Report to Congress on Black Carbon

Department of the Interior, Environment, and Related Agencies Appropriations Act, 2010

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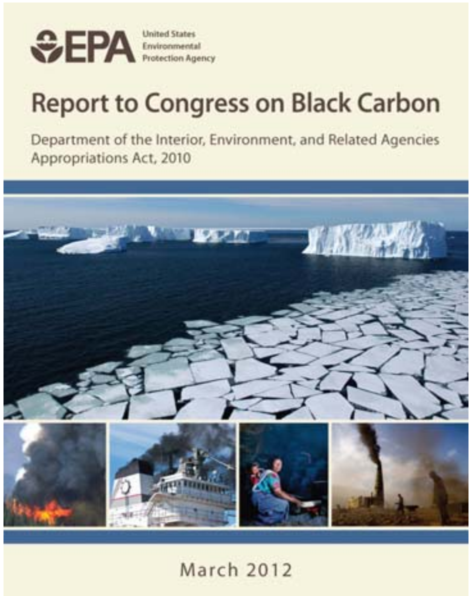
MARAMA Transportation & Air Quality Workshop
February 26, 2013

1

October 2009 Interior Appropriations Bill Requirement

- "Not later than 18 months after the date of enactment of this Act, the Administrator, in consultation with other Federal agencies, shall carry out and submit to Congress the results of a study on domestic and international black carbon emissions that shall include:
  - an inventory of the major sources of black carbon;
  - an assessment of the impacts of black carbon on global and regional climate;
  - an assessment of potential metrics and approaches for quantifying the climatic effects of black carbon emissions (including its radiative forcing and warming effects) and comparing those effects to the effects of carbon dioxide and other greenhouse gases;
  - an identification of the most cost-effective approaches to reduce black carbon emissions; and
  - an analysis of the climatic effects and other environmental and public health benefits of those approaches."

2



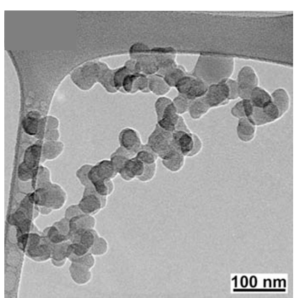
The Report:

- Defines black carbon (BC) and describes its role in climate change.
- Characterizes the full impacts of BC on climate, public health, and the environment based on recent scientific studies.
- Summarizes data on domestic and global BC emissions, ambient concentrations, deposition, and trends.
- Discusses currently available mitigation approaches and technologies for four main sectors:
  - Mobile Sources
  - Stationary Sources
  - Residential Cooking and Heating
  - Open Biomass Burning
- Considers the potential benefits of BC mitigation for climate, public health, and the environment.

Highlights, Executive Summary and Full Report available online at: www.epa.gov/blackcarbon

3

What is Black Carbon?



- Black carbon is the most strongly light-absorbing component of particulate matter (PM).
  - BC is a solid form of mostly pure carbon that absorbs solar radiation (light) at all wavelengths.
- Other types of particles, including sulfates, nitrates and organic carbon (OC), generally reflect light.

- BC is formed by incomplete combustion of fossil fuels, biofuels, and biomass.
- BC is emitted directly into the atmosphere in the form of fine particles (i.e., “direct $PM_{2.5}$”).
- BC is a major component of “soot”, a complex light-absorbing mixture that also contains organic carbon.

4

Climate Effects of Black Carbon

- BC influences climate by:
  - directly absorbing light (⇒ warming)
  - reducing the reflectivity ("albedo") of snow and ice through deposition (⇒ warming)
  - interacting with clouds (⇒ cooling and/or warming)
- BC's climate impacts likely include increased global average temperatures and accelerated ice/snow melt.
  - The direct and snow/ice albedo effects are widely understood to be warming; however, cloud effects are highly uncertain and net impact on climate is unclear.
- Sensitive regions such as the Arctic and the Himalayas are particularly vulnerable to warming/melting effects of BC.
- BC also contributes to surface dimming, the formation of Atmospheric Brown Clouds (ABCs), and changes in the pattern and intensity of precipitation.

5

Health and Environmental Effects of Black Carbon

Brick Kiln in Kathmandu

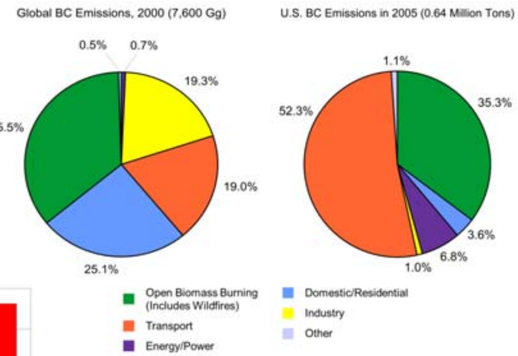
- BC contributes to the adverse impacts on human health, ecosystems, and visibility associated with $PM_{2.5}$.
- Short-term and long-term exposures to $PM_{2.5}$ are associated with a broad range of human health impacts, including respiratory and cardiovascular effects and premature death.
- The World Health Organization (WHO) estimates that indoor smoke from solid fuels is among the top ten major mortality risk factors globally, contributing to approximately 2 million deaths each year (mainly among women and children).
- Ambient particle pollution is also a significant health threat in both developed and developing countries. Emissions and ambient concentrations of directly emitted $PM_{2.5}$ are often highest in urban areas, where large numbers of people live.
- $PM_{2.5}$, including BC, is linked to adverse impacts on ecosystems, to visibility impairment, to reduced agricultural production in some regions, and to materials soiling and damage.

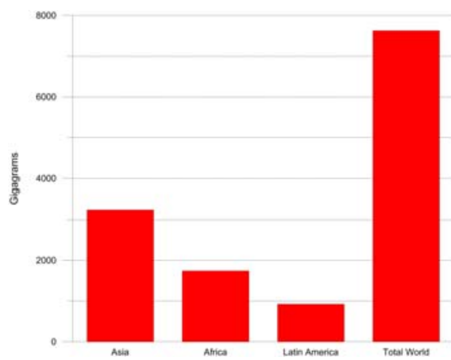
Traditional Cookstove in India

6

Black Carbon Emissions

- U.S. 2005 BC emissions = 640,000 tons, or approximately 12% of all direct $PM_{2.5}$ emissions nationwide.
- Mobile sources are the largest U.S. BC emissions category.
  - Diesel engines and vehicles account for 93% of mobile source BC emissions.





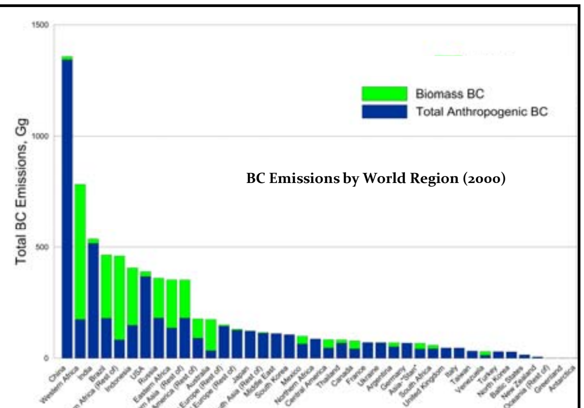
Aggregate BC Emissions in Selected World Regions (2000)

- Globally, the majority (75%) of global BC emissions come from Asia, Africa and Latin America.
- The United States currently accounts for approximately 8% of the global total, and this fraction is declining.
- Emissions patterns and trends across regions, countries and sources vary significantly.

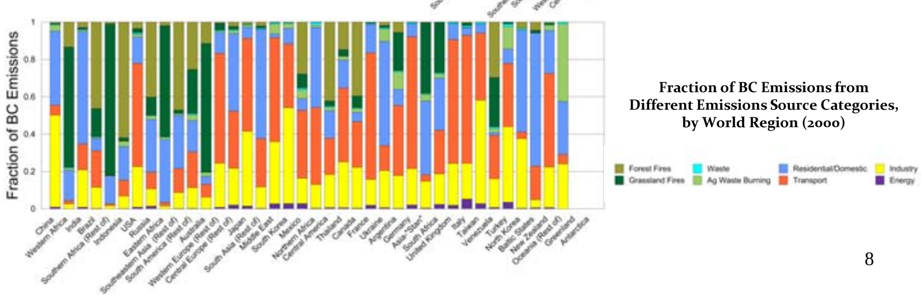
7

Regional Variability in Black Carbon Emissions

- In developing countries, biomass burning and residential sources (i.e., cookstoves) are the dominant sources of BC.
- In developed countries, emissions of BC are dominated by transportation and industry.



BC Emissions by World Region (2000)

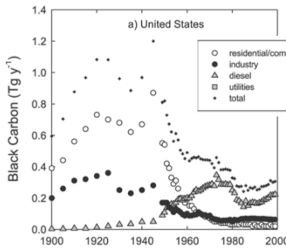


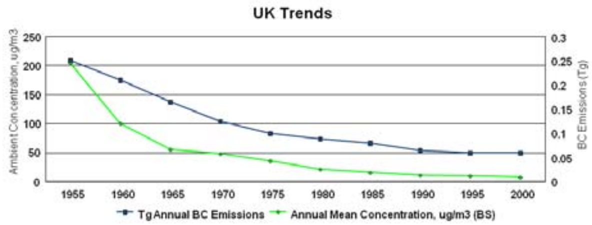
Fraction of BC Emissions from Different Emissions Source Categories, by World Region (2000)

8

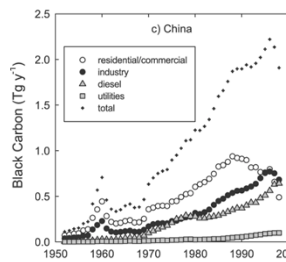
Black Carbon Emissions: Trends

- Long-term historic trends of BC emissions in the United States and other developed countries reveal a steep decline in emissions over the last several decades.
- Ambient BC concentrations have declined as emissions have been reduced.





- Developing countries (e.g., China and India) have shown a very sharp rise in BC emissions over the past 50 years.
- Total global BC emissions are likely to decrease in the future, but developing countries may experience emissions growth in key sectors (transportation, residential).



9

Potential Benefits of BC Mitigation

- Reducing current emissions of BC may help slow the near-term rate of climate change, particularly in sensitive regions such as the Arctic.
- BC's short atmospheric lifetime (days to weeks), combined with its strong warming potential, means that targeted strategies to reduce BC emissions can be expected to provide climate benefits within the next several decades.
- Due to the differences between BC and long-lived GHGs like carbon dioxide (CO_2), it is very difficult to compare them using standardized metrics. Reductions in BC and GHGs are complementary strategies for mitigating climate change.
- The health and environmental benefits of BC reductions are also substantial.
  - Average public health benefits of reducing directly emitted $PM_{2.5}$ in the U.S. are estimated to range from $290,000 to $1.2 million per ton $PM_{2.5}$ in 2030.
  - At the global scale, the $PM_{2.5}$ reductions resulting from BC mitigation measures could potentially result in hundreds of thousands of avoided premature deaths each year.

10

Metrics for Comparing BC to CO_2

- There is currently no single metric that is widely accepted by the science and research community for the purpose of comparing BC and CO_2.
- Choice of metric depends on the policy goal. Factors to consider in selecting a metric include:
  - the time scale (e.g., 20 years, 100 years, or more)
  - the nature of the impact (radiative forcing, temperature, or other damages)
  - the inclusion of different processes (indirect effects, snow/ice albedo changes, co-emissions)
  - whether impacts of concern are regional or global
- If goal is reducing long-term change, then a metric like a 100-year GWP or GTP is most appropriate.
- If goal is also to reduce the rate of change and near-term damages to sensitive regions, no single existing metric adequately weights impacts over both time periods, and a multi-metric approach may be preferred.

11

Mitigating BC: Key Considerations

- Targeted strategies to reduce BC emissions can be expected to provide near-term climate, health and environmental benefits.
- It is important to consider the location and timing of emissions and to account for co-emissions.
  - BC is emitted with other particles and gases (such as sulfur dioxide (SO_2), nitrogen oxides (NO_x), organic carbon (OC) and CO_2), many of which exert a cooling influence on climate. This needs to be considered in selecting mitigation strategies. Reductions in emissions from BC-rich sources (e.g., mobile diesels) have the greatest likelihood of providing climate benefits.
  - Some of the most significant climate benefits of BC-focused control strategies may come from reducing emissions affecting the Arctic, Himalayas and other ice and snow-covered regions.
  - Health benefits depend on how emissions reductions affect human exposure, in terms of both improvements in air quality and the size of the affected population.
- Control technologies are available to reduce BC emissions from a number of source categories. These reductions are generally achieved by improving combustion and/or controlling direct $PM_{2.5}$ emissions from sources.
- Though the costs of such mitigation approaches vary, many reductions can be achieved at reasonable costs. Controls applied to reduce BC will help reduce total $PM_{2.5}$ and other co-pollutants.

12

BC Mitigation Opportunities

United States

- The United States will achieve substantial BC emissions reductions by 2030, largely due to controls on new mobile diesel engines.
  - Diesel retrofit programs for in-use mobile sources are a valuable complement to new engine standards for reducing emissions.
- Other U.S. source categories have more limited mitigation potential due to smaller remaining emissions in these categories, or limits on the availability of effective BC control strategies. These include:
  - stationary sources (industrial, commercial and institutional boilers, stationary diesel engines, uncontrolled coal-fired EGUs)
  - residential wood combustion (hydronic heaters and woodstoves)
  - open biomass burning



Global

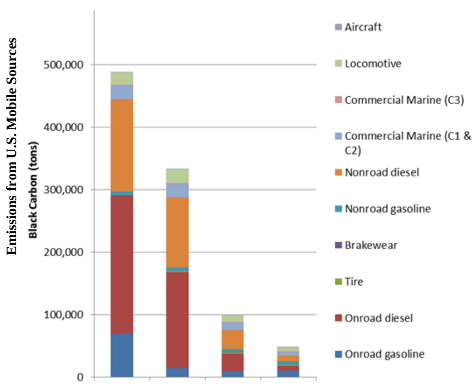
- The most important BC emissions reduction opportunities globally include:
  - residential cookstoves in all regions
  - brick kilns and coke ovens in Asia
  - mobile diesels in all regions
- A variety of other opportunities may exist in individual countries or regions.
- Other developed countries have emissions patterns and control programs that are similar to the United States, though the timing of planned emissions reductions may vary.
- Developing countries have a higher concentration of emissions in the residential and industrial sectors, but number of mobile sources increasing rapidly.

Sensitive Regions

- Arctic: transportation sector (land-based diesel engines and Arctic shipping); residential heating (wood-fired stoves and boilers); and forest, grassland and agricultural burning.
- Himalayas: residential cooking; industrial sources (especially coal-fired brick kilns); and transportation, primarily on-road and off-road diesel engines.

13

Mobile Sources



United States

- BC emissions from mobile diesel engines (including on-road, non road, locomotive, and commercial marine engines) controlled via:
  - Emissions standards for new engines, including requirements resulting in use of diesel particulate filters (DPFs) in conjunction with ultra low sulfur diesel fuel.
  - Retrofit programs for in-use mobile diesel engines, such as EPA's National Clean Diesel Campaign and the SmartWay Transport Partnership Program.
- Total U.S. mobile source BC emissions are projected to decline by 86% by 2030 due to regulations already promulgated.
  - EPA has estimated the cost of controlling $PM_{2.5}$ from new diesel engines at ~ $14,000/ton (2010$).

Global

- New engine standards and retrofits can both help reduce BC emissions.
  - Many other countries have already begun phasing in emissions and fuel standards.
- Mobile source BC emissions in developing countries are expected to continue to increase. Emissions control requirements lag behind in some regions, as does deployment of diesel particulate filters (DPFs) and low sulfur fuels.
  - Reducing BC will depend on accelerated deployment of clean engines and fuels.

14

Conclusions

- Mitigation of BC offers a clear opportunity: continued reductions in BC emissions can provide significant near-term benefits for climate, public health, and the environment.
- Effective control technologies and approaches are available to reduce BC emissions from a number of key source categories.
  - These approaches could be utilized to achieve further BC reductions in the United States and globally.
  - BC mitigation solutions vary significantly by region, and must be adapted based on the specific needs and implementation challenges faced by individual countries.
- Achieving further BC reductions, both domestically and globally, will require adding a specific focus on reducing direct $PM_{2.5}$ emissions to overarching fine particle control programs.
  - BC reductions that have occurred to date are mainly due to control programs aimed at $PM_{2.5}$ (especially secondarily formed $PM_{2.5}$), not targeted efforts to reduce BC per se.
  - Greater attention to BC-focused strategies has the potential to help protect the climate while ensuring continued improvements in public health.
- The options identified in this report for reducing BC emissions are consistent with control opportunities emphasized in other recent assessments. These represent important mitigation opportunities for key world regions, including the United States.

15

Bounding the role of black carbon in climate: A scientific assessment

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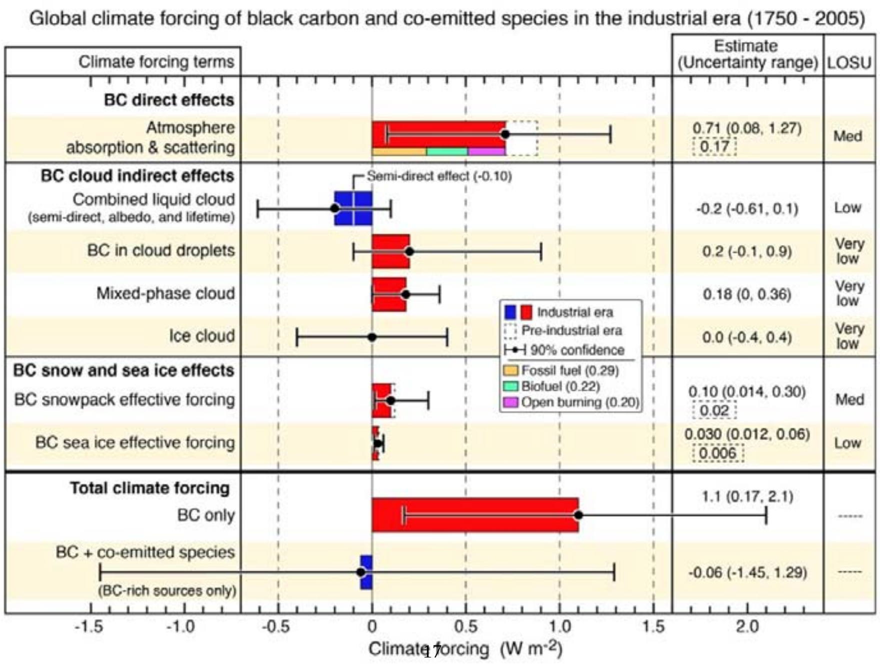
Accepted for publication January 2013
Journal of Geophysical Research – Atmospheres

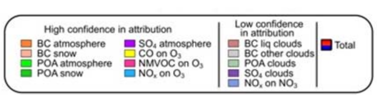


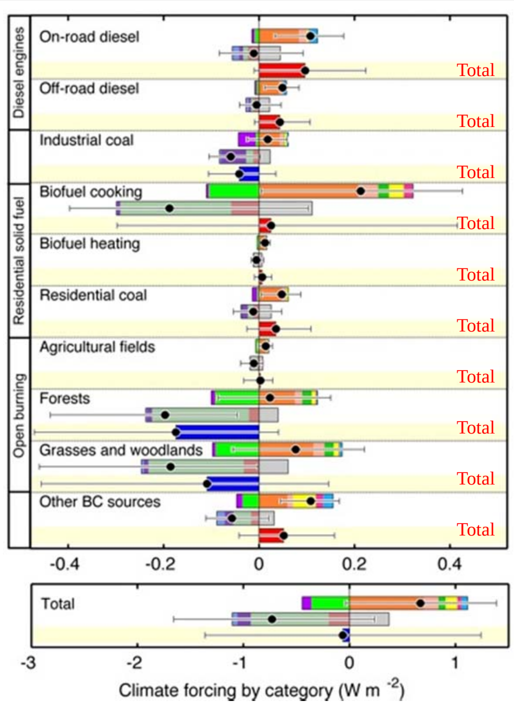
17

Analysis for BC-rich source categories

Short-lived species only

- Some categories are net positive (red)
- Some are net negative (blue)
- Some are uncertain– sign unknown





18