colder it gets, and so you start changing. By the time you get to the top, you are on snow. That was a while back. Now you get to the top, and you may see little sprinkles of snow. The snow on Kilimanjaro, it hasn't completely vanished, but it is going there.

In reading through the testimony and becoming a little more familiar with this issue, I started wondering, in this land where the Kilimanjaro Airport is not far from the mountain, and I am starting to think maybe more planes are landing here, maybe that is what is doing the damage. Because there is no industry. The industry there is the Western World stealing all the water to do plants so that we can have fresh plants in hotels every morning, but that is other another whole issue.

So I am wondering if what causes that haze is the same thing that is causing the melting of the snow.

Mr. RAMANATHAN. I will comment on that. First, you have to understand, when you see the haze above your head, particularly if it is above a mile, it may have nothing to do with the local source. These things transport over thousands of kilometers.

For example, in the dry season, between October to April, the entire Arabian Sea and the North Indian Ocean is filled with haze. It is transported both from the South Asian side and from Africa. We have seen elevated regions of the Himalayas covered with thick brown clouds. We have been there. We have taken pictures with aircraft.

So the issue of the whole Kilimanjaro, as you know, its retreat, originally it used to be thought it was all due to global warming. Now, some glaciologists have estimated at least half of that, a lot of it is coming from really what we call sublimation, just the air becoming dry and the snow evaporating.

So there are multiple causes happening in Kilimanjaro, but I would point out, no one has taken a look at really what this black carbon is doing to that retreat. It is an area, new research to find out. But we know from satellite images that soot looms hover around the Kilimanjaro region.

Mr. CLEAVER. Dr. Shindell.

Mr. SHINDELL. I was going to comment on the previous question a little bit, which was, if, say, the Waxman-Markey bill becomes law in this country, there will be a price on carbon, like there is in much of the world. I would think that it is not necessarily a useful thing to link funding that has been associated with the greenhouse gases that are controlled under the Kyoto Protocol, the clean development mechanism whereby the United States and other wealthy countries pay for reductions in other countries; I don't think it makes sense to link those with the short-term pollutants like black carbon because, as we have talked about, they operate on very different time scales.

But analogous sources, for example, there was an editorial in the Wall Street Journal about a global methane fund, where the U.S. could help other countries to pay for reductions or a global black carbon fund. I think all of these kind of ways that the United States can help the developing world to do things, like intervene in residential cooking stoves, are quite sensible, but I really think we need partners there.

I am chair of a United Nations environment program assessment of the effects of black carbon and ozone on climate. And what we are really trying to do is bring in the developing world scientists, as Dr. Bond was mentioning, and there is capacity there, too. I think if those scientists are able to convince their countries that these things are really in their own best interests because they are damaging their ability to grow crops to feed their population and they are affecting their development goals by air pollution—one of the leading causes of adverse health impacts in the developing world—if it is in their own interest and there is this additional kind of carrot of having funding from developing nations to help them do something about it, I think that is a combination that would actually help to get something done.

Mr. CLEAVER. It is a major challenge because the people who live in this area, the Maasai Tribe, which inhabits this particular area, they know nothing about global warming. I mean, you may as well keep speaking English because they have no idea what you are talking about when you start talking about global warming because all they know is that the snow on the mountain is not as thick as it used to be. That is all they know. And they have not had any intellectual conversations or debates about it, and nobody is bringing the issue forth. It is a challenge to us because I think we are partially responsible for much of what they experience. I simply wanted to get some kind of reading on this because I guess maybe I am personally involved in it and was hoping that—and I still hold that hope—that the Waxman-Markey bill will be approved, and if we need to tweak it later.

I like a world black carbon fund idea. I think if we tweak it later, it can be the major step to save the planet.

Anyway, thank you, Mr. Chairman.

The CHAIRMAN. Thank you, Mr. Cleaver, very much.

Here is what I am going to do; I am going to ask each one of you to give us your 1-minute summation of what it is that you want us to remember, which is a test because you have a lot that you want us to know about these subjects. We will go in the reverse order of the opening statements.

And we will begin with you, Mr. Schneider.

Mr. SCHNEIDER. Mr. Chairman, thank you very much.

I am going to just tick off the policy pieces that you really asked me to address today.

The first one is funding through the climate bill, if we are lucky enough to have one, funding for the Diesel Emission Reduction Act and through the Jobs bill, a reauthorization in funding, and funding through a transportation bill, reauthorization, which requires clean construction equipment and funds it as a part of that transportation bill.

And then, lastly, giving the EPA the regulatory authority to cover more of the existing in-use diesels that could require the use of today's technology to reduce the black carbon emissions from them. We have had a good discussion just now about the cook stove issue; I am not going to add to that. I do talk about the black carbon fund in my written testimony, so I would refer you to that.

And then, lastly, we haven't talked as much about the agriculture burning issue. That is an issue that deserves more attention. It is going to require international cooperation and enforcement of national laws in other countries to really accomplish that, but we probably can't get the full benefits of black carbon reduction unless we address that.

Thank you very much for the time today, I appreciate it.

The CHAIRMAN. Dr. Shindell.

Mr. SHINDELL. Well, I would start by reiterating that we have two problems: a long-term climate change problem and a near-term climate change problem. And we can't deal with the long-term problem without beginning to reduce carbon dioxide emissions as soon as possible.

But for the near-term problem, I think that consideration of the short-lived warming agents, as we are talking about today, and not just black carbon, but also methane, carbon monoxide and volatile organic carbons, which are also emitted by similar processes—for example, the diesel particulate filters we have been talking about substantially reduce about 90 percent black carbon, but also carbon monoxide and volatile organics. So if you target all of these as a basket, you are likely to make more effective decisions, reductions that can lead to significant improvements in air quality as well as mitigating climate change.

And I just repeat the summary of my testimony, that reductions in emissions of products of incomplete combustion will virtually always improve health. And if targeting emissions that are rich in black carbon, carbon monoxide, VOCs and methane, you can often find options whose co-benefits are so large that they can simultaneously mitigate climate change and improve air quality at substantially reduced cost.

The CHAIRMAN. Thank you.

Dr. Ramanathan.

Mr. RAMANATHAN. The Copenhagen Accord requires us to limit climate change to less than 2 degrees from pre-Industrial. We have already put enough greenhouse gases on the planet, according to our climate models, they would already warm the planet by 2 degrees. So we are losing time. So we have a Herculean task in front of us to meet the Copenhagen Accord, and I consider black carbon reductions as an important component of our battle to meet that 2 degree warming.

Thank you.

The CHAIRMAN. Thank you.

Dr. Bond.

Ms. BOND. Thank you very much.

We have discussed some emission sources that produce black carbon and other pollutants. And we have also discussed how there is the long-term and the short-term effect. What I really want you to think about is that we have a portfolio of potential solutions that can address climate change in the long term and the short term. So don't think about either/or; think about, how will we manage the atmospheric trajectory during our lifetimes and your children's lifetimes and our grandchildren's lifetimes? And our lifetime is a significant component of that and of interest to many people.

The United States has the opportunity to lead in both technology and in engagement internationally in this endeavor. There are ways to improve both climate and human welfare at the same time. I will leave it there. We have a lot in front of us, but we have a lot of solutions, and I think we have a lot of opportunities.

The CHAIRMAN. Thank you very much.

And a lot of opportunities to create new jobs, a lot of opportunities to engage in technological transfer, a lot of incredibly great side benefits from working on this problem if we do so in a way that sees the opportunities as well.

We thank all of you for your tremendous testimony and for your incredible work on this subject. That is what made it possible for us to have this hearing today.

With that, this hearing is adjourned. Thank you.

[Whereupon, at 11:40 a.m., the committee was adjourned.]

ILLINOIS
UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

Department of Civil & Environmental Engineering
Newmark Civil Engineering Laboratory, MC-350
205 North Mathews Avenue
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April 16, 2010

Dr. Ana Unruh-Cohen
Deputy Staff Director
Select Committee on Energy Independence & Global Warming
B243 Longworth House Office Building
Washington, DC 20515

Dear Ana,

Thank you for the opportunity to respond to the Committee's further questions. My responses are included with this letter.

Sincerely yours,

Tami Bond

Tami Bond
Associate Professor
Arthur & Virginia Nauman Endowed Faculty Scholar

Tami Bond, Response to Additional Questions
House Select Committee on Energy Independence and Global Warming
March 16, 2010 Hearing: "Clearing the Smoke: Understanding the Impacts of Black Carbon Pollution"

My answers to the following questions focus on black carbon, but many of the answers are also true for other short-lived climate forcing agents such as tropospheric ozone and its precursors. I will abbreviate "greenhouse gas" as GHG. I will also refer to the American Clean Energy and Security Act (ACES), HR2454.

1) Would eliminating or reducing black carbon emissions merely "buy us time" while we figure out how best to deal with GHG emissions, or do we need to include it as a critical component of a balanced portfolio of climate change actions?

Time is of the essence, but only if you care. The choices posed in the question above do not oppose each other: time *is* a critical component of climate change actions. In fact, reducing black carbon makes sense *only* if we intend to proceed with mitigation of greenhouse gases. *Meinhausen et al.*[1] contrasted two types of emission scenarios. At one extreme, GHG emissions continue unabated, and temperature change eventually becomes very large (above 9° F). If we follow this trajectory, there is no point in addressing black carbon or any other short-lived species for climate reasons. It matters little if Arctic melt is delayed by 10 years, although it does give more time for adjustment. In the other type of scenario, the world decides to make a hard run at the 3.8°F target. In most emission trajectories that are successful at meeting this goal, global emissions begin to decrease by 2020 and are halved by 2050. The developed-country portion of this global target is largely consistent with ACES goals. Waiting 10 years to begin GHG reductions does not give a successful emission trajectory: too much GHG builds up in the atmosphere during the delay, regardless of whether black carbon is reduced. Meeting these targets requires immediate action toward GHG reductions.

If black carbon does not reduce the ultimate GHG burden and climate forcing, what is the purpose of discussing it? There are at least three possibilities, all of which make sense when managing climate impact is a priority.

Offsetting sulfate reductions. Particles that reflect light, such as sulfates, are being removed to improve air quality. These particles also have short atmospheric lifetimes, and the warming impact of removing them will be felt quickly. A set of actions that has an equally fast effect may be needed to counteract the loss of cooling.

Leverage for sensitive regions. Global-average temperature targets don't reflect very different responses among regions and critical change points. Poles warm faster than the global average, and snow melts above 32° F. Because there is disproportionate *impact* in

[1] Meinshausen, M., N. Meinshausen, W. Hare, S. C. B. Raper, K. Frieler, R. Knutti, D. J. Frame, and M. R. Allen (2009), Greenhouse-gas emission targets for limiting global warming to 2 degrees C, *Nature*, *458*(7242), 1158-1196; see Figure 2. The underlying models are discussed more thoroughly in papers referenced in this article, and by the Intergovernmental Panel on Climate Change, but this article provides a nice summary.

sensitive regions, it is wise to have some mitigation tools that also have disproportionate *benefit* there. Black carbon is one of those.

Delaying warming, which is different than delaying reductions. The response of the earth to changes in GHG emissions is slow. The atmospheric burden of greenhouse gases continues to increase after emissions decrease. With sufficient emission reductions, the burden will come down, as well. Temperature continues to increase after the burden decreases. We have already committed to this warming and we don't know its magnitude. We can avoid experiencing some of it by reducing short-lived warming species.

2) *Why did the Kyoto Protocol fail to address black soot and other tropospheric ozone as methods of addressing global warming?*

I cannot comment on why these pollutants were not addressed, as I was not present at the discussions. I will comment on why they might not have been addressed.

The Kyoto Protocol was a first step toward "stabilization." Climate negotiators were attempting to meet the objective of the United Nations Framework Convention on Climate Change (UNFCCC).[2] That treaty was ratified by the United States Senate (during the administration of George H.W. Bush) and 192 other countries. Its purpose is to "stabilize concentrations of greenhouse gases in the atmosphere." We don't actually want to stabilize air pollutants in the atmosphere; we want them to be eliminated. It is quite possible the Kyoto negotiators dealt only with those gases for which stabilization is a realistic goal. Also, by the UNFCCC's definition, soot is not a greenhouse gas, but tropospheric ozone is. In its first attempt at commitments toward global climate change, the Kyoto Protocol addressed only the goal of stabilization.

The Framework Convention allows a discussion of short-lived climate forcers. The UNFCCC authors had to know that new science would arise. The Principles section states that the precautionary measures "should...be comprehensive, cover all relevant sources, sinks and reservoirs of greenhouse gases and adaptation..." By their definition, particles are included in sources. So the UNFCCC technically covers the topic under discussion here, short-lived climate forcers. It also has language in the objectives addressing the pace of climate change, an area in which short-lived forcers may assist.

In 1997, the stage was not ready to be fully comprehensive. At the time of the UNFCCC negotiation, the role of traditional air pollutants in the climate system was not thoroughly discussed. The first scientific papers on the influence of sulfates (cooling particles) had just been published[3]. Black carbon was not extensively discussed until some years later[4]. The Kyoto Protocol wasn't comprehensive, but it wasn't fatally flawed

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[2] Available at http://unfccc.int/essential_background/items/2877.php
[3] Charlson, R. J., J. Langner, H. Rodhe, C. B. Leovy, and S. G. Warren (1991), Perturbation of the northern hemisphere radiative balance by backscattering from anthropogenic sulfate aerosols, *Tellus, 43AB*(4), 152-163.
[4] Haywood, J. M., and K. P. Shine (1995), The effect of anthropogenic sulfate and soot aerosol on the clear sky planetary radiation budget, *Geophys. Res. Let.*, *22*(5), 603-606.

because of the missing species. A reasonable subset of global warming gases was chosen, consistent with the scientific understanding at the time.

3) *It seems that most GHG and black carbon emissions are coming from India, China and developing nations. Shouldn't efforts to address global warming be focused mainly on them?*

Focusing on large emitters makes sense. I agree that it's prudent to focus on nations that have the largest emissions. Solutions implemented in such countries will make the biggest difference and provide demonstrations of best practices for smaller nations.

The United States should be a focus of GHG reductions, by all measures. The United States and China are approximately equal in GHG emissions today. China recently surpassed the U.S.; before that, the United States was dominant. India has much lower GHG emissions. By the measure of present-day emissions, the U.S. deserves focus. Next, the United States is responsible for a much larger fraction of the atmospheric burden of CO_2: about 30% of the total. The UNFCCC acknowledges this historical contribution, and the demonstrated history of environmental responsibility in our country indicates that we believe that responsible for pollution should also contribute to cleanup. It is true that developing nations should enter the discussions, and that the trajectory of emissions cannot be fully managed without their participation. Here the U.S. can also play a role; a large fraction of China's GHG emissions result from producing goods for export, including to the U.S.[5], so there is certainly some leverage.

For black carbon, large emissions and inexpensive mitigation occur in Asian countries. Most black carbon emissions are indeed coming from South and East Asia, partly because of the large population living there. No serious effort to reduce black carbon can be undertaken without engaging them. Reductions there would also be cheaper than they are in the United States.[6]

Leadership could be the U.S. role in black carbon reductions. The United States is a relatively small emitter of black carbon precisely *because* it has already targeted reductions, devised and implemented solutions. These solutions include infrastructure, regulation, and technology, and the U.S. can work with other major emitting countries on implementation. Since the U.S. produces only about 5% of global black carbon, should we try for continued reductions? In the case of off-road diesel, yes; we have already developed much of the technology. These actions would serve as a further demonstration of the programs required to benefit both health and climate.

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[5] Davis, S. J., and K. Caldeira (2010), Consumption-based accounting of CO2 emissions, *Proc. Natl. Acad. Sci. U. S. A.*, *107*(12), 5687-5692.
[6] Bond, T. C., and H. Sun (2005), Can reducing black carbon emissions counteract global warming?, *Environ. Sci. Tech.*, *39*, 5921-5926.

4) Why is the Antarctic spared from the effects of black carbon?

It's far from emission sources. Air, and the pollutants it carries, require over one year to mix across the equator. Pollutants with relatively short lifetimes don't stay in the atmosphere long enough to travel between hemispheres. Most black carbon is emitted in the Northern Hemisphere, as shown in the graph below. Because particles have short atmospheric lifetimes, they wash out before they reach the Southern Hemisphere. Black carbon from open biomass burning is emitted in the Southern Hemisphere, so it could possibly affect Antarctica. However, continents—where most emissions originate—are not as near to Antarctica as they are to the Arctic. Shipping can also affect Antarctica, but again the emissions are further away, and the levels are far lower than they are for the Arctic.

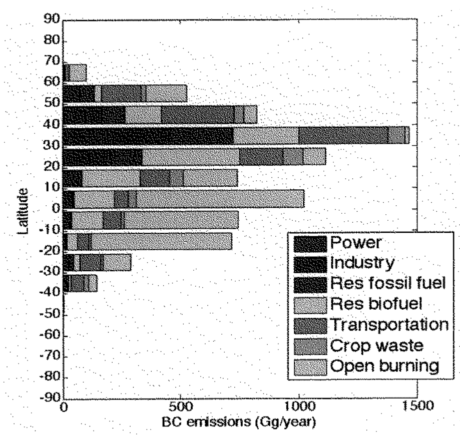

Figure: Latitude dependence of black carbon emissions.[7]

5) *As scientists, do you consider the work done by the IPCC to be the "gold standard" of scientific research?*
   - *Would you use the information and conclusions from IPCC reports, especially the most recent one in 2007, without any reservation?*
   - *Would you incorporate IPCC data into your body of work without hesitation?*

The IPCC assessment is useful. I believe that the IPCC report is assembled by honest people who strive to be comprehensive in collecting and interpreting current scientific

[7] Bond, T. C., E. Bhardwaj, R. Dong, R. Jogani, S. Jung, C. Roden, D. G. Streets, S. Fernandes, and N. Trautmann (2007), Historical emissions of black and organic carbon aerosol from energy-related combustion, 1850-2000, *Glob. Biogeochem. Cyc.*, *21*, GB2018, doi:2010.1029/2006GB002840; gridded data manipulated to produce figure.

studies. This is the process of assessment, and I think they are doing reasonably well. I do not consider them to be the "gold standard" of scientific research, because the IPCC is not supposed to do scientific research. Their mandate is only to assess the research that has already been done. This research tends to be guided by individual investigators and by the national funding agencies.

Nobody should use data without question. I would never use the information from IPCC reports, nor incorporate it into my work, without reservation or hesitation. This statement has nothing to do with mistrust of the IPCC. It is just a natural scientist's skepticism. The IPCC summarizes information from individual studies, and the data contained in the IPCC reports is therefore considered "secondary information"—it is not delivered along with the methods used, caveats given, or further research required. It would be irresponsible to use this information without returning to the original source. On the other hand, it is very difficult for the non-specialist to get a broad view of any topic; that would require reading hundreds of papers. Assembling that view is the mission of the IPCC. A close analogy would be Wikipedia, with the additional benefit that the authors are certain to be experts (although they are still volunteers!). Everyone goes there first, but one must always check the background before drawing conclusions.

6) *If you were in the position to do so, how would you structure a comprehensive climate change bill?*

I like some of the ACES structure. I don't have the expertise to create a truly comprehensive climate change bill, and the two houses of Congress are currently working on one. The things I like best about the American Clean Energy and Security Act are: (1) It sets overall economy-wide emission targets that are consistent with international goals, over a significant time span. (2) It sets targets for particular sectors—without doing so, we won't spur the innovation that's needed to accomplish ambitious overall reductions. (3) It invests in infrastructure and allows risks rather than placing too much weight on a near-term target. (4) It gives substantial levers to the states. (5) It considers social impacts including job creation and displacement. I would like to see more effort on transportation and its infrastructure; the present bill appears to continue emphasis on individual transportation. I like the reduction of international offset credit that begins in 2018, although I would like to see that ramped up (i.e. an offset would be worth progressively less), with the difference credited to the implementing country. I will not comment on cap-and-trade, which has been hotly debated by people with far deeper understanding of the topic than I.

My research tends to look at the overall picture of emissions and the resulting climate impact, and I am far from the "nuts and bolts" of implementation in different sectors. That perspective will frame the rest of my statements, because I think our efforts have not been quite comprehensive enough.

Integrate climate and air quality trajectories in planning climate outcomes. When we determine what *has* happened and what *could* happen under future scenarios, we must consider all pollutants: greenhouse gases, warming and cooling particles, and short-lived gases like ozone. We should evaluate the impact of all projected emission changes, including air quality regulations, and plan climate mitigation strategies accordingly. This discussion should take place at a high strategic level, when setting global and economy-wide emission targets. For this recommendation, I don't have a prescriptive role for black carbon and ozone reductions; their contributions should become apparent with a comprehensive analysis.

Fully evaluate risks and be ready to move quickly. It's clear that we must manage the trajectory of emissions and climate forcing, not just total emissions. This evolution is considered in ACES. ACES also provides for periodic reviews by the Environmental Protection Agency and by the National Academy of Sciences. These reviews should explicitly address the question, "What are all possible and most-likely trajectories of emissions of greenhouse-gas and short-lived climate forcers? If trajectories exist that result in unacceptable climate change, what mitigation options must be immediately ready for implementation?" Here, "unacceptable climate change" must focus on regional climate change, including regions with ice and snow, not just global-average warming. We must keep assessing the potential outcomes, not just the emission targets. A comprehensive plan will prepare the research and the capacity required for quick implementation of climate solutions, including those that address short-lived pollutants.

7) *Given the extent of the impact of black carbon on the Arctic and Himalayan glaciers, and the potential consequences for various water supplies, shouldn't this be a number one priority issue for those Asian countries that would be directly affected? Why is this not the case?*

The Arctic is a common resource. We should separate the discussion of the Arctic and the Himalayas. Arctic ice is not providing water supply for many people, so the issues with the Arctic are different. Large changes in the Arctic would affect a sensitive region. They could have positive feedbacks to global warming, through the loss of permafrost and the release of methane. They could also change atmospheric circulation. In terms of public opinion, Arctic change has many of the features of global change: the benefits are diffuse and it is sometimes difficult to determine who should accept responsibility and take action.

Himalayan glaciers are a priority, but there is disagreement on appropriate action. Water resources in the Himalayas directly affect the people in South Asia, and politicians there (especially including the Indian prime minister, Manmohan Singh) have indeed expressed concern about melting glaciers. Although the impacts of black carbon on the Himalayan glaciers are thought to be significant[8], this research is preliminary and has not been reproduced by multiple models as is standard practice. More accepted is the notion that glacier loss results from GHG warming, to which India has contributed little. The discussion of which nations have caused the glacier loss, who should be responsible, and who should take action, needs to be handled gently. Framing this issue in terms of shared

[8] Flanner, M. G., C. S. Zender, P. G. Hess, N. M. Mahowald, T. H. Painter, V. Ramanathan, and P. J. Rasch (2009), Springtime warming and reduced snow cover from carbonaceous particles, *Atmos. Chem. Phys.*, *9*, 2481-2497.

concern and collective action may allow it to become more of a priority than it has been in the past.

8) *What source of black carbon emissions should we focus on the most in order to get the most reductions?*

Tier I (immediate): diesel plus near-snow. Diesel engines are a good first target because technology exists for reducing emissions, and because the emitted particles are mostly black carbon with few reflective particles. Refinements needed include a better understanding of retrofit potential, and applicability of current technology to off-road engines. Also on the first list should be any anthropogenic sources (including crop burning) that are very near snow and ice fields.

Tier II (rapidly following): small industry and household energy. As the first-pass regulations are being implemented, we should also be developing the capacity required to retrofit particular high-emitting industries and disseminate clean, acceptable, field-tested and user-friendly cooking devices and fuels so that programs can be implemented in the second wave of black carbon reductions. This development should have a large component of technology transfer and capacity building, because successful implementation of these measures requires a deep understanding of local resources, practices, culture and governance. These two sources make up a large fraction of global emissions. They are in the second wave because the amount of associated reflective particles is larger, and because proven technologies and infrastructure will require some time for development. Furthermore, the science is also developing: interaction of the emitted particles with clouds is not fully understood, raising questions about the magnitude of the benefit.

9) *Widely regarded to be the largest regional sources of soot, how can the U.S. address black carbon emissions from biomass burning and brush fires in Asia?*

Open burning is difficult to regulate. I will assume that this question refers to open burning of biomass, not biofuel for domestic uses. This is the most challenging source to regulate. This difficulty holds not just for Asia, but also for the remaining open burning in the United States. There are, however, alternatives to crop burning in agriculture, which have been successfully (but not completely) implemented in both the United States and Europe. The difficulty in control is one reason that I did not list it as a top-tier target in my answer to Question 8. A second reason is the large amount of reflective particles (organic carbon) emitted along with the black carbon. It is not even certain that these sources are net warming, especially when they are far from snow fields.

In many Asian countries, emissions are not dominated by open burning. I estimate that open burning results in less than 15% of black carbon emissions in India and China.

10) *In the U.S., when using wood as an energy source, do you consider it to be a significant source of black carbon? What about as a source of GHG emissions?*

Simple wood burning is a source of black carbon. Compared with other sources of heat, wood burned in an average domestic fireplace or heating stove has significant black carbon emissions. It also has high emissions of organic carbon (reflective particles). Here, "significant" means that emission per fuel mass, or per energy delivered to the user, are high compared with other fuels. I estimate that residential wood combustion makes up slightly less than 15% of U.S. black carbon emissions. Wood burning also emits large quantities of organic gases that can lead to formation of ozone, a short-lived greenhouse gas. However, because wood harvested in the United States is usually regrown, CO_2 from wood burning is not a net addition to greenhouse gases. Only the short-lived species have a greenhouse impact.

Wood burning can be improved. Pellet stoves and masonry heaters are two relatively simple residential technologies that can dramatically reduce pollutant emissions. Emissions of particles and other short-lived pollutants from modern biomass boilers are also much lower. Wood is "carbon-neutral" when it is burned cleanly, so it can be a part of the greenhouse solution if pollutant-free burning can be assured.

11) Given the global warming impact from black carbon, can a global climate change treaty that ignores black carbon and focuses solely on GHG emissions be effective in addressing global warming?

There is a faint possibility that GHG reductions alone could allow an acceptable trajectory, but it would be a challenging one. Such a trajectory would definitely require more extreme GHG reductions sooner. Furthermore, the warming that will occur as sulfate particles are removed from the atmosphere is still being explored. It is not certain that we can counteract that warming with greenhouse gas reductions.

My answers to Questions 1 and 6 provide more detail for the discussion of this question.

THE SELECT COMMITTEE ON
ENERGY INDEPENDENCE AND GLOBAL WARMING

April 1, 2010

Dear Dr. Ramanathan:
Following your appearance in front of the Select Committee on Energy Independence and Global Warming, members of the committee submitted additional questions for your attention. I have attached the document with those questions to this email. Please respond at your earliest convenience, or within 2 weeks. Responses may be submitted in electronic form, at Ana.UnruhCohen@mail.house.gov. Please call with any questions or concerns.

Thank you,
Ali Brodsky

Ali Brodsky
Chief Clerk
Select Committee on Energy Independence and Global Warming
(202)225-4012
Aliya.Brodsky@mail.house.gov

1) Would eliminating or reducing black carbon emissions merely "buy us time" while we figure out how best to deal with GHG emissions, or do we need to include it as a critical component of a balanced portfolio of climate change actions?

   Black carbon emission reductions should be part of a portfolio of climate change actions.

2) Why did the Kyoto Protocol fail to address black soot and other tropospheric ozone as methods of addressing global warming?

   The science of black carbon and ozone impacts on climate change were too new at the time of Kyoto Protocol discussions (late 1980s).

3) It seems that most GHG and black carbon emissions are coming from India, China and developing nations. Shouldn't efforts to address global warming be focused mainly on them?

   GHG: Global warming as of now from GHGs are a result of GHGs that have accumtlated over the last 2 centuries. China, India and other developing nations are not the major contributors to the global burden of GHGs in the atmosphere. But they may become the major contributors to the build up during this century.

   Black Carbon: About 50% of the current global emissions are from China, India and other nations in Asia. But the emissions from N America and Europe are not small. Their combined emissions are more than India's emissions. Furthermore, the BC that is contributing to Arctic Sea Ice retreat is mostly from countries north of about 40deg latitude.

4) Why is the Antarctic spared from the effects of black carbon?
We don't know this yet. For example the global arming due to BC will have impacts on Antarctic too.

5) As scientists, do you consider the work done by the IPCC to be the "gold standard" of scientific research?

Yes. Of course, there is room for improvement.

- Would you use the information and conclusions from IPCC reports, especially the most recent one in 2007, without any reservation?

  The IPCC reports are excellent reference sources for information on climate change science. I will continue to use the IPCC findings in my lectures and papers, but will check their sources before including them in my papers and lectures.
- Would you incorporate IPCC data into your body of work without hesitation?
  I will check their sources and references before incorporating them.

6) If you were in the position to do so, how would you structure a comprehensive climate change bill?
I recently wrote a detailed paper on this topic and it will be published May first week.
I can send this paper by May 5th.

7) Given the extent of the impact of black carbon on the Arctic and Himalayan glaciers, and the potential consequences for various water supplies, shouldn't this be a number one priority issue for those Asian countries that would be directly affected? Why is this not the case?
It should be among the top priorities, consisting of CO_2 and other GHGs.
I can only guess why this is not the case. The Science of this is only 10 years old.

8) Why does the IPCC's latest Assessment Report in 2007 estimate black carbon's radiative forcing to be 0.44 Watts per meter square, which is almost half that of your figures of 0.9 Watts per meter square?

IPCC's estimates are based solely on models. My estimate(along with DR Carmichael's) is based on available satellite and ground based observations. Both approaches have uncertainties and there are several efforts to understand the source of the difference.

National Aeronautics and Space Administration
Headquarters
Washington, DC 20546-0001

May 24, 2010

Reply to Attn of: OLIA/2010-00422:MDC:eel

The Honorable Edward J. Markey
Chairman
Select Committee on Energy Independence
and Global Warming
U.S. House of Representatives
Washington, DC 20515

Dear Mr. Chairman:

Enclosed are responses to written questions submitted by Members of the Select Committee resulting from the March 16, 2010, hearing at which Dr. Shindell testified regarding "Clearing the Smoke: Understanding the Impacts of Black Carbon Pollution."

This material completes the information requested during that hearing.

Sincerely,

L. Seth Statler
Associate Administrator
for Legislative and Intergovernmental Affairs

Enclosure

Response to questions from the Select Committee on Energy Independence and Global Warming

Dr. Drew Shindell

NASA Goddard Institute for Space Studies

These responses reflect my own opinions and are not meant to represent an official position of NASA.

1) Would eliminating or reducing black carbon emissions merely "buy us time" while we figure out how best to deal with GHG emissions, or do we need to include it as a critical component of a balanced portfolio of climate change actions?

There are two distinct issues at play – short-term and long-term climate change. They are distinct not only in the time frame over which they occur, but more importantly in this case because they are driven by different agents. Dealing with climate change over the long-term (several decades to centuries) requires sharp reductions in emissions of long-lived greenhouse gases, especially carbon dioxide. The annual reduction rate needed is relatively small if reductions begin quite soon, but becomes larger if the start date for reductions is delayed assuming a fixed target for maximum allowable warming (e.g. avoiding dangerous climate change, as the US agreed to at the Earth Summit in 1992 or as in the 2 C warming target in the Copenhagen Accord). The long-lived greenhouse gases are the dominant drivers of long-term climate change due to human activity because they accumulate in the atmosphere. Conversely, relatively short-lived climate warming agents including black carbon, carbon monoxide, volatile organic compounds (VOCs) and methane, play a lesser role in long-term climate change as they do not remain in the atmosphere nearly as long. This means, however, that they offer strong leverage over climate change in the near-term (years to a few decades) since they respond rapidly to emissions changes. Hence reductions in black carbon and other short-lived warming agents along with reductions in emissions of long-lived greenhouse gases are both necessary to accomplish the largely independent goals of mitigating near-term and longer-term climate change.

2) Why did the Kyoto Protocol fail to address black soot and other tropospheric ozone as methods of addressing global warming?

There are three primary reasons that I believe the Kyoto Protocol did not address black carbon or tropospheric ozone precursors (other than methane) as methods to address global warming. The first is that there is much less data available that shows how these pollutants have changed since the Industrial Revolution than there is for long-lived greenhouse gases. The abundance of the greenhouse gases can be determined from air bubbles trapped in ice cores, but measurements of black carbon or tropospheric ozone are minimal a century or more ago. As the concentration of those short-lived pollutants varies greatly from place to place, vastly more data than is available would be needed to accurately quantify their preindustrial distributions. The second reason is that the global impact of these pollutants on climate is less certain. A commonly used metric to evaluate climate impact is global mean annual average radiative forcing (a change in the balance between incoming solar radiation and outgoing terrestrial radiation). For long-lived greenhouse gases, this forcing is known to within about 10%. The Kyoto Protocol drew on the prior IPCC Second Assessment Report (SAR) from 1995, which estimated the radiative forcing from soot to have "an uncertainty of at least a factor of 3". Forcing from tropospheric ozone also had substantially greater uncertainty than long-lived greenhouse gas forcing. Furthermore tropospheric ozone is not directly emitted but results from multiple atmospheric chemical interactions, so that the link to emissions of a particular precursor pollutant that might be included in an international treaty is much more complex. Finally, the third reason is that unlike the case for the long-lived greenhouse gases, the climate impact of emissions of black carbon or tropospheric ozone precursors depends upon both the location and time of emission. This makes their inclusion in any policy that requires evaluating the relative impact of emissions changes in different nations much more complicated than is the case for the long-lived greenhouse gases included in the Kyoto Protocol.

3) It seems that most GHG and black carbon emissions are coming from India, China and developing nations. Shouldn't efforts to address global warming be focused mainly on them?

Annual average carbon dioxide emissions from China recently exceeded those from the US, but the sum from all developed countries (US, EU, Japan, former Soviet Union, Canada, Australia, Korea, Taiwan, etc) is still greater than the total emissions from developing nations. Growth in emissions in China and other developing countries is very high, however, so that their share of emissions may in fact soon exceed that of developed nations. However, given the long residence time of carbon dioxide in the atmosphere and large historical emissions, the contribution to climate change from the emissions by the developed nations will continue to outweigh that of the developing world for many decades. Hence it is important that both developed nations, which bear the brunt of the responsibility for changing climate thus far, and the developing nations, whose emissions are increasing so rapidly, reduce GHG emissions in order to mitigate long-term climate change.

Emissions of black carbon are indeed greatest in the developing world at present. However, substantial emissions still do take place in developed nations as well. Given the well-documented adverse impacts of these emissions on human health, it is clearly in the interest of every country to reduce their own emissions for the sake of their own population's well-being. In addition to the local health benefits, the climate benefits from reducing black carbon extend more broadly, so that it is everyone's interest for global emissions to decrease. While it certainly makes sense to encourage efforts to mitigate global warming by reducing black carbon emissions in the developing world where they are greatest, it also makes sense to reduce them elsewhere. Differing local conditions both in the atmosphere and in socio-political systems mean that there will be different costs and benefits associated with emissions reductions from region to region and even from source to source. A logical strategy would be to target those emissions for which the benefit/cost ratio is greatest regardless of where they are located.

4) Why is the Antarctic spared from the effects of black carbon?

There is minimal transport of black carbon to the Antarctic primarily because it is so far from most of the black carbon emissions. This means that little black carbon reaches the ice sheet or surrounding sea ice in comparison with the Arctic or lower latitude snow and glaciers. Climate change in response to black carbon can nonetheless extend well beyond the locations with substantial black carbon amounts as the atmosphere and ocean efficiently transport heat to even remote areas. Hence while Antarctica may receive very little black carbon from lower latitudes, it most likely experiences a temperature change due to black carbon that is only slightly lower than the global mean value - perhaps a few tenths of a degree warming since the preindustrial. This is much smaller than the probable effect of black carbon on the Arctic or Northern Hemisphere mid-latitude areas, however.

5) As scientists, do you consider the work done by the IPCC to be the "gold standard" of scientific research?
   - Would you use the information and conclusions from IPCC reports, especially the most recent one in 2007, without any reservation?
   - Would you incorporate IPCC data into your body of work without hesitation?

It is important to be aware that the IPCC does not perform any original scientific research but simply assesses work done by the scientific community. Their assessments can provide substantial added value in interpreting the results of the large body of studies that have been published, but it is the studies themselves that are the 'gold standard' of research. In my opinion, the conclusions of the IPCC reports, including the 2007 report, are extremely reasonable and reliable with the exception of a very small number of well-known and acknowledged errors. I have, and will continue to, use the IPCC assessments as a guide to both our current state of knowledge and to the best available underlying scientific work that I attempt to build on in my own studies.

6) If you were in the position to do so, how would you structure a comprehensive climate change bill?

Taking into consideration that I am not a policy expert and that the specifics of such a bill are well beyond my expertise, and reiterating that I am not speaking on behalf of NASA and the Executive Branch, in my opinion the overarching aims of such a bill should be to simultaneously reduce emissions to mitigate long-term climate change and to target short-lived black carbon, methane, carbon monoxide and VOCs to mitigate near-term change. As part of the effort to mitigate emissions of short-lived pollutants, I would also attempt to correct the current situation where the damages from highly polluting activities are largely not included in the costs associated with those activities, distorting the marketplace to artificially encourage emissions that have serious adverse health and climate impacts (the cost of emissions permits for the Clean Air Act's criteria pollutants accounts for only a small fraction of their impact). While putting a price on carbon dioxide emissions has been widely discussed, emissions of particulate can cause substantial health impacts while emissions of tropospheric ozone precursors lead to both adverse health impacts and reduced agricultural and forestry yields. So-called 'green accounting' includes these environmental impacts.

These impacts could be included using any of the mechanisms discussed for putting a price on carbon dioxide emissions that would bring the power of the market and of policy tools to bear on emissions reductions. In my opinion, the critical need is to rectify the current situation where a clean power source such as wind is very expensive compared to a coal-fired power plant because the comparison includes only the cost paid by power generators and ignores the environmental damages resulting from the coal burning (solid waste, atmospheric emissions, etc). In contrast, a full accounting is likely to find the opposite results, namely that the overall impact on society including valuation of human health impacts and crop yield and forestry losses shows coal-fired power plants being more expensive than many renewable energies. Associating an economic cost proportional to the damages resulting from emissions would remove the present implicit favoring of highly polluting activities and would be a fairer approach than the current system.

7) Given the extent of the impact of black carbon on the Arctic and Himalayan glaciers, and the potential consequences for various water supplies, shouldn't this be a number one priority issue for those Asian countries that would be directly affected? Why is this not the case?

While there is an impact of black carbon on Asian glaciers, it is not yet clear exactly how large this impact is. Glaciers are melting around the world, so observation of glacier retreat in the Himalayas is by itself not enough to implicate black carbon in that retreat. More work is needed to better clarify the relative importance of local black carbon versus global greenhouse gas increases in the melting of glaciers in Asia. A strong regional effect of black carbon on the Arctic is more clearly established, and the Arctic Council nations have indeed begun making this a priority issue, at least in discussions.

In Asia, emissions of black carbon also likely alter monsoon rainfall, which may have profound consequences on human well-being. Again, these effects are difficult to demonstrate from observations alone, as changes in rainfall will arise from other factors such as increasing greenhouse gases as well. Hence the role of black carbon in altering Asian water supplies is difficult to quantify and to demonstrate clearly, and in my opinion this has delayed appreciation of its importance. The physical principles that underlie black carbon's ability to change the water cycle are well understood however, and the impacts from changes in the monsoon are potentially so large that the current range of results carries substantial risk and should be given higher priority by Asian countries. As in the US, efforts to deal with black carbon (whose adverse health impacts are extremely clear and arguably should by themselves be enough to motivate action) must compete with other national priorities, and often short-term economic or political interests trump the long-term problem of climate change. While there are ongoing efforts to reduce emissions, for example by improving the efficiency of rural cookstoves, these could benefit from increased national and international funding, which can be a large barrier to implementation in developing nations even if the will to reduce emissions is there.

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CLEAN AIR TASK FORCE

April 14, 2010

House Select Committee on Energy Independence and Global Warming

March 16, 2010 Hearing: "Clearing the Smoke: Understanding the Impacts of Black Carbon Pollution"

Responses of the Clean Air Task Force to Additional Questions

1) Would eliminating or reducing black carbon emissions merely "buy us time" while we figure out how best to deal with GHG emissions, or do we need to include it as a critical component of a balanced portfolio of climate change actions?

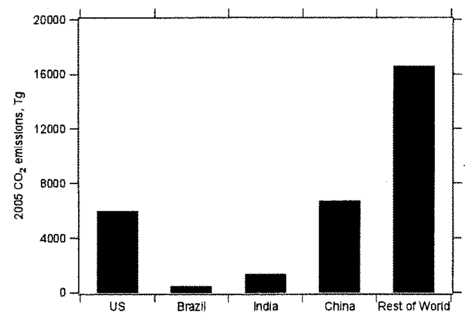
We are out of time and must take all feasible steps simultaneously to slow, stop, and reverse global warming. As CATF testified at the hearing, addressing black carbon and the other short-lived climate forcing pollutants such as methane and ozone is not a substitute for enacting comprehensive climate change legislation to deal with carbon dioxide emissions. We are going to need both and then some in order to address the climate crisis. So, yes, addressing black carbon emissions is a critical component of a comprehensive approach to addressing climate change.

2) Why did the Kyoto Protocol fail to address black soot and other tropospheric ozone as methods of addressing global warming?

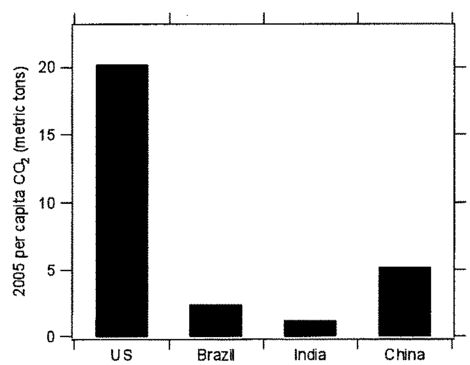
Thirteen years ago, when the Kyoto Protocol was negotiated, the importance of black soot and tropospheric ozone as short-lived climate forcing pollutants was much less well understood than it is today. Since that time, scientific research and assessments have clarified that these pollutants are important agents warming the climate.

3) It seems that most GHG and black carbon emissions are coming from India, China and developing nations. Shouldn't efforts to address global warming be focused mainly on them?

To solve the climate crisis, each nation must take responsibility for reducing its emissions, an effort not as likely to succeed without international cooperation and coordination. No nation can solve this problem on its own. Even if we could somehow magically zero out all of the GHG and black carbon emissions from China and India, we could not solve the problem. The same is true for the U.S. See bar charts below. Note also the per capita share of these emissions by nation.

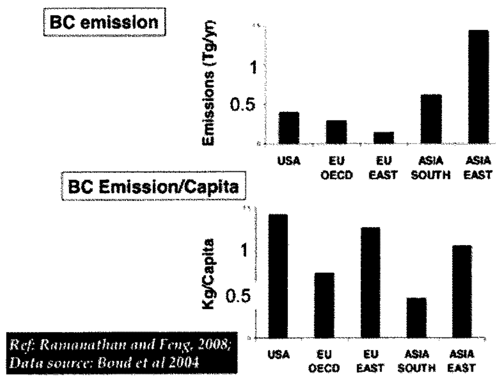


CO2 emissions by nation



Per Capita CO2 emissions

Data Sources for Graphs: Carbon Dioxide emissions from EDGAR - EC-JRC/PBL. EDGAR version 4.0. http://edgar.jrc.ec.europa.eu/, 2009. Population (2005) from the Population Reference Bureau: *2005 World Population Data Sheet*, http://www.prb.org/Publications/Datasheets/2005/2005WorldPopulationDataSheet.aspx, 2005.



BC emissions by nation and per capita

See: http://www.yaleclimatemediaforum.org/pics/0709_blackcarbon_1_431.gif

4) If the U.S. does not address black carbon, and only focuses on GHGs, then even if Congress passed a stringent cap and tax bill today, would the world still experience global warming from the continued black carbon emissions from some developing nations?

To solve the climate crisis, it will take all nations working together to address both carbon dioxide and the short-lived climate forcing agents (like black carbon, methane, and ozone). The most likely pathway to success involves joint international cooperation and action, not a blame game to justify inaction. The advantage of a focus on short-lived forcers like black carbon is that reducing their emissions will deliver immediate climate benefits because of their short residence life in the atmosphere. Reducing short-term climate forcing agents offers a very complimentary strategy to efforts to reduce longer-lived pollutants like carbon dioxide, which also need to begin immediately because they will take longer to counteract warming.

5) There is tremendous global pressure on developed countries like the U.S. to implement a cap and tax bill. Why is there not an equal push/pressure on developing countries to reduce black carbon emissions through elimination of inferior cooking stoves and the immediate replacement of inefficient diesel engines with new and more efficient products?

There needs to be more emphasis on reducing short-lived climate forcing agents <u>everywhere</u>, and the Waxman-Markey bill and this hearing were a good start. The U.S. must demonstrate leadership in this matter by significantly reducing U.S. diesel black carbon emissions (the largest domestic source) while helping facilitate reductions in other countries by encouraging adoption of more stringent diesel emissions standards, the replacement of inefficient cook stoves, and the curtailment of agricultural burning in the spring. The comprehensive climate bills, such as the Waxman-Markey bill, feature a cap on carbon dioxide and other greenhouse gases. Carbon dioxide is the primary cause of observed warming to date, so reducing carbon dioxide is critical to any global warming mitigation strategy. But, the Waxman-Markey bill also includes measures to address short-lived climate forcers. The choice is not one or the other. Some strategies, like replacing inefficient, dirty cook stoves, present an opportunity to mitigate climate change by reducing both gases (CO2, CH4, N2O, CO) as well as black carbon. The stoves that achieve the greatest black carbon reductions also achieve the greatest overall reductions in unhealthful smoke, so there is a potential for a win-win.

6) What sort of mechanisms do you think the U.S. can implement to encourage foreign countries, specifically Russia and China, to reduce their black carbon output?

In China, 80 percent of the population uses solid fuels for cooking or heating. According to the World Health Organization, this practices leads to an estimated over 380,000 deaths per year.[1] In many parts of China, coal is used as the fuel for cooking, so moving from dirty, coal-fueled stoves to clean efficient stoves fueled either by renewable biomass or LPG has the potential to achieve even more substantial climate benefits in terms of both GHG and aerosols. China also has wide access to electricity, so that more advanced biomass stoves that require electricity to power a fan are more credibly an option today in China than in many parts of the world.

As for Russia and other countries that engage in agricultural burning, one mechanism by which the U.S. can encourage black carbon reductions is by supporting development and testing of pyrolysis equipment to convert biomass – such a crop wastes -- to biochar in a low oxygen environment. If designed and run correctly, these units can emit much few air pollutants, including black carbon, than would occur during traditional field burning. Biochar is the carbon (C) rich product that can then be applied to soil as a means to improve soil health, to filter and retain nutrients from percolating soil water, and to provide carbon storage.

A significant hurdle to full evaluation of biochar is the lack of available equipment for biochar production. Bench-scale units are available and have led to important advances in research, but they are not scalable in the field. There is an urgent need to develop prototype units capable of producing biochar from multiple feedstocks. The U.S. government could support this early stage production of equipment that would be capable of generating biochar from crop wastes and applying the char to agricultural fields.

[1] http://www.who.int/indoorair/publications/indoor_air_national_burden_estimate_revised.pdf at page 4.

7) Despite China's recent reductions in the number of older diesel engines, what has been the overall trend for China's black carbon output? Has the increase of vehicles in China and construction boom resulted in a net increase of black carbon?

The increase in the vehicle fleet and the construction boom in China are not expected to be large contributors to additional black carbon emissions there. Although the motor vehicle populations have increased in major cities by over 10% from 1995 to 2005, the growth rates of vehicular emissions of particulate emissions are much lower (compared to CO2), due to the implementation of more stringent vehicle emission standards.[2]

The Chinese Ministry of Construction estimates that 30 billion m^2 of new buildings will be built between 2005 and 2020.[3] This is likely to come from a combination of bricks, cement, steel and timber. Historically, coke and brick making have been significant sources of black carbon emissions. In the case of brick kilns, while black carbon measurements are nearly non-existent, particulate emission measurements and observation strongly suggest that primitive kilns are much higher emitter of black carbon than improved kilns. Because of this, China has been pushing for bricks produced from kilns with higher efficiency. The 'Tenth Five Year Plan' stipulated that by the end of 2005 the output of solid clay bricks (derived from the most inefficient and highest polluting kilns) should be reduced to 450 billion blocks (from 540 billion blocks in 2000). If this is reductions came to pass, brick emissions would be unlikely to cause a net increase in Chinese black carbon.

A portion of the construction materials will come from the steel and iron produced from coke making. As with brick kilns, while there are very limited measurements, primitive, indigenous coke ovens are significantly higher emitters of particulate matter—and black carbon -- than clean coke ovens. In 2006, China's coke production was roughly 300 million tonnes, accounting for 64% of the world's total coke production. A very rough calculation, based on current growth, predicts that China's coke production will double and reach 600 million tonnes in year 2020.[4] While this growth has the potential for significant black carbon emissions, a large fraction of China's primitive coke ovens have been phased out, and elimination of nearly all primitive coke oven production in China and replacement with modern kilns is expected to occur within the next several years. [5]

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[2] Wang, H. K., L. X. Fu, Y. Zhou, X. Du, and W. H. Ge (2010), Trends in vehicular emissions in China's mega cities from 1995 to 2005, Environ. Pollut., 158(2), 394-400.
[3] Ma, Y. and Bao, S.M. (2006) Status quo of building energy conservation and green building in China. China Construction Newspaper, 29 Match, P1
[4] Polenske, K.R, X. Zhang, S. Li, J. Li, and H. Liu (2009) *Cokemaking Report to the Clean Air Task Force.*
[5] China Mining, *China to eliminate 70 mln tons of small coke production facilities*, www.ChinaMining.org, 3/31/08, visited May 9, 2009.

The biggest unknown associated with black carbon emissions in China is the residential heating and cooking sectors. The black carbon emissions trajectory in China will be governed largely by how quickly cleaner fuels and improved stoves diffuse into the residential sector.

8) What is the cost of retrofitting existing diesel engines with the necessary diesel particulate filters? How much additional cost is added to clean diesel engines?

For on-road engines, the cost of retrofitting an existing engine with a passive diesel particulate filters ranges from ~$6500-$10,000. For non-road engines, the cost varies more but $15,000 is about the average (with a range from $10,000 to $60,000). For both on- and non-road engines, active diesel particulate filters generally cost more. EPA in its Regulatory Impact Analysis to the "2007 Heavy-Duty Engine" rule estimated an average incremental cost, for example, to a new Class 8 engine is about $3000. Because of the variety in engine horsepower in the non-road sector, the average per engine cost of the "Clean Air Non-Road – Tier 4" rule is harder to calculate. See: http://www.epa.gov/nonroad-diesel/2004fr/420r04007g.pdf at page 6-82 et seq. for the range of costs for example types of equipment.

9) How do you respond to the observation that diesel engine filters that reduce black carbon are known to reduce fuel efficiency and increase GHG emissions?

CATF and M.J. Bradley & Associates have performed a thorough literature search on this topic. The best evidence suggests that there is no fuel penalty (and therefore no increase in GHG emissions) from the installation of a diesel particulate filter (DPF). See: The Carbon Dioxide-Equivalent Benefits of Reducing Black Carbon Emissions from U.S. Class 8 Trucks Using Diesel Particulate Filters: A Preliminary Analysis Sept 10, 2009 pages 6-11, available online at: www.catf.us/publications/reports/CATF-BC-DPF-Climate.pdf

10) How do you encourage poor people to purchase cooking stoves that are better for the environment, but cost more to heat their food than what they currently use? How do you deal with the cultural resistance/issues that lead to skeptical views of new technology?

This is an excellent question and goes to the core of why many past stove efforts have failed. Any solution that does not meet users' needs is doomed to fail. The basis of any solution must include offering not just stoves that are cleaner and more efficient in the lab, but ones people can afford, that cook the food people want to cook, at the time of day they want to cook, using available fuels, that can be repaired locally, and that do not substantially increase the time of cooking. However, a more subtle issue lurks here, too. Ideal solutions from an emissions perspective like Liquefied Petroleum Gas (LPG) -- essentially what we use in our gas stoves in the U.S. – may offer a "leapfrog" technology for many consumers in the developing world – from primitive biomass burning to a much cleaner cooking technology. Consumers would recognize the value in switching to these stoves because LPG has several key characteristics as a fuel: you can start and stop it immediately, turn up or down the heat as needed (and so you can heat things quickly like tea, or simmer things a long time like stews), and, it is very clean and efficient. But everyone does not have access to LPG and most cannot afford it. So, there is a policy question about whether to invest in a leapfrog technology that would entail more expensive stoves and fuel supply issues vs. less expensive stoves that may face more consumer acceptance issues. Moreover, while it is important to be aware of meeting people's needs, it may be unnecessary to create a different solution for every village or region. One challenge is to develop other leapfrog technologies that can approximate the performance of LPG. One promising development in this regard is very clean advanced biomass stoves that are not as flexible as LPG stoves, but which have fans (and thus are nearly as clean) and that are adjustable. In addition, these technologies must be developed across a wide range of price points so that solutions are available for everyone, not only the relatively well-off among the world's poor. Such an effort will require support for applied R&D in all these areas to bring very clean, efficient, safe, reliable, and affordable solutions (stoves or fuel) to all.

Another part of the solution is relying on commercial markets to deliver stoves. Unlike government or research programs -- which often design to the donor needs (e.g., reducing black carbon) -- the private sector must design to the preferences of the customer. Private firms must test and retest stoves over and again with users before going to production. They typically mass produce only the stoves that people want. So, for example, they think about designing aspirational products that make people feel modern or better for other reasons, but are not sold solely based on the low emissions. And they would be more likely to sell stoves they can service. As a result, the stove ceases to be a handout, but rather becomes another consumer good that requires the full supply, distribution, and the type of service that we would expect. Adopting this perspective would entail a huge leap of imagination for this field, but a necessary one to deliver sustainable solutions at a very large scale.

Another leap forward has been the progress in learning what messages work in selling stoves. Once again, the messages again have to speak to the consumer, and they are different in different regions, for men vs. women, and in many other ways. The Shell Foundation has been a recent leader in this area and is starting to distill lessons from their public awareness campaign targeting three stove manufacturers in India.

Another key to the private sector's ability to sell stoves is the development of global standards as to what constitutes a clean stove. Absent that, anyone can make a stove and call it improved. The Waxman-Markey bill wisely includes such a set of standards. And once those standards are in place, consumers need credible, local sources to tell them which stoves meet the standards e.g., a network of national or regional stove testing centers.

Funding is also a key to success. Because more efficient stoves reduce carbon dioxide, carbon financing is already helping stove sellers across the globe. But, it can be a very difficult, onerous process leading to a situation where few are able to get the financing, and many who do are beholden to large corporate entities that are willing to provide up-front financing (at considerable risk), but which then take nearly all of the value of the carbon credits, leaving little economic benefit behind. If a large public fund could be created to provide seed capital to stove businesses that had high quality stoves and a proven business model, these credits could instead be used to reduce the price of stoves to consumers, and also fund expansion of stove businesses, all of which would help make stoves cheaper and available to more people. See answer to Question 12. Village financing schemes are also important parts of any strategy, since the very poor will always have difficulty paying for even a decent, inexpensive stove. Microcredit tools could be invaluable in this regard.

Helping to reduce duties and tariffs for stoves that are mass-produced out of country is another way to make stoves more affordable. High quality stoves that are imported often see their price rise by as much as 10-20 percent due to these duties and tariffs.

In addition, recently some have proposed very innovative distribution ideas, such as giving high quality stoves to pregnant women that visit health clinics (reduced smoke exposure reduces infant mortality) including even giving them vouchers to encourage them to use the stoves (monitoring devices can now measure this). This would help reach the most vulnerable (the poor and children), and would critically not upset commercial business activity to sell stoves. Indeed, it may even be a good way to seed commercial markets by showing that improved stoves are so important that they are given to pregnant women. It is a scalable strategy – especially for the very poor – and could also be leveraged to research the impacts of smoke exposure on birth weight and perinatal mortality.

Finally, several leading stove manufacturers are piloting new devices that could help completely change the nature of the consumer proposition, by using the heat of the stove to charge a cell phone or light a bulb (or two or five). If these products can be shown to be reliable enough for the marketplace, they flip the value to the consumer from one of having an improved version of what they already have (a stove) to providing a much desired service, at relatively low cost, for something else they want. That could be a game changer for this field.

11) In your testimony, you note your support for a provision of the Waxman-Markey bill which "calls for providing assistance to foreign countries to reduce, mitigate, and otherwise abate black carbon emissions, and specifically outlines action to provide affordable stoves, fuels or both stoves and fuels to residents of developing countries."

- How much assistance do you believe will be necessary to make a significant reduction of black carbon?

- What sort of "assistance" would be most effective and how could the United States hold those countries accountable for responsible use of such assistance?
- What are your thoughts on ventures between private businesses and countries that appear to be successful, e.g. Envirofit, which has sold 100,000 stoves in India for about $15 a stove?

One estimate is that as little as a $0.5-$1 billion investment over 10 years could reach 20 percent of the global population – 100 million homes -- while also addressing the core infrastructural issues for the field -- priority applied research, stove standards, global revolving load fund, public awareness, etc. But this should not be considered as just aid given to countries to the tune of: "here is $50M for stoves, Country X – Good luck." Rather it should be a strategic investment that builds critically on private sector solutions, or sustainable and scalable government programs. Merely giving money away here will not succeed. The U.S. does not need to fund the entire amount, but it can lead by partnering with other donor countries, leading foundations, and corporate donors. For example, the UN Foundation has recently announced its intention to launch a Global Alliance on Clean Cook Stoves this September. That is precisely the type of venue that should be funded -- one that is bringing together leadership across the field to develop a robust strategy to create serious and sustainable solutions on a global scale. This effort will build on existing efforts that have been successful at a smaller scale such as EPA's Partnership for Clean Indoor Air, Shell Foundation's Breathing Space program, GTZ's HERA program, and other leading global efforts.

The financial support must address global infrastructure needs of the field (awareness, financing, standards, etc.), answer priority research needs, leverage high-level diplomatic channels, and focus operationally in a targeted set of markets around the world, in close cooperation with leading stove producers.

Envirofit is one stove producer that has entered the market in the past few years, working in close partnership with (and with substantial funding from) the Shell Foundation. That firm has made some very good innovations, and has plans for many more. Testing to date indicates that Envirofit stoves achieve comparable performance as other leading stoves in the marketplace. Envirofit's sales, while impressive, are also not substantially greater than other leaders in the marketplace. Envirofit should be considered simply one of many emerging leaders in this field. Producers that are making high-quality, mass produceable, aspirational stoves at various price points include: GERES (Cambodia and SE Asia), First Energy (India), Philips (India), StoveTec (global), EnviroFit (India and soon Africa), Worldstove (primarily Africa and Haiti), and HELPS (Central America). In sum, we do not just need Envirofit -- we need a hundred Envirofits or more.

12) Your encouragement of offsets for stove replacement programs raise some troubling questions about who would get the offsets – manufacturers of the stoves? The government of the foreign country? The individuals who purchase the stoves?

Successful stove replacement projects require funding. There are many options for funding stove replacement, of which offsets is one. Cook stove replacement is already eligible for carbon financing under the CDM mechanism and other trading schemes because replacing existing cook stoves with more efficient models reduces carbon dioxide and other greenhouse gases. Adding eligibility for black carbon reductions may or may not add much additional economic incentive. EPA should report on this as part of its Congressionally required black carbon study. But, the question of precisely how such an offset program could best be made to work deserves attention. CATF, in our testimony, assumed that offsets for black carbon projects would be handled in the same way with the same safeguards as the Waxman-Markey bill envisioned for offsets in the bill i.e., with strict assurances of baseline and measurement verification, additionality, permanence, leakage, etc. With respect to the parties who would receive the offsets, we assumed that black carbon offsets would be handled similarly to the other eligible offsets in the bill. As we understand that process, the ultimate holder of the offsets would be the entity regulated under the bill's cap. If this process follows the CDM process, we would expect that aggregators will scour the globe looking for opportunities and providing capital for these projects with participation all the way to the customer/user. These middlemen take on most of the financial risk of the enterprise, and accordingly take a good share of the return.

Public financing provides another model that could help facilitate getting more of the value of the offsets to the stove sellers. The advantage to this is that they in turn could either reduce the price of the stove (which in essence then is a pass-through to the purchaser), use the funds to expand manufacturing operations, invest in building a better kiln, or increase marketing operations (all of which will bring better products to more people). So, in the worst-case scenario, the carbon financier takes all the credit, but the stove project still happens. That is not a bad outcome. In the best case, the value of the credit accrues to the local partners and better facilitates sales and growth. That is an even better outcome. To implement this, we would make the following two policy recommendations:

1. Publicly financing efforts to help stove businesses navigate the carbon financing process, so as to reduce the need for middlemen and help all eligible projects take advantage of this financing tool. This is an important, but not enormous investment (likely several millions of dollars to do well).
2. Publicly funding large revolving loan funds to provide the upfront capital for stove projects that meet certain thresholds (e.g., achieve substantial reductions in black carbon in addition to fuel use). This would entail larger investment (tens of millions of dollars).

13) How much funding do you anticipate a 1% allocation of auction value from an economy wide cap-and-trade bill would generate? Are there other options which may offer a stronger alternative to reduce global warming?

The Clean Air Task Force believes significant reductions in U.S. diesel black carbon will require two things: mandates and money. On the money side, CATF recommends that 1 percent of the full allowance value (not the auction proceeds) of the Waxman-Markey or other comparable cap and trade bill for the first ten years be set aside to fund U.S. diesel black carbon reductions. According to EIA's analysis of the Waxman-Markey bill, one percent of the allowance value of the bill for the first ten years would equal $14.6 billion.

In terms of mandates, The U.S. has adopted standards for new engines that the U.S. EPA estimates will reduce particulate matter and black carbon emissions from diesel 90 percent by the year 2030.[6] However, the current economic downturn has brought the rate of fleet turnover to a standstill and, even if the economy comes roaring back, two decades may be too late to avoid triggering dramatic near-term climate impacts. Both to protect the climate and to continue our leadership in reducing health impacts from particulate matter, the U.S. should expeditiously address emissions from our in-use diesel fleet. EPA should exercise its existing regulatory authority under the Clean Air Act and issue a rule requiring all Class 8 trucks built between 1998 and 2006 (after which the new engine standards took effect) to meet emissions standards commensurate with the installation of a filter whenever their engines are rebuilt.[7] Class 8 trucks, which comprise long-haul tractor-trailer trucks, dump trucks, and transit buses, consume nearly 75 percent of the diesel fuel used by on-road trucks in the U.S. and thus are responsible for a commensurate share of black carbon emissions. M.J. Bradley & Associates has estimated that targeting this fleet of approximately 1 million engines for retrofit could achieve the same climate benefits as removing 21 million cars from the road and would save approximately 7500 lives through reduced particulate matter.[8] But, such a rule would cover only 1 million of the 11 million diesel engines in use today. Congress should expand EPA's regulatory authority to require clean up of all of the existing diesel engines that lack diesel particulate filters.

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[6] EPA (2004) *Final Regulatory Analysis: Control of Emissions from Nonroad Diesel Engines*, EPA420-R-04-007; EPA (2000) *Regulatory Impact Analysis: Heavy-Duty Engine and Vehicle Standards and Highway Diesel Fuel Sulfur Control Requirements*, EPA420-R-00-026.

[7] Clean Air Act Sec. 202(a)(3)(D) [42 U.S.C. Sec. 7521(a)(3)(D)].

[8] See CATF Report: *The Carbon Dioxide-Equivalent Benefits of Reducing Black Carbon Emissions from U.S. Class 8 Class 8 Trucks Using Diesel Particulate Filters: A Preliminary Analysis*. http://www.catf.us/projects/diesel/