DIESEL TECHNOLOGY FORUM

Climate Change, Black Carbon & Clean Diesel

January 2014

Introduction: Over the last few years there has been increasing interest in global warming and emissions of carbon dioxide and the role of short-lived climate agents including black carbon. Scientific and policymaking communities have concluded that black carbon plays a role in climate change by heating our planet and altering precipitation patterns. Diesel engines have been identified as one of the many global sources of black carbon emissions. Today the U.S. is estimated to account for about five percent of all black carbon emissions, and is expected to account for only two percent of global on-road vehicle emissions by 2020. This remarkable progress is as a result of new clean diesel technology that includes changes in domestic fuel composition along with advances in engine design and emissions control technology.

Particulate matter (black carbon) emissions have been essentially eliminated from new diesel engines in on-road vehicles as well as off-road equipment in the U.S. Regulations in place for heavy-duty truck engines beginning in model year 2007 and further tightened rules for model year 2010 engines have required a 98 percent reduction in particulate matter emissions – a leading contributor to black carbon. These clean diesel advances in the U.S. have been recognized by other countries, who are expanding the introduction of clean diesel technologies in part to reduce black carbon emissions, and by the United Nations Environment Programme which is advocating their adoption in countries around the world.

This paper provides a basic understanding of black carbon, its sources, occurrence and trends in the U.S. and on a global basis. It highlights the small and declining role of diesel engines as sources of black carbon, and provides a greater perspective about the technical and policy issues of black carbon and climate change.

What is black carbon? Black carbon, often equated with elemental carbon, is a component of particulate matter, or soot, produced from the incomplete combustion of fossil fuel, biofuels and biomass.

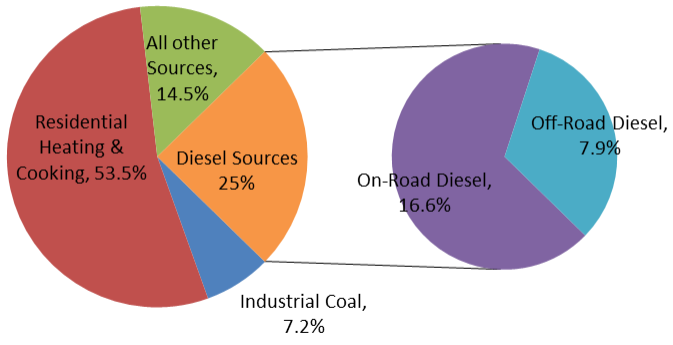

Figure 1: Global Sources of Black Carbon

Source: Black Carbon Report to Congress. U.S. EPA. March 2012. http://www.epa.gov/airquality/blackcarbon/

What are the primary sources of black carbon? The main sources of black carbon are open burning of biomass including residential burning of solid fuels such as coal, wood, dung and agricultural residue; fossil fuel combustion for transportation; and industrial activities. Globally, diesel engines account for 25 percent of all black carbon emissions. In the U.S, the transportation sector accounts for roughly 53 percent of black carbon emissions and diesel engines account for over 90 percent of the transportation sector's share.[i]

What is the geographic distribution of black carbon emissions on a global basis? East Asia, predominantly China, is the largest aggregate source of global black carbon emissions, with the greatest amount of emissions coming from the residential and industrial sectors.[ii] The U.S. produces approximately five percent of the world's fossil-fuel and biofuel soot.[iii]

What effect is black carbon believed to have on climate change? Black carbon is thought by many scientists to have a net warming effect on the earth by absorbing light and turning that energy into heat. It also is believed to darken the surfaces of ice and snow when deposited on them, reducing their ability to reflect light while increasing heat absorption and melting. Black carbon also plays a role in climate change by altering precipitation patterns and cloud formation.

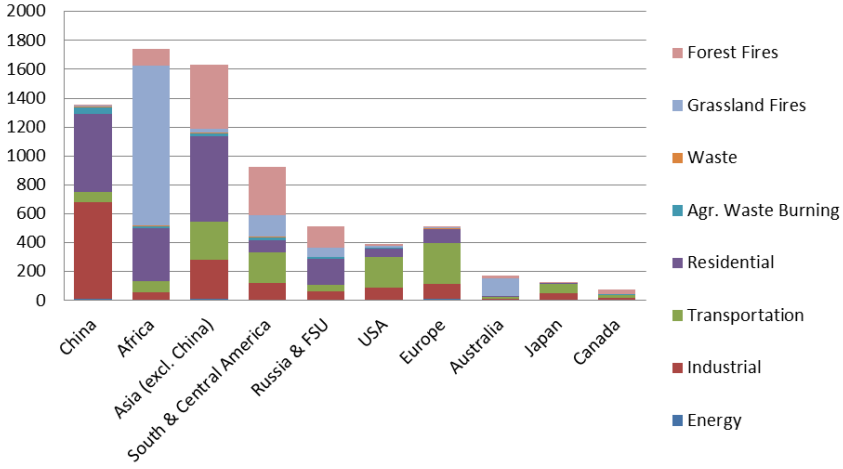

Figure 2: Global Black Carbon Emissions[v]

How does black carbon compare to CO_2? Unlike CO_2 which remains in the atmosphere for decades, black carbon remains in the atmosphere for days or weeks and washes out of the atmosphere within a few thousand kilometers of its emission source. Particular concern has been raised about the Arctic, where melting of ice and snow has been accelerated by deposition of wind-blown soot particles. While studies continue to determine the most likely sources affecting the Arctic, the latest research suggests that biomass burning, particularly from Eurasia, is the dominant source of black carbon in Arctic snow.[iv]

Are U.S. black carbon emissions rising or falling? U.S. transportation-related black carbon emissions are projected to decline by almost 70 percent between 2005 and 2030.[v] This impressive emissions reduction is achieved by technologies designed to meet regulations already promulgated concerning particulate matter emissions on heavy-duty trucks and off-road equipment such as construction, agricultural and mining equipment.

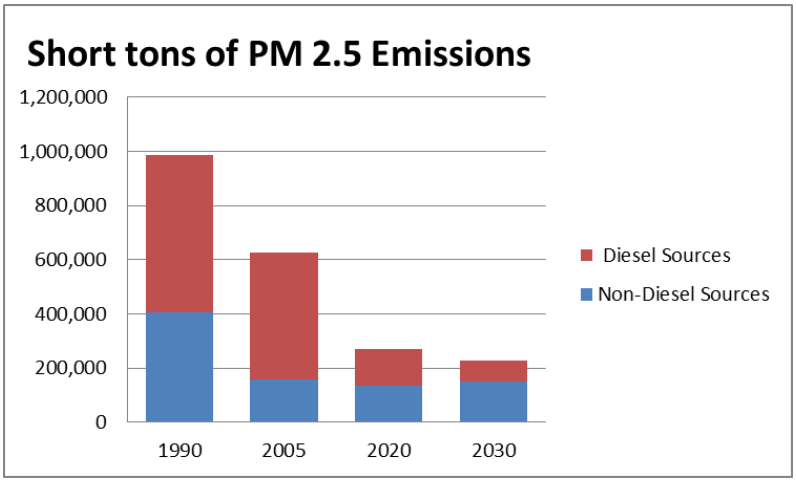

Figure 3: U.S. Emission of PM 2.5

"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."
- Report to Congress on Black Carbon (2012) U.S. EPA

How does clean diesel technology reduce black carbon? Thanks to the use of ultra-low sulfur diesel (ULSD) fuel, more efficient engines and more effective emissions control technologies, new U.S. clean diesel trucks and buses have significantly lower particulate matter emissions and 99 percent less black carbon emissions than those manufactured before 2004.[vi] Today's new diesel cars and trucks have advanced filters that trap particulate matter.

The latest clean diesel technology is also now standard in most new off-road diesel engines and equipment such as construction machines, agricultural vehicles, stationary generators, locomotives and marine vessels. These strict emissions standards for particulate matter emissions are known as Tier 4 requirements. In addition, many older versions of these vehicles and machines can be retrofitted to trap or reduce particulate matter emissions anywhere from 20-90 percent.

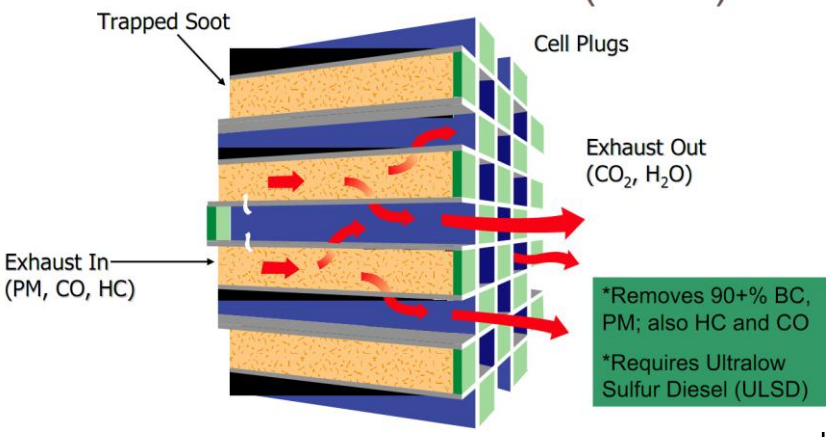

Figure 4: Schematic of Diesel Particulate Filter Substrate

What has the U.S. done to reduce its black carbon emissions form diesel sources? Over the last decade, EPA has promulgated several new emissions standards for diesel fuel and diesel engines including the introduction of ultra-low sulfur diesel (ULSD) fuel in 2006, the on-highway diesel rule for model year 2007 and 2010 trucks, and Tier 4 rules for most off-road equipment have already been implemented.

In addition to regulations for new diesel engines, EPA provides grant funding through the National Clean Diesel Funding Assistance Program to help reduce emissions from existing diesel engines through a variety of strategies. Clean diesel funding appropriated between 2008 and 2010 retrofitted, repowered or replaced over 52,000 older engines found on a wide variety of applications from school buses, long haul trucks, construction equipment and even ferryboats. Diesel particulate filters were among the most popular technology choice among vehicle and equipment. Retrofit funding provided between 2008 and 2010 resulted in over 12,000 tons of particulate matter emissions eliminated.[vii]

Other funds for retrofitting existing diesel vehicles are available through the Federal Highway Administration's Congestion Mitigation and Air Quality program, national and state supplemental environmental projects and several state government sponsored programs.

Have other countries adopted similar measures to reduce black carbon emissions from diesel sources? The impressive and dramatic reduction in black carbon from diesel sources in the U.S. has not gone unnoticed by other countries. Most developed economies including Europe, Canada and Japan adopted low sulfur diesel fuel standards along with diesel engine emission rules. The United Nation's Environment Programme is encouraging developing economies to introduce clean diesel technologies. The first step in the process of introducing clean diesel technologies rests on the availability of low sulfur diesel fuel and the group is working to encourage the production and distribution of low sulfur diesel fuel with a sulfur content of at most 50 parts per million in many developing economies.

"If California's black carbon reduction from diesel can be replicated globally, the projected global warming for the coming decades can be mitigated by about 10 to 15 percent, slow down glacier melt and sea ice retreat in addition to protecting lives and crops."
-Prof. Veerabhadran Ramanathan. Distinguished Professor, Scripps Institution of Oceanography, University of California at San Diego; UNESCO Professor

Remarks before the India California Air Mitigation Pollution (ICAMP) Meeting. October 22, 2013. Oakland CA.

Other nations with clean fuel standards have adopted modern engine emissions standards – either U.S. or European Union rules – including Argentine, Brazil, Mexico, Chile, Peru, India, Korea, Singapore, Thailand, Russia and Turkey. Yet, diesel emissions are smaller sources of black carbon in these emerging economies than other sources including biomass burning for heat, cooking and industrial processes. The United Nations is working to introduce technologies and change practices to reduce these sources of black carbon through cleaner cookstoves and industrial kilns.

Can black carbon emission reductions mitigate climate change? Black carbon is known to play a role in global warming and climate change and the reduction of black carbon may help reduce the impact of a warming planet. The United Nations estimates that efforts to control all sources of black carbon emissions may ease the rise in global temperatures by .5 degree Celsius. Global warming mitigation through black carbon reduction is regional with the largest temperature reduction occurring in the Artic, Antarctic and Himalayan regions. The World Bank estimates that roughly 16 million tons of crop losses can be reversed due to global controls on diesel source of black carbon.[viii]

In the U.S., the state of California implemented measures to control black carbon emissions since the 1960s. Researchers estimate that diesel particulate matter emission reductions achieved in California since the 1980s is equivalent to reducing carbon emissions by 21 million metric tons and is roughly equivalent to five percent of all carbon dioxide emissions.[ix]

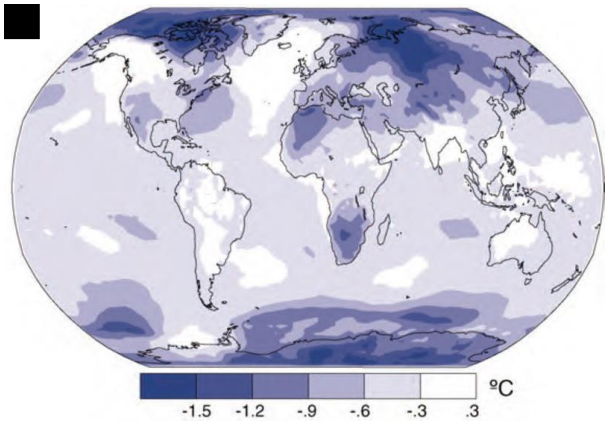

Figure 5: Regional Temperature Reductions from Black Carbon. *Source: On Thin Ice: How Cutting Pollution and Save Slow Warming and Save Lives. The World Bank. October 2013.* *http://www.unep.org/ccac/Portals/50162/docs/on_thin_ice.pdf*

Summary

The introduction of clean ULSD fuel and advanced engine emissions control systems and filters is well on the way to virtually eliminate particulate and black carbon emissions from new diesel engines in all categories.

Today, the U.S. is estimated to account for about five percent of all black carbon emissions, and as a result, is expected to account for only two percent of global on-road vehicle emissions by 2020 as a result of these technology improvements. Modernizing and upgrading existing diesel engines with particulate control technology has proven effective for many applications with the use of clean diesel fuel.

For more information visit:
www.dieselforum.org
http://www.epa.gov/airquality/blackcarbon/
www.unep.org/ccac

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[i] Black Carbon Report to Congress. U.S. EPA. March 2012. http://www.epa.gov/airquality/blackcarbon/
[ii] Black Carbon Report to Congress. U.S. EPA. March 2012.
[iii] Ibid
[iv] Ibid
[v] Ibid
[vi] Coordinating Research Council, *Phase 2 of the Advanced Collaborative Emissions Study*, Alpharetta, GA, November 2013. http://www.crcao.org/reports/recentstudies2013/ACES%20Ph2/03-17124_CRC%20ACES%20Phase2-%20FINAL%20Report_Khalek-R6-SwRI.pdf
[vii] Second Report to Congress: Highlights of the Diesel Emission Reduction Program. U.S. EPA. March 2013. http://www.epa.gov/cleandiesel/documents/420r12031.pdf
[viii] On Thin Ice: How Cutting Pollution and Save Slow Warming and Save Lives. The World Bank. October 2013. http://www.unep.org/ccac/Portals/50162/docs/on_thin_ice.pdf
[ix] India California Air Pollution Mitigation Program: Inception Note. October 2013. http://www-ramanathan.ucsd.edu/about/oaklandworkshop.php