Soot-Free Urban Bus Fleets

Ray Minjares, Clean Air Program Lead

Achieving Clean Bus Fleets: International Seminar
5 October 2015
Johannesburg, South Africa

THE INTERNATIONAL COUNCIL ON CLEAN TRANSPORTATION

Key Topics

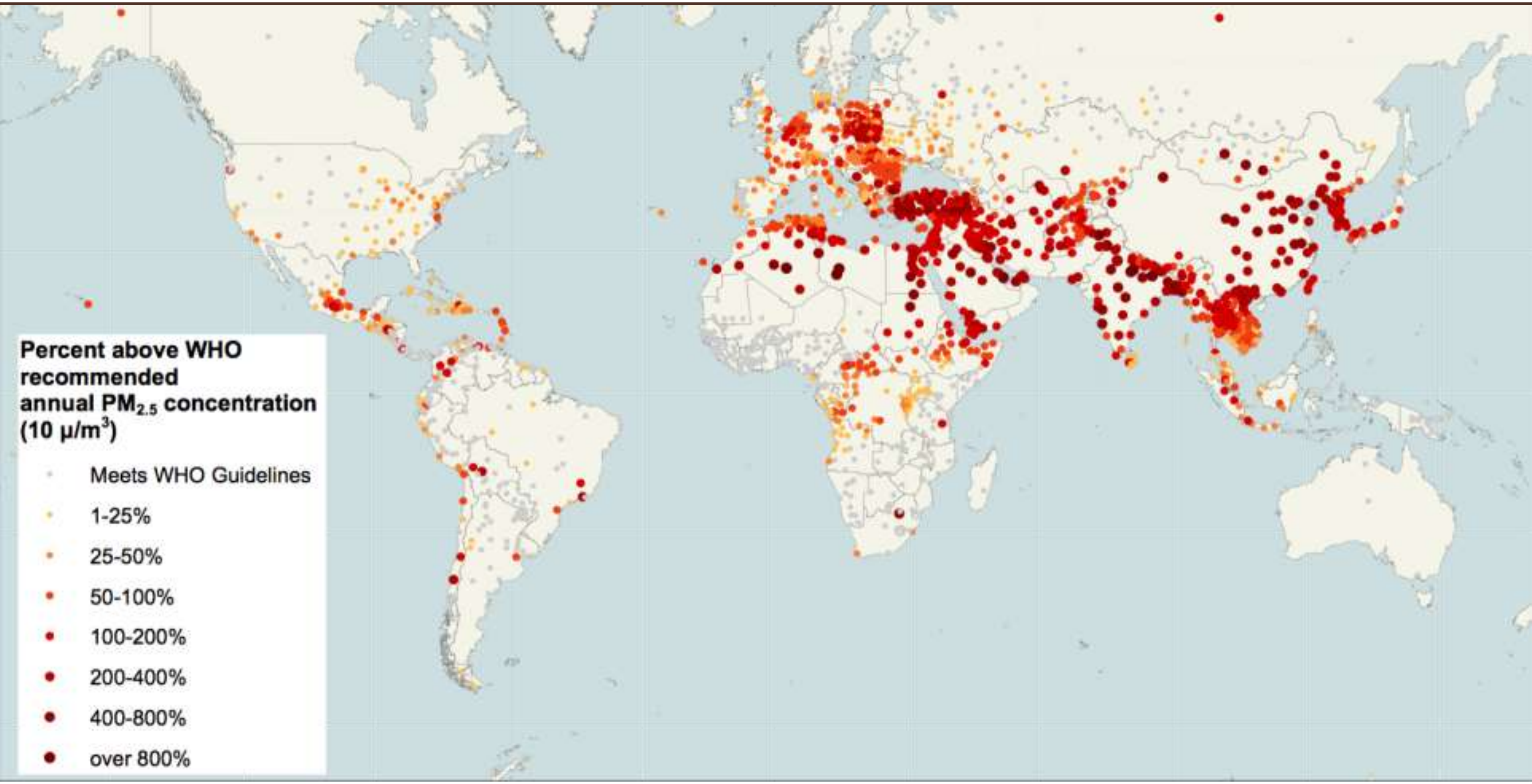
- Climate and health impacts of diesel bus fleets
- Cost-effective strategies to nearly eliminate diesel soot
- How cities can shift to soot-free bus fleets
- The magnitude of benefits that cities can realize from cleaner fleets

icct
THE INTERNATIONAL COUNCIL ON CLEAN TRANSPORTATION

Soot-Free Urban Buses Fleets

The Problem

Global Air Quality: 2010

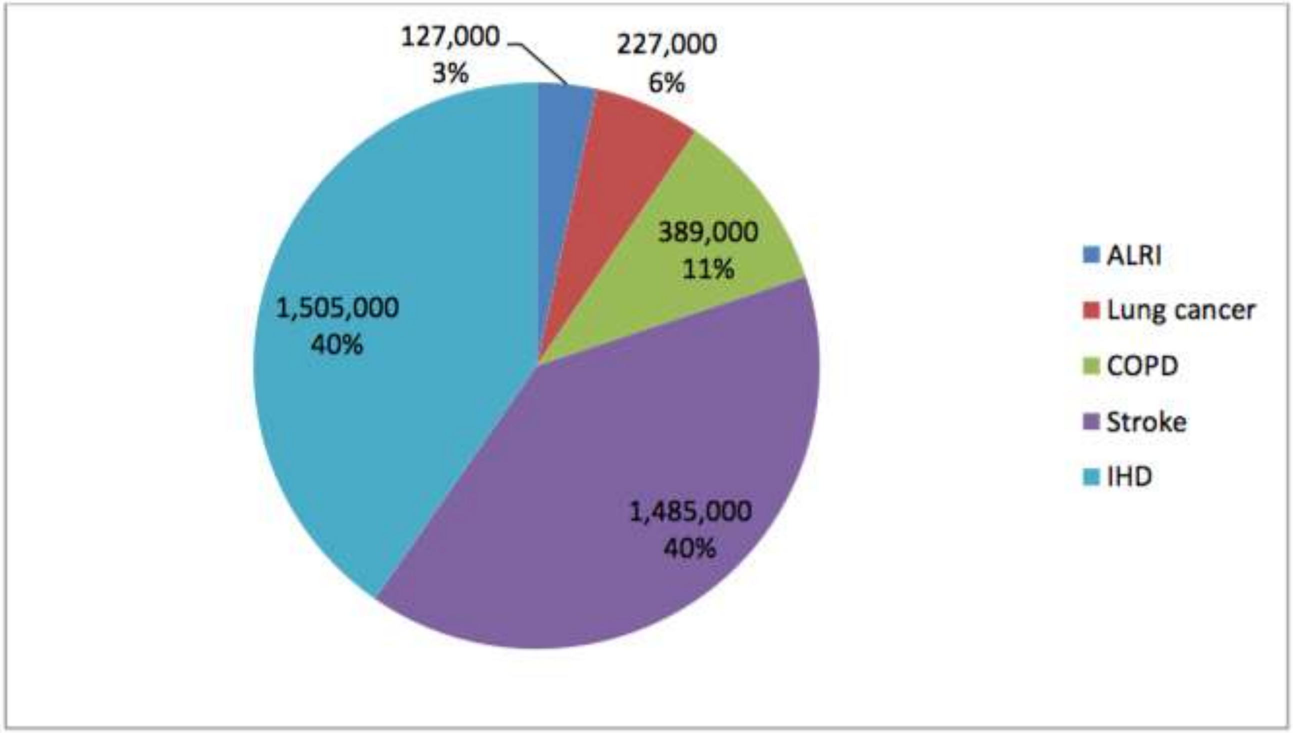


Adapted from Brauer, M., Amann, M., Burnett, R. T., Cohen, A. J., Dentener, F., Ezzati, M., et al. (2012). Exposure Assessment for Estimation of the Global Burden of Disease Attributable to Outdoor Air Pollution. Environmental Science and Technology, 46(2), 652–660. doi:10.1021/es2025752

icct

3.7 million deaths from ambient air pollution in 2012

***Figure 3**. Deaths attributable to AAP in 2012, by disease*



icct WHO (2014). Ambient (outdoor) and household (indoor) air pollution global and regional burden of disease data. Annual Review of Public Health. Geneva, Switzerland: World Health Organization.

Diesel Engines are a Key Target

"The scientific evidence was compelling and the Working Group's conclusion was unanimous: diesel engine exhaust causes lung cancer in humans."

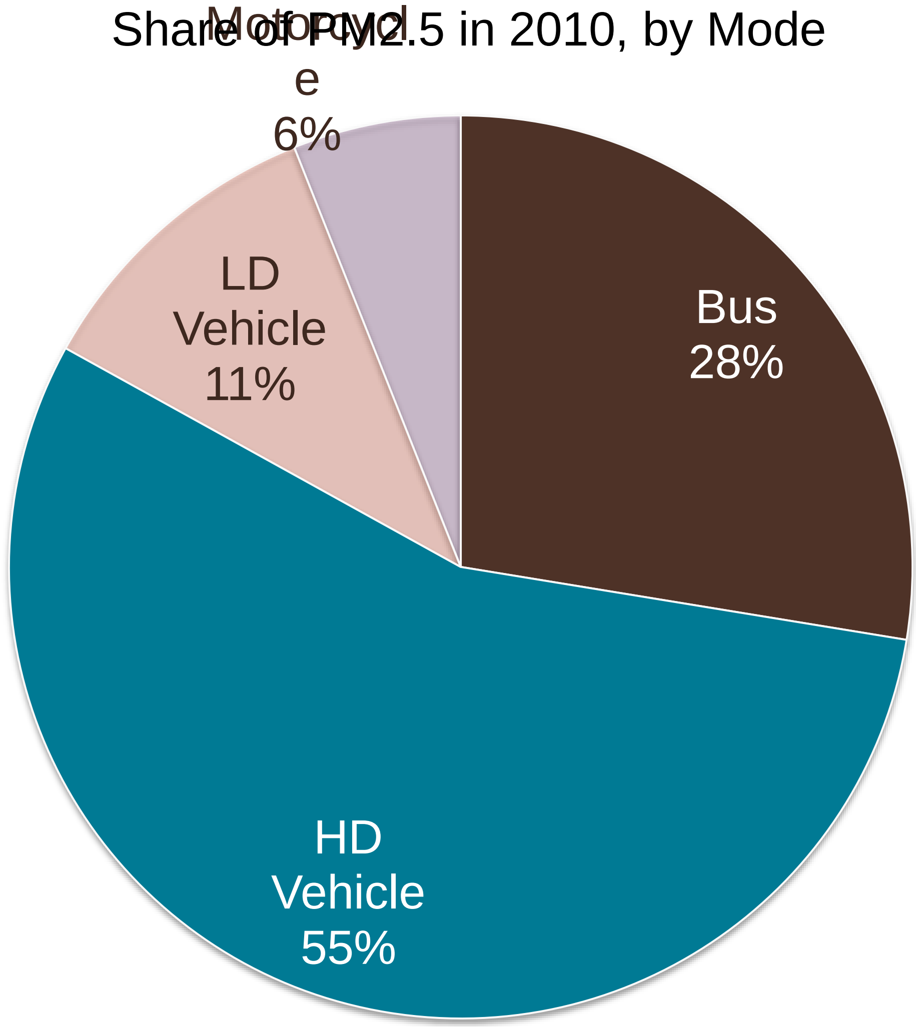
-Dr. Christopher Portier

International Agency for Research on Cancer

World Health Organization

International Agency for Research on Cancer. (2012, June 12). IARC: Diesel Engine Exhaust Carcinogenic. JNCI Journal of the National Cancer Institute. Lyon, France: World Health Organization. doi:10.1093/jnci/djs034

Diesel engines are more than 80% of transport-related PM2.5



Chambliss, S., Miller, J., Facanha, C., Minjares, R., & Blumberg, K. (2013). The Impact of Stringent Fuel and Vehicle Standards on Premature Mortality and Emissions (pp. 1–96). Washington, DC: International Council on Clean Transportation. Retrieved from http://www.theicct.org/global-health-roadmap

Diesel PM2.5 consists mostly of black carbon

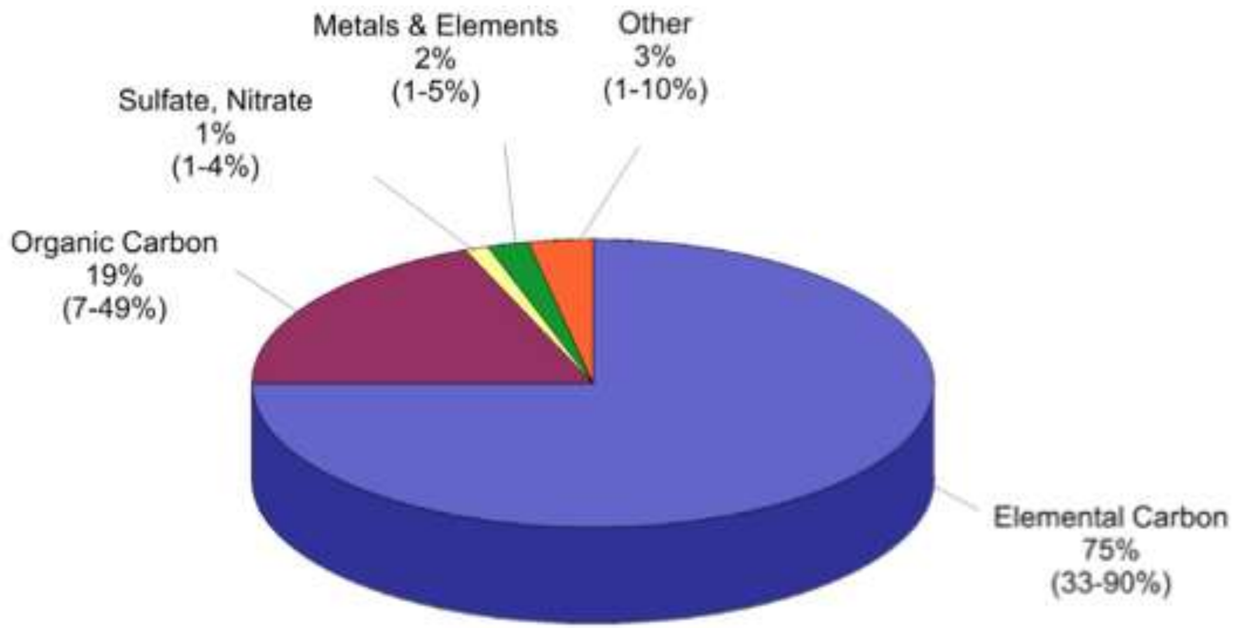
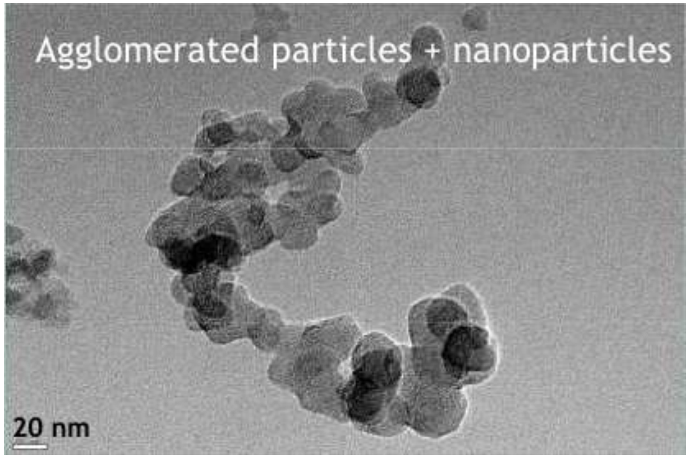


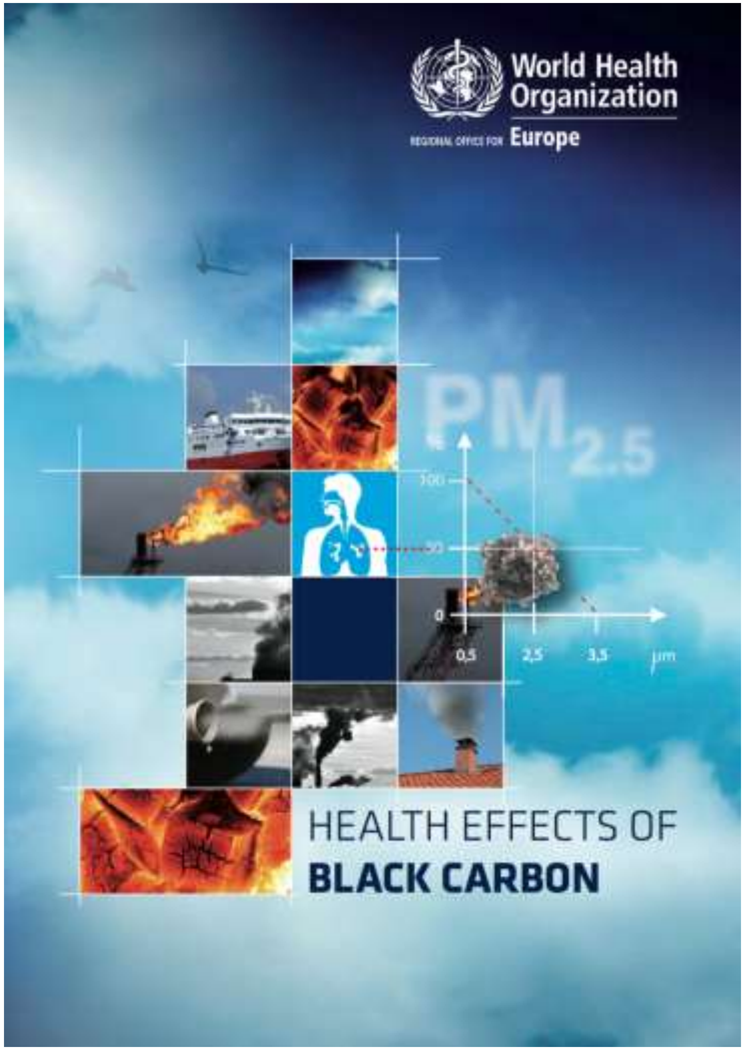
Figure 4-2. Heavy-Duty Diesel $PM_{2.5}$ Emissions Profile.
(Source: U.S. EPA, 2002b)

Sasser, E., & Hemby, J. (2012). *Report to Congress on Black Carbon* (No. EPA-450/R-12-001) (pp. 1–388). US Environmental Protection Agency. Retrieved from http://www.epa.gov/blackcarbon/

What is black carbon?



WHO Report on Health Impacts of Black Carbon (2012)



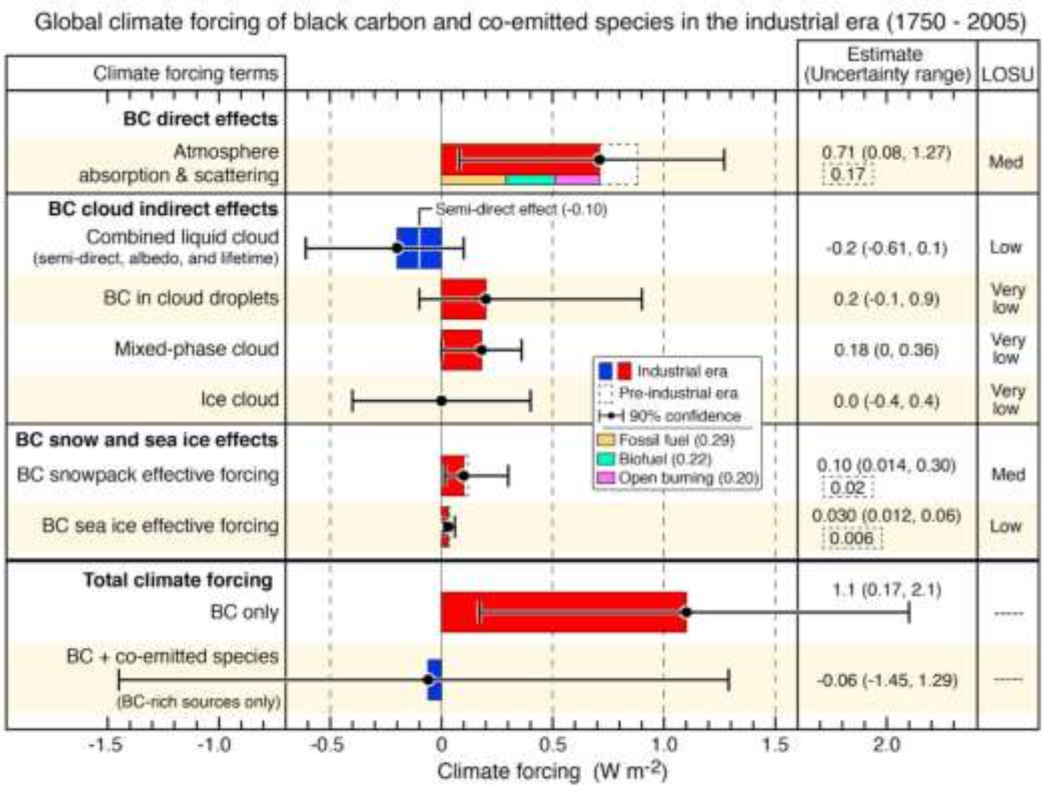
"**BC may** not be a major directly toxic component of fine PM, but it may **operate as a universal carrier of a wide variety of chemicals of varying toxicity..**"

"…removing particulates with a modern diesel particle trap …resulted in a complete absence of cardiovascular effects."

icct THE INTERNATIONAL COUNCIL ON Clean Transportation

Janssen, N. A. H., Gerlofs-Nijland, M. E., Lanki, T., Salonen, R. O., Cassee, F., Hoek, G., et al. (2012). Health Effects of Black Carbon (pp. 1–96). Copenhagen: World Health Organization.

Bounding the Role of Black Carbon in the Climate System (Bond et al, 2013)



"We estimate that **black carbon,** with a total climate forcing of +1.1 W m², is the **second most important human emission in terms of its climate forcing** in the present-day atmosphere"

"**Diesel sources of BC appear to offer the most promising mitigation opportunities** in terms of near-term forcing and maturity of technology and delivery programs."

icct THE INTERNATIONAL COUNCIL ON CLEAN TRANSPORTATION

Bond, T. C., Doherty, S. J., Fahey, D. W., Forster, P. M., Berntsen, T. K., DeAngelo, B. J., et al. (2013). Bounding the role of black carbon in the climate system: A scientific assessment. Journal of Geophysical Research-Atmospheres. doi:10.1002/jgrd.50171

Climate Impacts of Global Road Transport

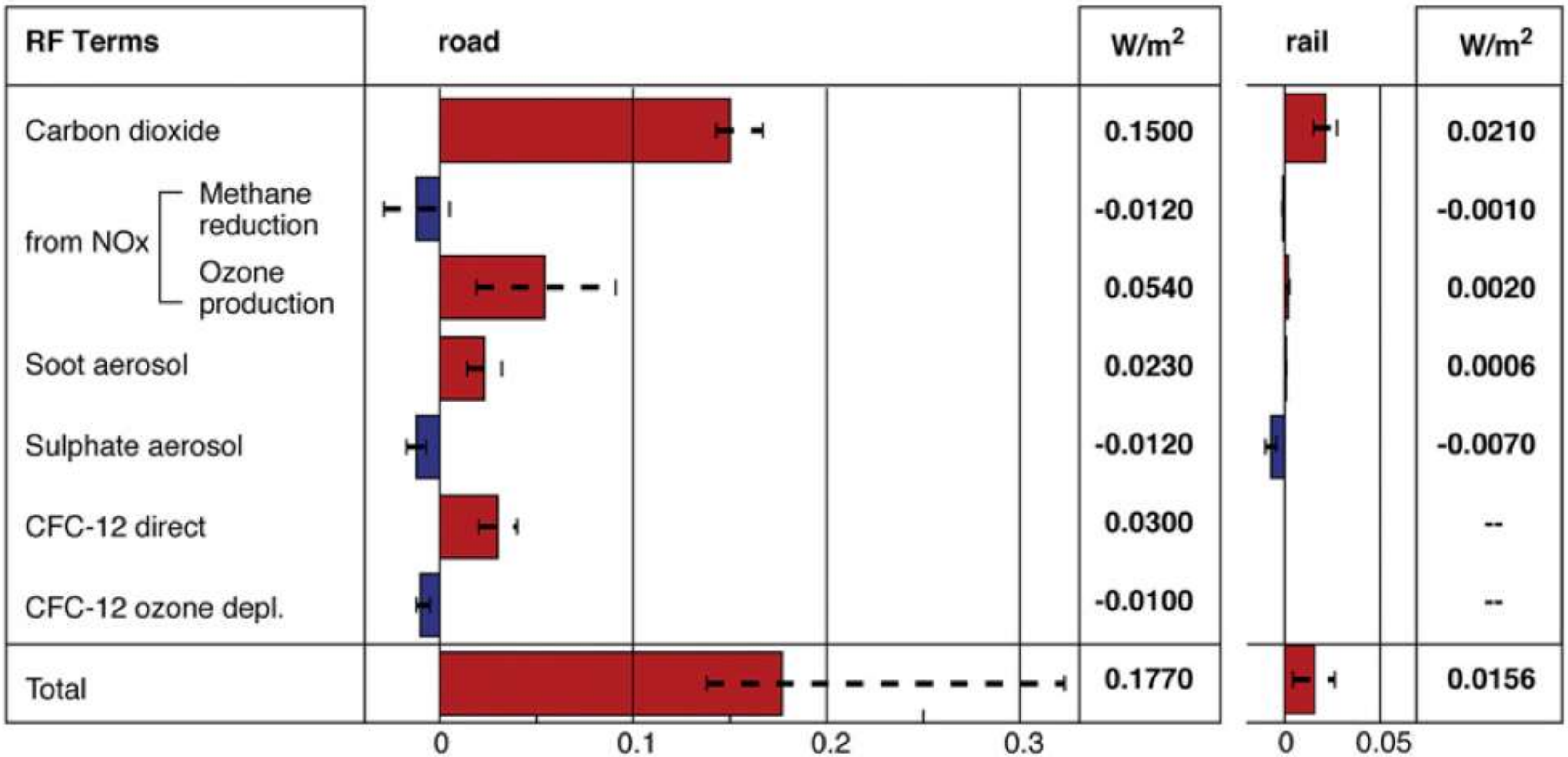


Fig. 16. Radiative forcing for road and rail transport in 2000.

Uherek, E., Halenka, T., Borken-Kleefeld, J., Balkanski, Y., Berntsen, T. K., Borrego, C., et al. (2010). Transport impacts on atmosphere and climate: Land transport. *Atmospheric Environment*, *44*(37), 4772–4816.

Mechanisms for Black Carbon Warming Impacts

Atmospheric Heating

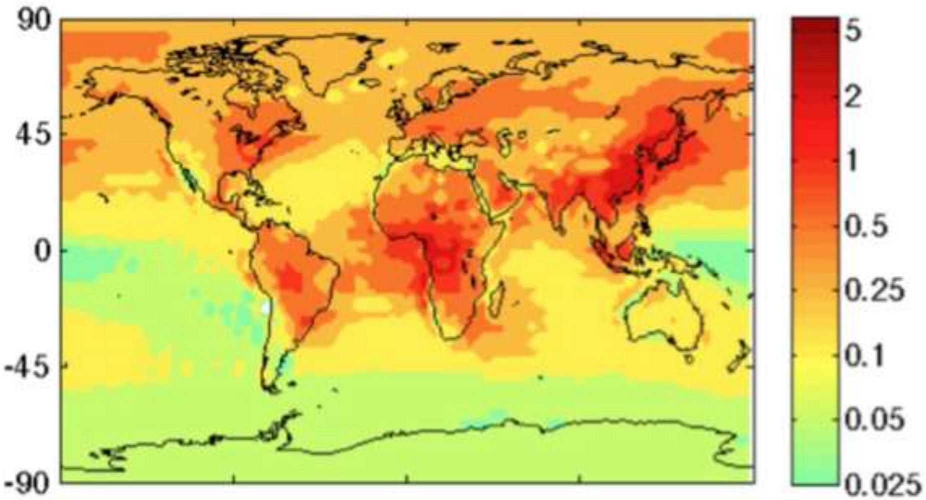


Figure 2-13. Direct Radiative Forcing (W m^{-2}) of BC from All Sources, simulated with the Community Atmosphere Model. (Bond et al., 2011)

Snow and Ice Darkening

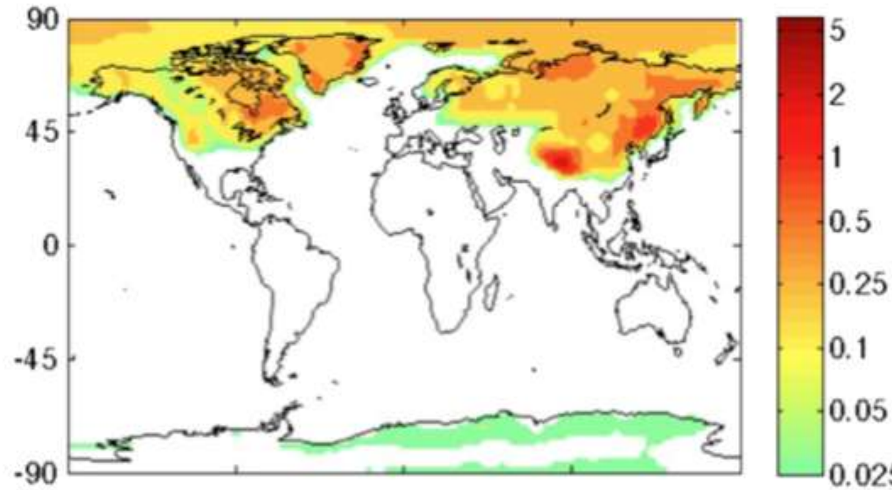
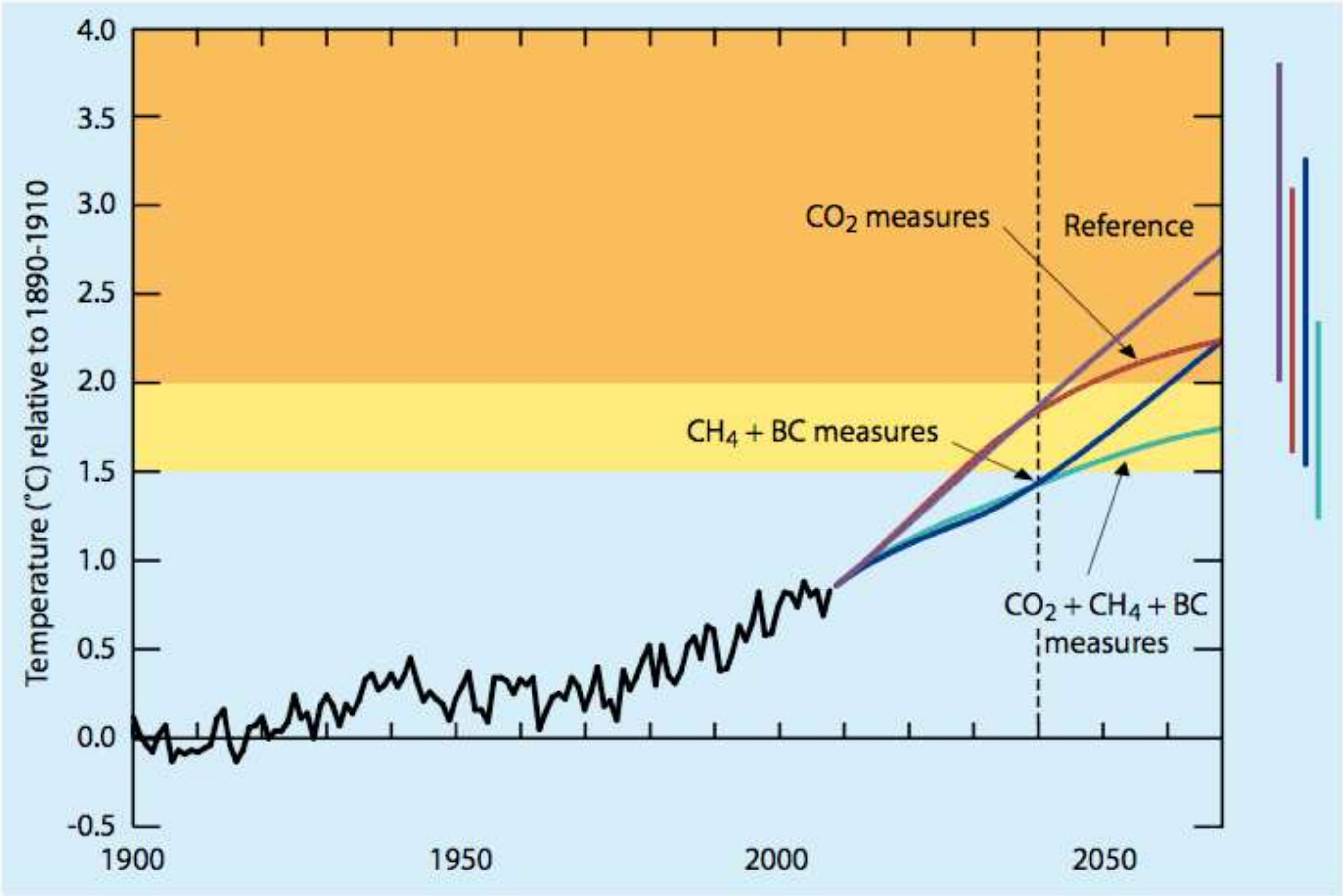


Figure 2-15. Snow and Ice Albedo Forcing by BC, simulated with the Community Atmosphere Model. (Bond et al., 2011)

Sasser, E., & Hemby, J. (2012). Report to Congress on Black Carbon (No. EPA-450/R-12-001) (pp. 1–388). US Environmental Protection Agency. Retrieved from http://www.epa.gov/blackcarbon/

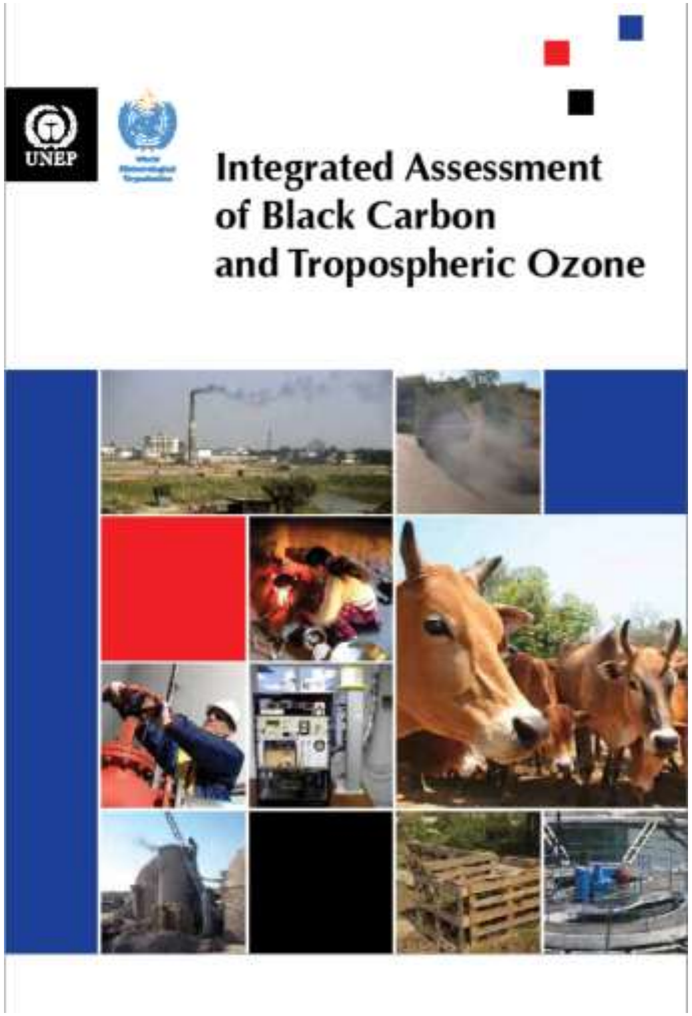
How does the climate respond to black carbon emissions?

BC Control Supports Climate Change Mitigation Goals



Shindell, D., Ramanathan, V., Raes, F., Cifuentes, L., & Kim Oanh, N. T. (2011). *Integrated assessment of black carbon and tropospheric ozone* (pp. 1–285). Nairobi: UNEP and WMO. Retrieved from http://www.unep.org/dewa/Assessments/Ecosystems/ClimateChange/tabid/7002/Default.aspx

UNEP Integrated Assessment of Black Carbon and Tropospheric Ozone (Shindell et al, 2011)



Diesel BC measures among 16 total measures to reduce radiative forcing from short-lived substances

1. Diesel particulate filters as part of a Euro 6/VI package for road and off-road diesel vehicles
2. Elimination of high-emitting vehicles in on-road and off-road transport

icct THE INTERNATIONAL COUNCIL ON Clean Transportation

Shindell, D., Ramanathan, V., Raes, F., Cifuentes, L., & Kim Oanh, N. T. (2011). Integrated assessment of black carbon and tropospheric ozone (pp. 1–285). Nairobi: UNEP and WMO. Retrieved from http://www.unep.org/dewa/Assessments/Ecosystems/ClimateChange/tabid/7002/Defa

Climate and Clean Air Coalition Established: Adopts Heavy-Duty Diesel Initiative (2012)

Diesel BC Activities

- Global Fuel Sulfur Strategy
- Technical support to Mexico, China and Indonesia
- Soot-Free Urban Bus Project
- Low-Sulfur Fuels in Western and Southern Africa
- Green Freight Project

CCAC
CLIMATE AND CLEAN AIR COALITION
TO REDUCE SHORT-LIVED CLIMATE POLLUTANTS

icct
THE INTERNATIONAL COUNCIL ON CLEAN TRANSPORTATION

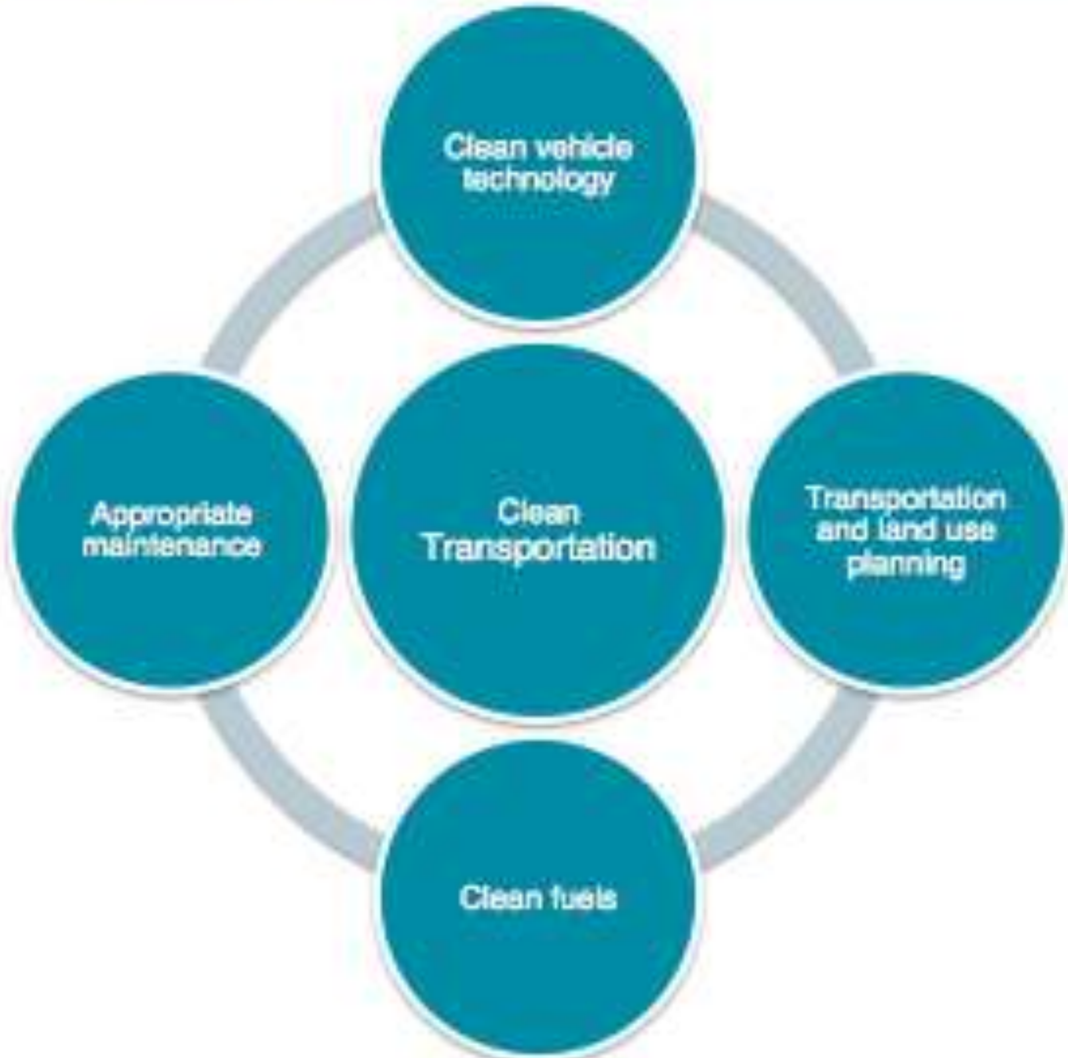
http://www.ccacoalition.org

Soot-Free Urban Bus Fleets

The Solution

THE INTERNATIONAL COUNCIL ON CLEAN TRANSPORTATION

Elements of a comprehensive vehicle pollution control strategy



Fuels and Vehicles Act as a Single System

Diesel particulate filter

50 ppm sulfur is necessary for diesel filters to function ….

10-15ppm sulfur is necessary for them to work well

Technology Shift Towards Emissions Control

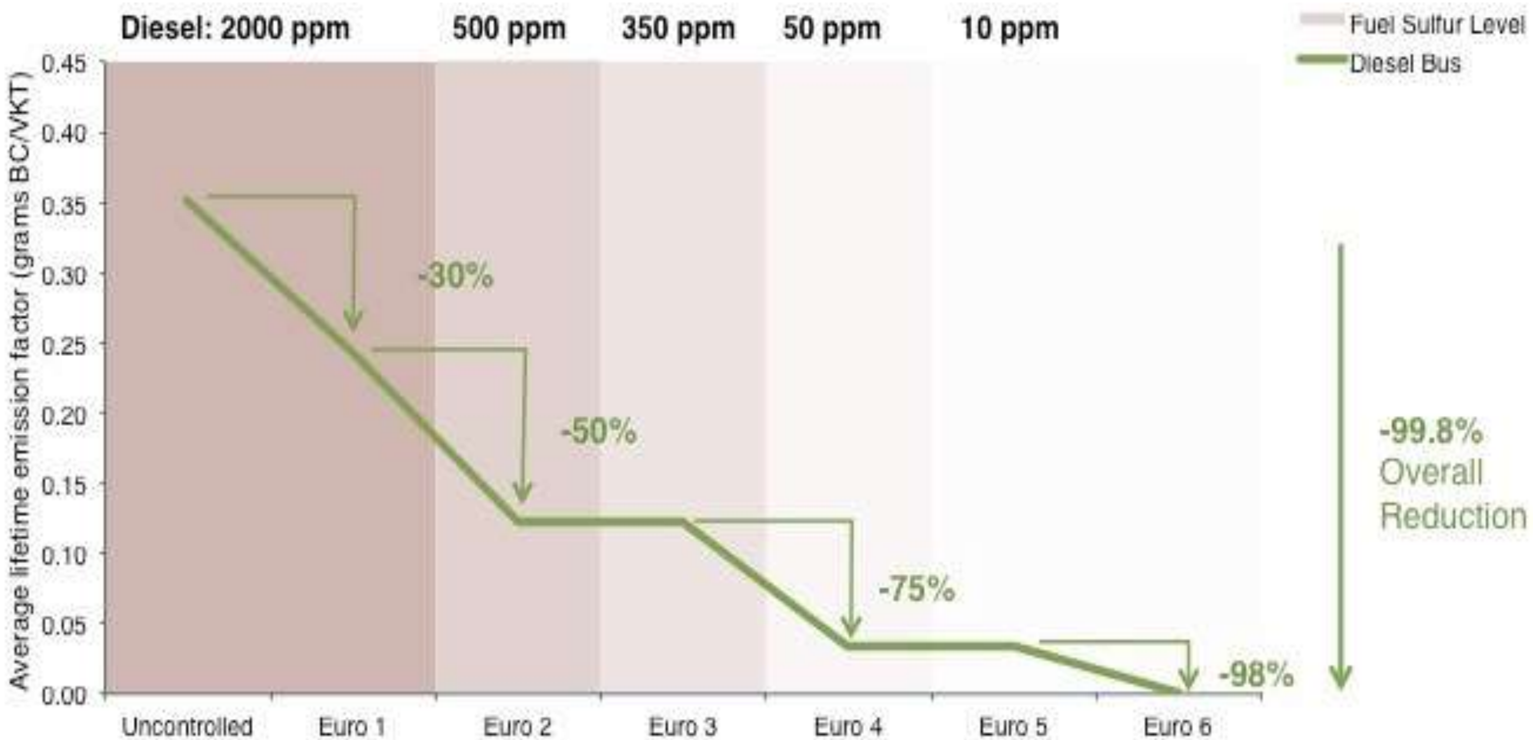
Overview: The exhibits above are actual PM collection samples from an engine testing laboratory used to collect and measure diesel particulate matter (PM) emissions. Test conditions are:

- Test Cycle: UDDS (Urban Dynamometer Driving Schedule)
- Test Distance: 5.5 miles over 17 minutes
- Fuel Consumed During Test: 1.1 gallons
- Test Vehicle: Heavy-duty truck with a 370 hp Cummins engine (1999 model year)
- PM material on collection samples is 1/1,800th of actual

Courtesy of ClearAire, Inc.

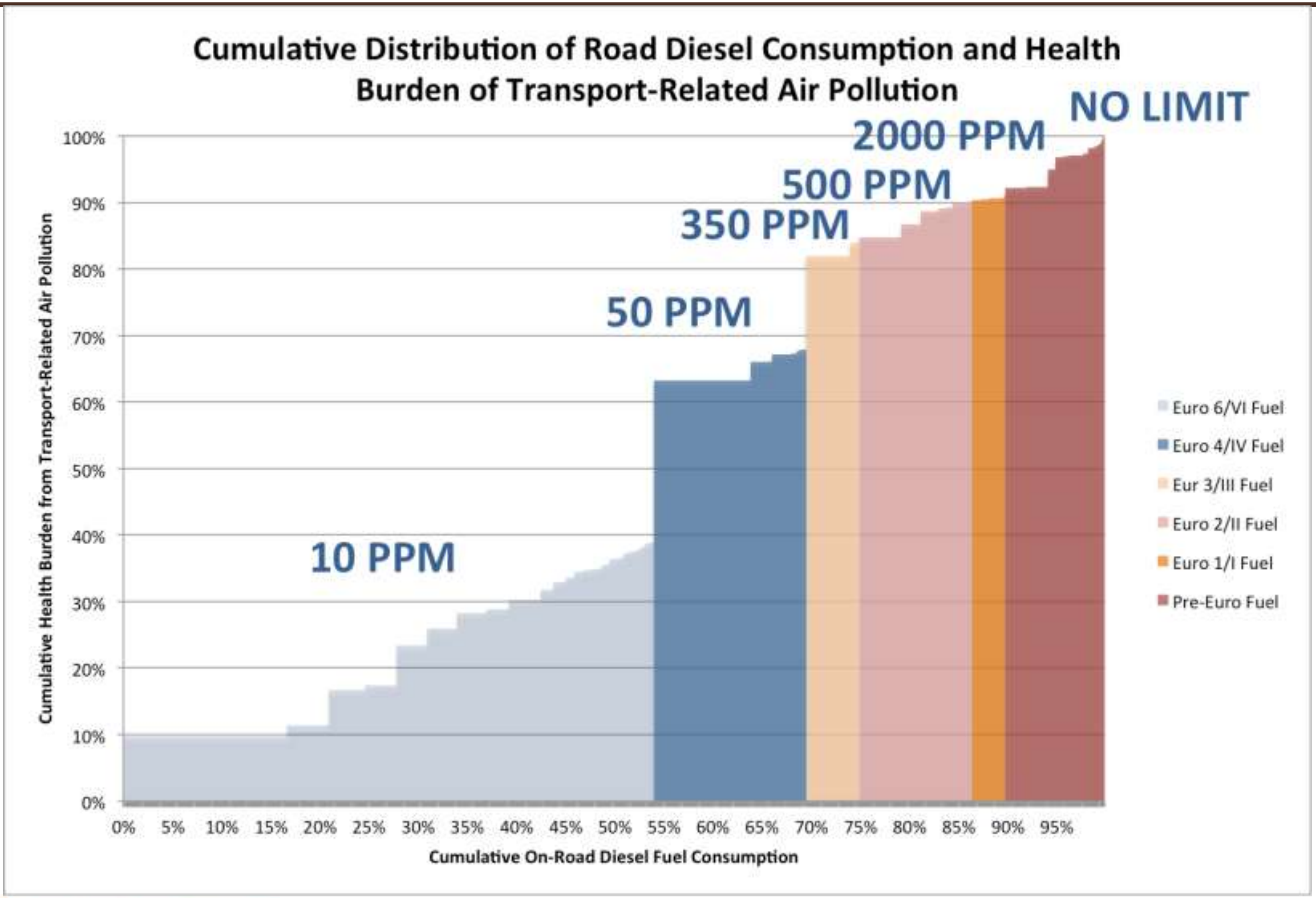
Urban Bus Fleets: Theory of Change

Stages of Black Carbon Emissions Control Based on European Regulatory Approach to Urban Bus Fleets



Source: COPERT Emissions Model

Status of Low-Sulphur Fuels in 2015



Costs of Euro 6/VI Fuels in other countries

	Total Investments (USD)	Per liter costs: Gasoline	Per liter costs: Diesel
China	**$6.9 billion**	**0.66-0.78¢**	**1.42-1.83¢**
Mexico	**$3.3 billion**	**1.10-1.40¢**	**2.50-3.20¢**
Brazil	**$6.3 billion**	**1.64-1.96¢**	**1.55-1.96¢**
India	**$4.1 billion**	**0.70-0.87¢**	**0.64-0.88¢**

50% of G-20 Nations Have Require Soot-Free Diesel Engines Equal to Euro VI

Region	Total Vehicle Sales in 2014	Emission standards		Fuel sulfur standards	
		Light-duty	Heavy-duty	Gasoline	Diesel
China	23,491,893	China 4[a]	China IV	10 [2017]	10 [2017]
EU	16,841,973	Euro 6	Euro VI	10	10
US	14,935,563	Tier 3 [2017]	US 2010	10 [2017]	15
Japan[b]	5,562,887	PNLTES	PNLTES [2016]	10	10
Brazil[c]	3,498,012	L-6	P-7	50	500 (10)[d]
Germany	3,356,718	Euro 6	Euro VI	10	10
India	3,176,763	Bharat III[e]	Bharat III[e]	150 (50)	350 (50)
UK	2,843,025	Euro 6	Euro VI	10	10
Russia	2,545,666	Euro 5 [2016]	Euro V [2016]	10 [2016]	10 [2016]
France	2,210,927	Euro 6	Euro VI	10	10
Canada	1,889,437	Tier 2[f]	US 2010	30[g]	15
South Korea	1,730,322	Euro 6	Euro VI	10	10
Italy	1,492,642	Euro 6	Euro VI	10	10
Indonesia[h]	1,208,019	Euro 2	Euro II	500	3500 (avg.), (500)
Mexico	1,176,305	Tier 1 / Euro 4	US 2004/Euro IV	80 (30)	500 (15)
Australia[j]	1,113,224	Euro 6 [2018]	Euro V/US07/JE05	50	10
Saudi Arabia	828,200	Euro 2	Euro II		500[k]
Turkey	807,331	Euro 5	Euro VI	10	10
South Africa[l]	644,504	Euro 2	Euro II	500 (50)	500 (50)
Argentina[m]	613,848	Euro 5	Euro V	150	30 (10) [2016]
Total G-20	**80,063,947**				
Total World	**88,164,642**				
G-20 Share	**90.8%**				

Euro-equivalent[n]

No standard	Euro 2/II	Euro 3/III	Euro 4/IV	Euro 5/V	Euro 6/VI	Post Euro 6/VI

Kodjak, D., 2015. POLICIES TO REDUCE FUEL CONSUMPTION, AIR POLLUTION, AND CARBON EMISSIONS FROM VEHICLES IN G20 NATIONS. pp.1–28.

Soot-Free Urban Buses Fleets

The Action

Implementers of the CCAC Soot-Free Urban Bus Fleets Project

icct
THE INTERNATIONAL COUNCIL ON CLEAN TRANSPORTATION

UNEP
United Nations Environment Programme
environment for development

C40CITIES
CLIMATE LEADERSHIP GROUP

Centro Mario Molina Chile

20 Target Cities

	Name	Country	CCAC Member	2014 Population	Annual $PM_{2.5}$ ($\mu g/m^3$)	Euro emissions stage
Tier 1 Cities (immediate potential for soot-free engines)						
1	Mexico City	Mexico	Yes	22,200,000		IV
2	Sao Paulo	Brazil	No	21,700,000	19	V
3	Buenos Aires	Argentina	No	15,700,000	16	IV
4	Istanbul	Turkey	No	14,000,000	32	V
5	Sydney*	Australia	Yes	4,775,000	5	V
6	Santiago	Chile	Yes	6,600,000	26	V
Tier 2 Cities (immediate potential for Euro IV; fuel shift required for Tier 1 status)						
7	Manila	Philippines	No	22,500,000	22	II
8	Bangkok	Thailand	No	14,900,000	20	III
9	Lima	Peru	Yes	9,800,000	38	III
10	Bogotá	Colombia	Yes	9,150,000	27	IV
11	Dar es Salaam	Tanzania	No	5,000,000		none
12	Johannesburg	South Africa	No	8,750,000	51	III
13	Nairobi	Kenya	No	4,950,000		import restriction
14	Casablanca	Morocco	Yes	4,200,000		none
Tier 3 Cities (fuel shift required to for Tier 1 or Tier 2 status)						
15	Jakarta	Indonesia	No	27,000,000	21	II
16	Dhaka	Bangladesh	Yes	16,700,000		I
17	Lagos	Nigeria	Yes	13,500,000		import restriction
18	Abidjan	Côte d'Ivoire	Yes	4,900,000		none
19	Accra	Ghana	Yes	4,400,000	49	none
20	Addis Ababa	Ethiopia	Yes	3,325,000		none

*Incremental costs related to Sydney's participation would be covered by Australia and not by the CCAC Trust Fund

icct
THE INTERNATIONAL COUNCIL ON CLEAN TRANSPORTATION

Project Strategy

20 Target cities (> 3m pop)	CCAC HDDI support	New Commitments	Implementation	Final outcomes
Tier 1 cities: **Access to Euro VI fuels**	Active engagement through a web presence, meetings and workshops to: • Provide technical information and advice • Pool requirements and connect to industry stakeholders • Connect to financing opportunities • Build a global picture and track progress	Shift new bus purchases to soot-free engines within 3 years	6 early committers receive implementation support	Pathway to soot-free engines in all 20 target cities
Tier 2 cities: Access to Euro IV fuels		Shift new bus purchases to Euro IV, Euro III+DPF, or Euro V within 3 years; adopt timeline for Tier 1 status + soot free engines		
Tier 3 cities: No access to Euro VI or IV fuels		Within 3 years set target date for Tier 1 status		

Core Project Activities

Inform, motivate, and secure a **public commitment** from city officials to shift to cleaner buses

Provide **implementation support** at the request of committed cities and guided by an agreed upon work plan

Establish an industry partnership with a private **sector coalition of clean bus manufacturers and suppliers**

Collect and report data needed to monitor and evaluate progress in this sector

icct
THE INTERNATIONAL COUNCIL ON CLEAN TRANSPORTATION

Steps for City Officials to Pursue Soot-Free Urban Bus Fleets

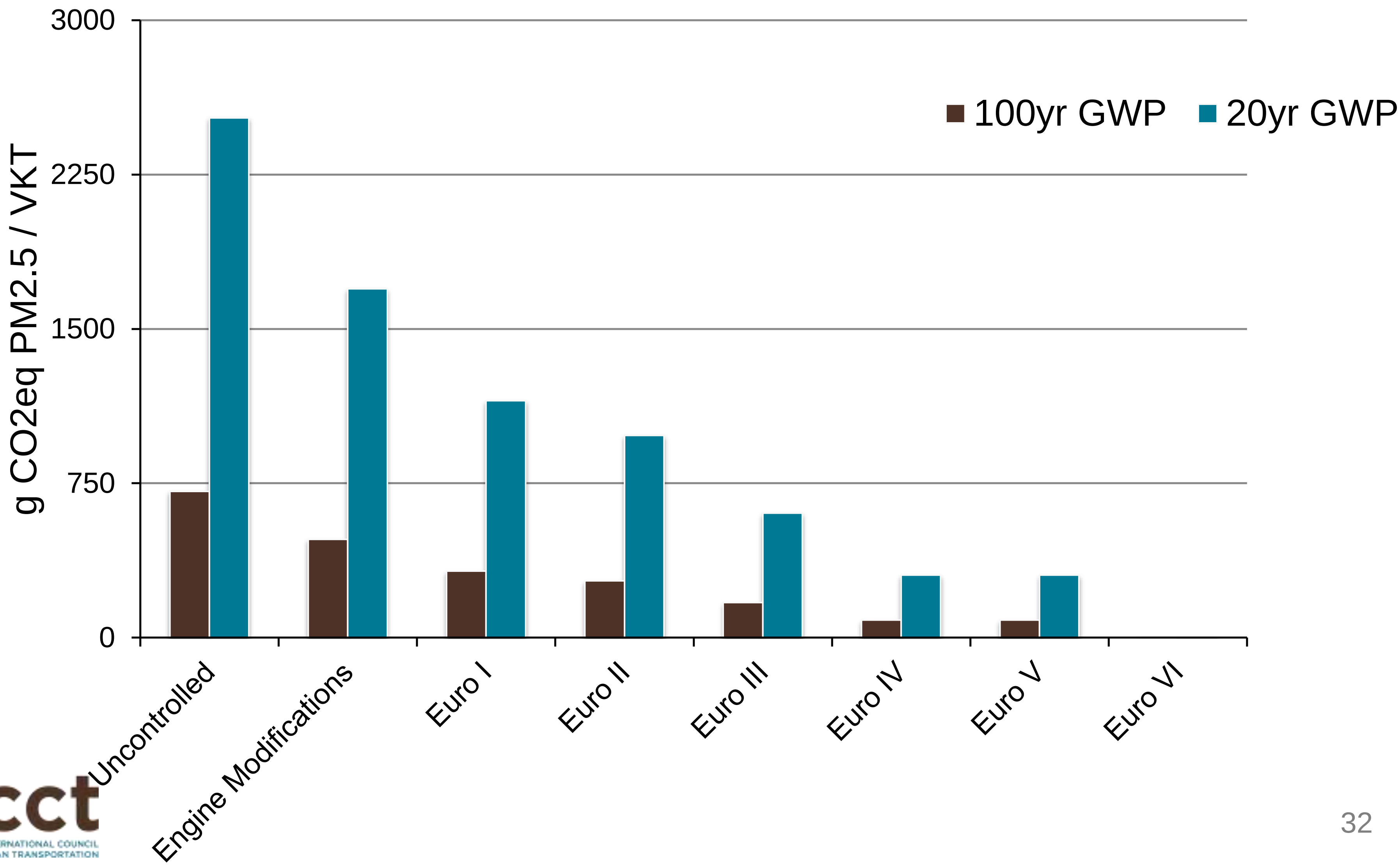
1. **Identify existing procurement requirements** for emissions p
2. **Make a public commitment** to procure soot-free urban buses
3. **Implement your commitment** to soot-free urban buses. Seek
4. **Share your data** with CCAC partners in order to measure and

THE INTERNATIONAL COUNCIL ON CLEAN TRANSPORTATION

Soot-Free Urban Buses Fleets

The Benefits

Climate Impacts of Diesel Soot from Urban Buses falls with Emission Controls



ICCT
THE INTERNATIONAL COUNCIL ON CLEAN TRANSPORTATION

Nearly 4,000 early deaths could be avoided from soot-free urban bus fleets in 20 target cities

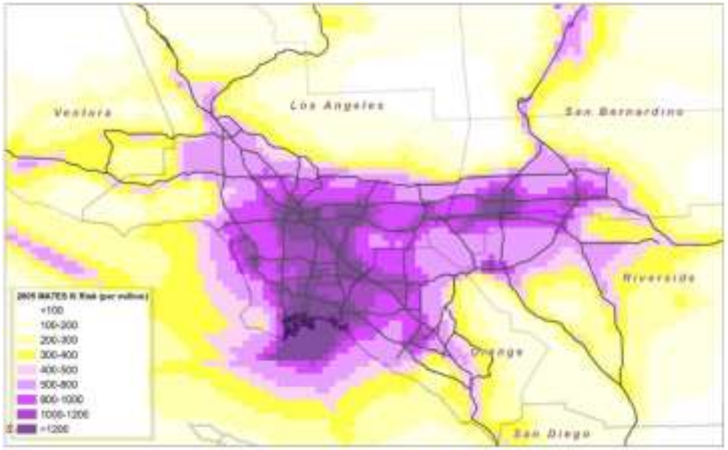
Preliminary estimate of benefits from a shift to soot-free urban bus fleets in 20 target cities in 2030

Category	BC Reduction (Kt)	Climate Benefit (MMT)		Early Deaths Avoided
		GWP-20	GWP-100	
Tier 1 Cities	0.27	0.87	0.23	1,100
Tier 2 Cities	0.96	3.02	0.80	1,300
Tier 3 Cities	0.85	2.66	0.70	1,390
Total	2.09	6.56	1.73	3,700

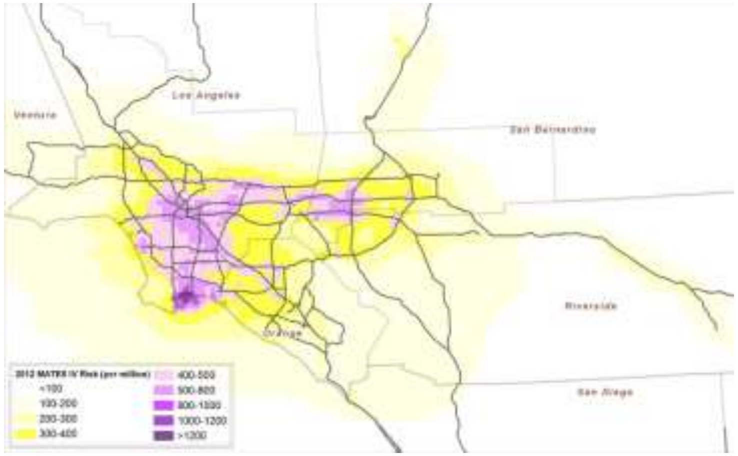
icct
THE INTERNATIONAL COUNCIL ON CLEAN TRANSPORTATION

Los Angeles reduced airborne cancer risk by 50% since 2005 largely from diesel controls

2005



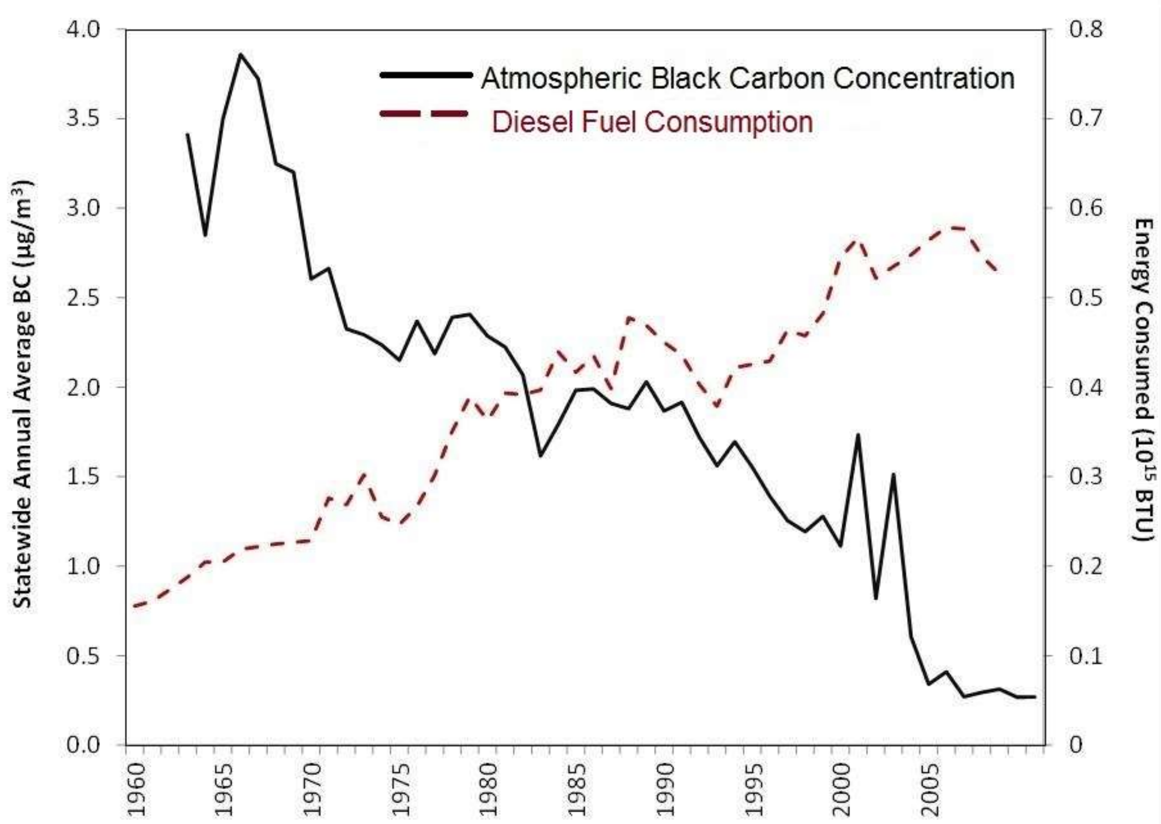
2012



Hypothetical: No Diesel PM

http://www.aqmd.gov/docs/default-source/air-quality/air-toxic-studies/mates-iv/mates-iv-draft-report-10-1-14.pdf?sfvrsn=4

California de-Linkage of BC pollution and diesel activity



"…reductions in black carbon as a result of clean air regulations were equivalent to r

http://www.arb.ca.gov/newsrel/newsrelease.php?id=444

Key Takeaways

- Diesel bus fleets produce significant climate and health impacts
- Fuel and engine strategies are widely available to nearly eliminate diesel soot
- Cities should update procurement practices to shift to soot-free bus fleets
- Cities can realize significant health and climate benefits from cleaner fleets

icct
THE INTERNATIONAL COUNCIL ON CLEAN TRANSPORTATION

Thank you!

Ray Minjares
Clean Air Program Lead
International Council on Clean Transportation
ray@theicct.org

THE INTERNATIONAL COUNCIL ON CLEAN TRANSPORTATION

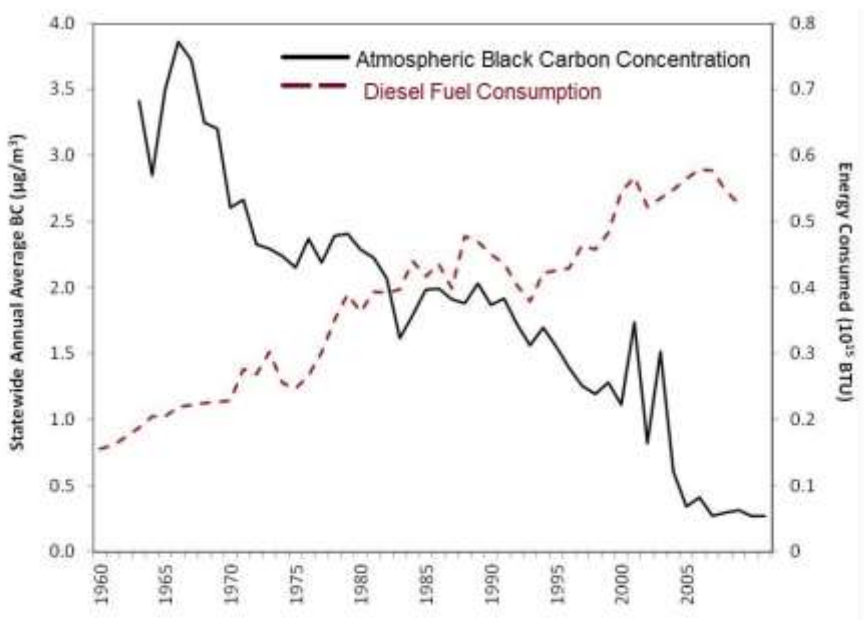
Additional Slides

THE INTERNATIONAL COUNCIL ON CLEAN TRANSPORTATION

The 20 Target Cities

How does black carbon relate to diesel controls?

Key Results from 2013 CARB study

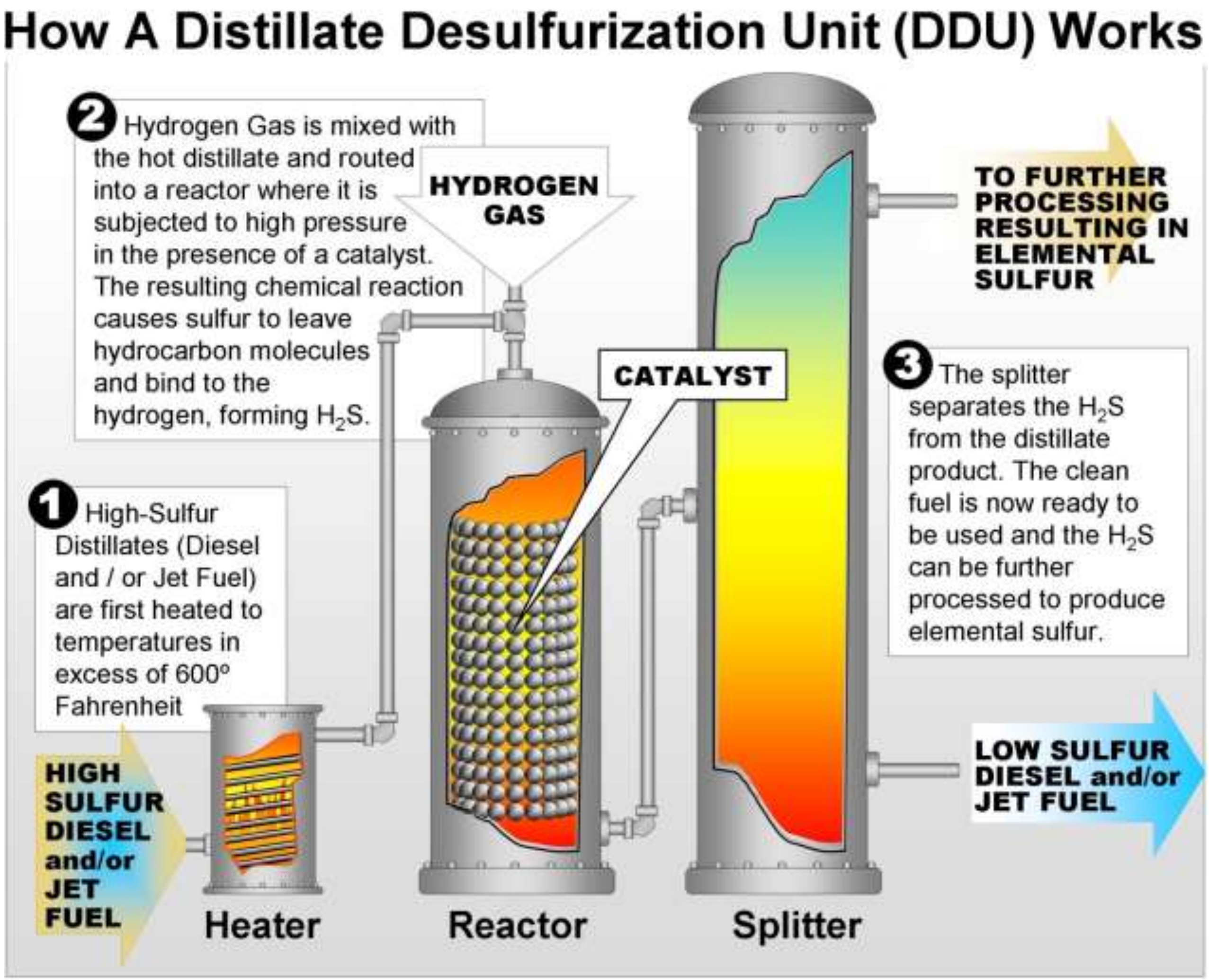


Change in BC concentrations and diesel fuel consumption in CA, 1960-2010

- BC concentrations have fallen by factor of 5 since 1960s
- Diesel emission control is the primary driver of decreased BC
- California has experienced atmospheric cooling of 0.5-1.5 W/m^{-2} statewide from BC controls

Ramanathan, V., Bahadur, R., Praveen, P. S., Prather, K., Cazorla, A., Kirchstetter, T., et al. (2013). *Black carbon and the regional climate of California* (pp. 1–211). University of California, San Diego.

Desulfurization Technology



Graphic from Business Wire (http://www.businesswire.com/news/home/20051122005664/en/Tesoros-Kenai-Refinery-Produce-Cleaner-Diesel-Alaska#.VVTXDflVhBd)

A Comprehensive Approach to Vehicle Emissions Control

New vehicle standards

Must consider emissions from all mobile sources: on-road, off-road, marine, locomotives, aviation, construction…

Limit values only as good as:

- Compliance and enforcement
- Real-world performance

Fuel quality standards

High fuel quality (especially low sulfur levels) enables advanced emission control technologies to be deployed in the fleet.

Fuel quality compliance programs critical to prevent damage to engines and prevent misfueling

In-use vehicle emission control

Measures include:

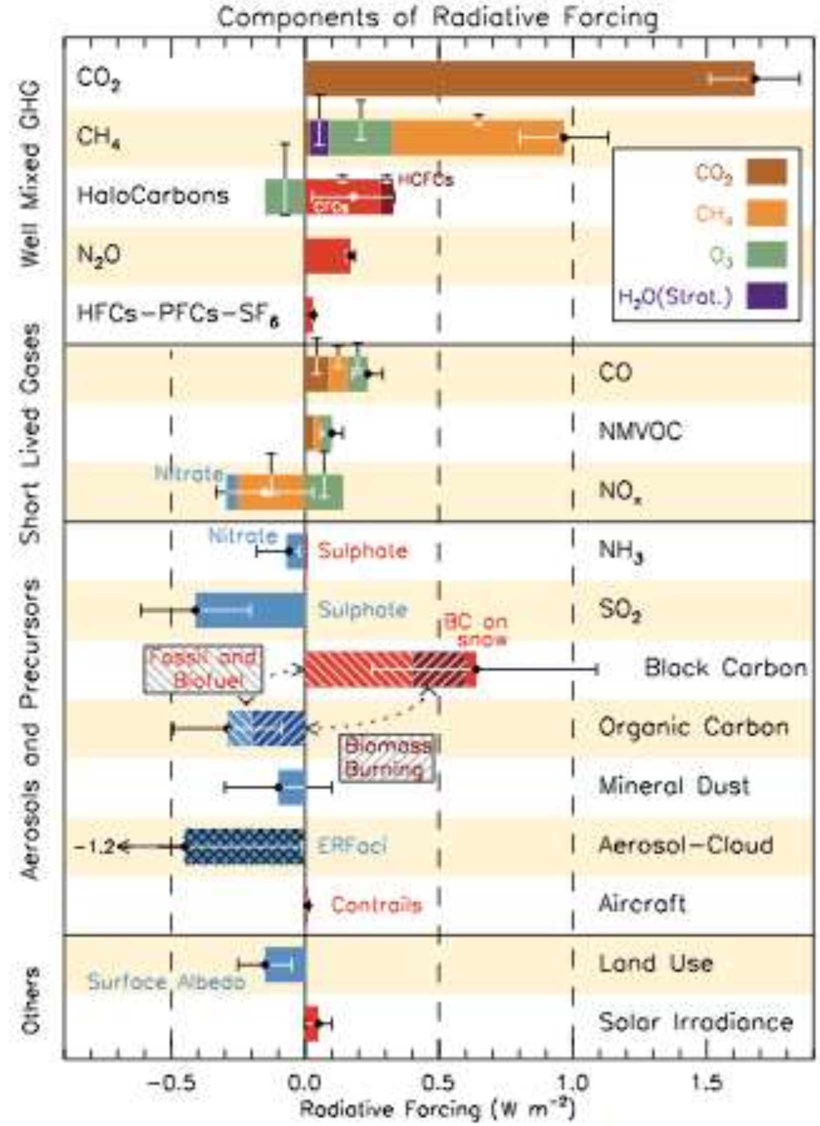
- Catching gross-emitters (I/M, remote sensing, maintenance) - Cleaner fuels
- Fleet renewal
- Retrofit programs
- Complementary strategies (low emission zones, driver training, etc.)

"Systems Approach"

Not shown but also important: transportation demand management, modal shift, traffic optimization, and more

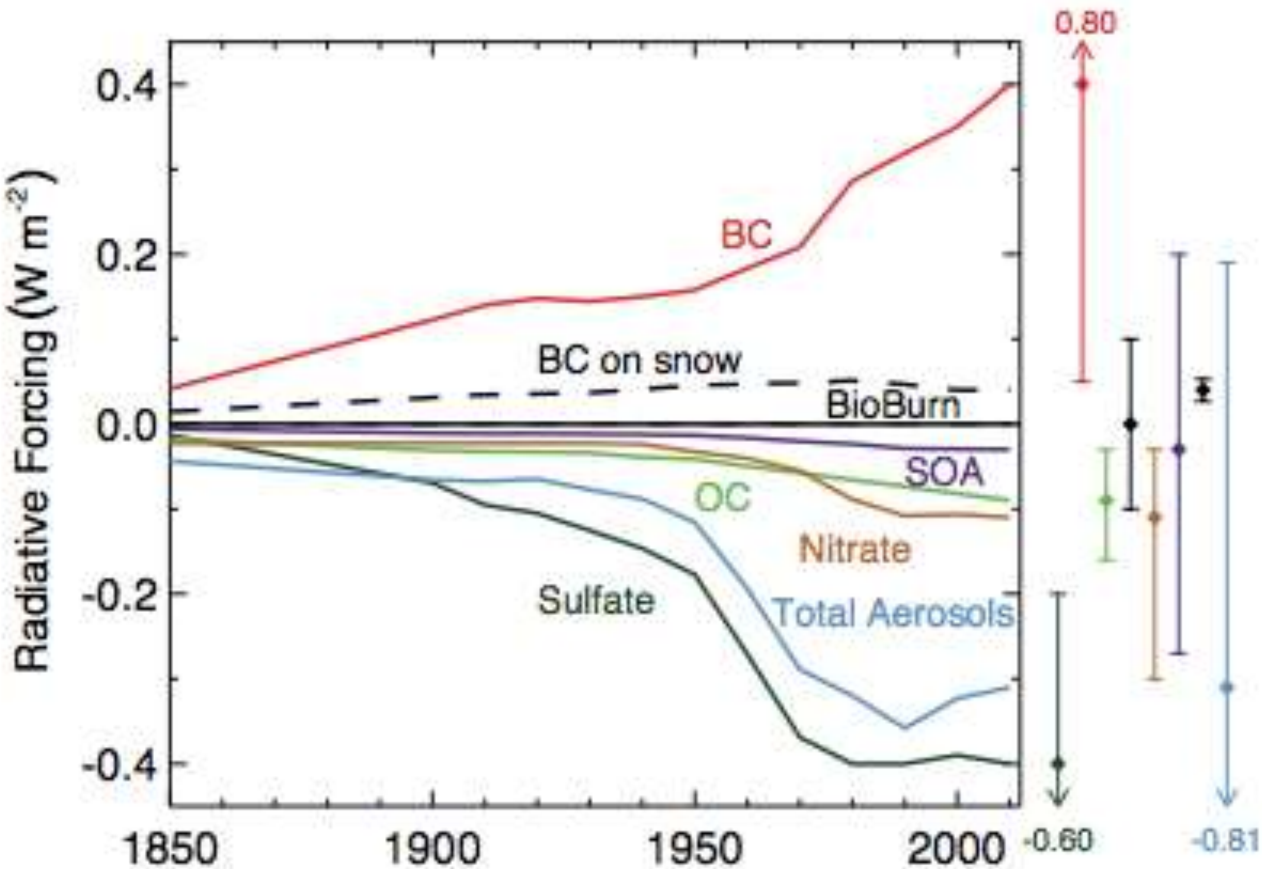
Project Highlights

1. Inform, motivate, and secure a **public commitment** from city officials to shift to cleaner buses;
2. Provide **implementation support** at the request of committed cities and guided by an agreed upon work plan;
3. Establish an industry partnership with a private **sector coalition of clean bus manufacturers and suppliers** to serve as an ongoing technical resource to cities and to serve as a point of contact for clean bus procurement;
4. Assess **current and future market demand for clean buses and estimate the total financial assistance needed** for their deployment in developing countries; communicate these findings to the CCAC Black Carbon Finance Study Group; and ensure that the outcomes of the Group and any available funding opportunities are communicated to committed cities;
5. Conduct a **baseline assessment of urban bus fleets** in cities, and identify barriers to clean bus deployment to guide future research and activities at the international level.



Components of Radiative Forcing
Well Mixed GHG
Short Lived Gases
Aerosols and Precursors
Others
CO2
CH4
HaloCarbons
N2O
HFCs-PFCs-SF6
CFCs
HCFCs
CO2
CH4
O3
H2O(Strat.)
CO
NMVOC
NOx
Nitrate
NH3
Nitrate
Sulphate
SO2
Sulphate
BC on snow
Black Carbon
Fossil and Biofuel
Organic Carbon
Biomass Burning
Mineral Dust
Aerosol-Cloud
-1.2
ERFaci
Aircraft
Contrails
Land Use
Surface Albedo
Solar Irradiance
-0.5
0.0
0.5
1.0
1.5
Radiative Forcing (W m-2)

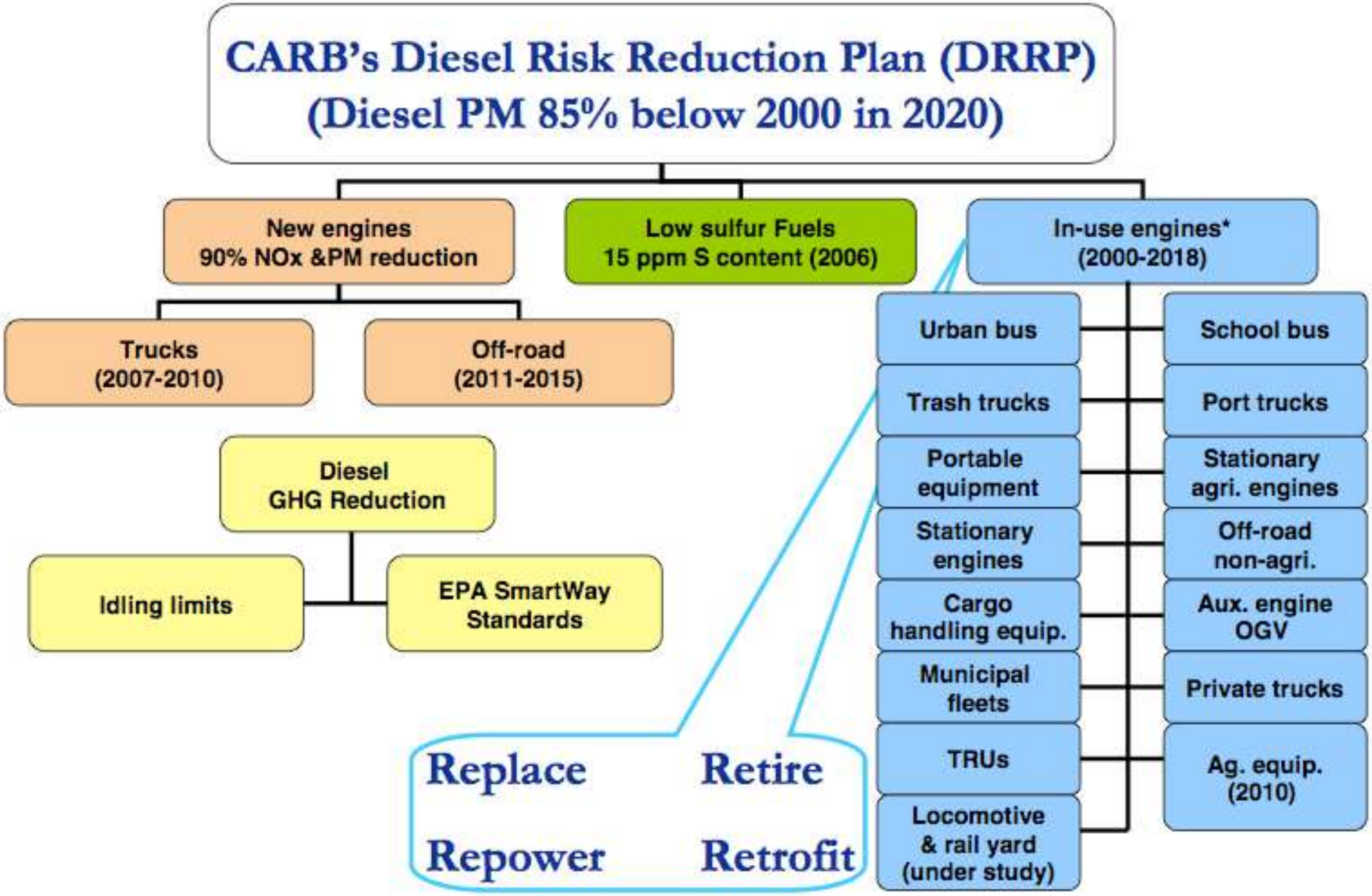
Climate Impacts of Aerosols



El catalazidor de oxidaciónes diesel no captura efectivamente el carbono negro

- Captura los hidrocarburos líquidos
- Efectiva a reducir su contribución a PM
- No tiene mecanismo para capturar las partículas sólidas como carbono negro

The California Model



Source: Ayala, A. (2009) Black carbon controls in California: emissions, abatement and knowledge gaps. 2009 International Workshop on Black Carbon in Latin America, 19 October, Mexico City, Mexico.

100-year CO2-eq emission factors of new vehicles

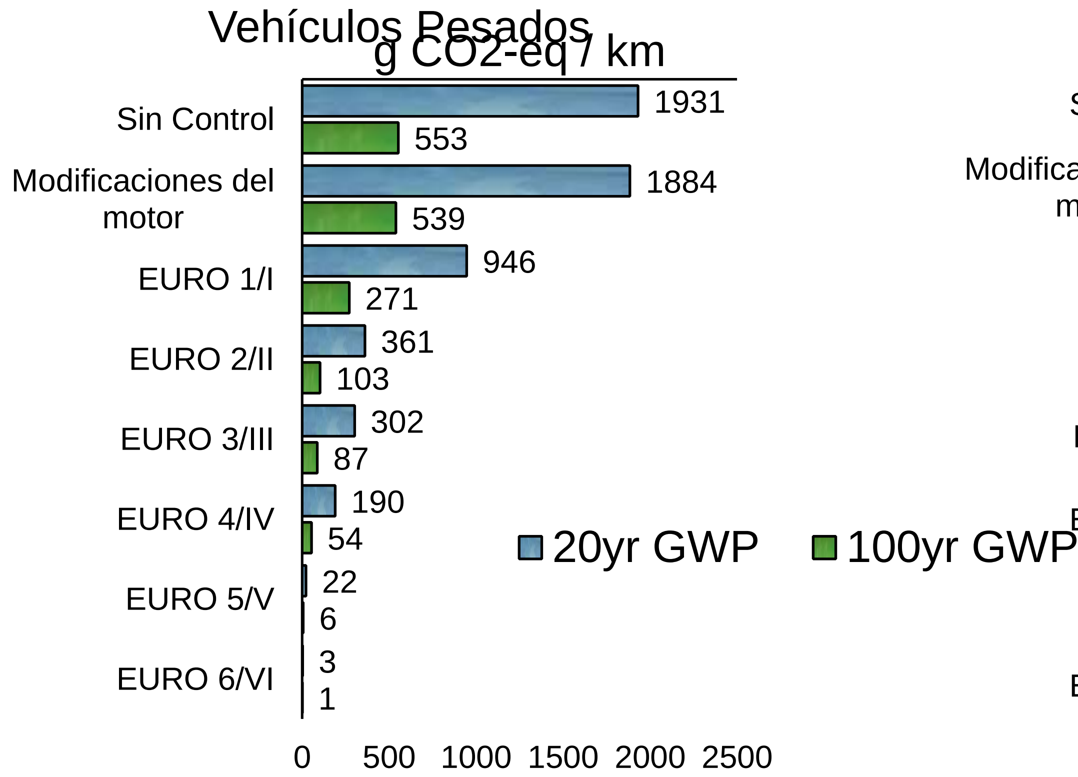
Mode	Fuel	Emission Factors (g/km)							
		Uncontrol	Engine Mods	Euro I	Euro II	Euro III	Euro IV	Euro V	Euro VI
LDV	Gasoline	-0.2	-0.2	0.5	0.3	0.3	0.3	0.3	0.3
	Diesel	289.0	192.7	148.2	62.3	34.5	17.6	0.8	0.8
Bus	Gasoline	-0.2	-0.2	0.5	0.3	0.3	0.3	0.3	0.3
	Diesel	711.1	477.5	323.9	276.5	170.3	85.6	85.6	1.3
LHDT	Gasoline	-0.2	-0.2	0.5	0.3	0.3	0.3	0.3	0.3
	Diesel	196.1	135.5	83.8	77.4	45.1	7.9	2.3	1.5
MHDT	Gasoline	-0.2	-0.2	0.5	0.3	0.3	0.3	0.3	0.3
	Diesel	189.5	156.9	130.6	119.2	70.7	13.2	3.8	2.3

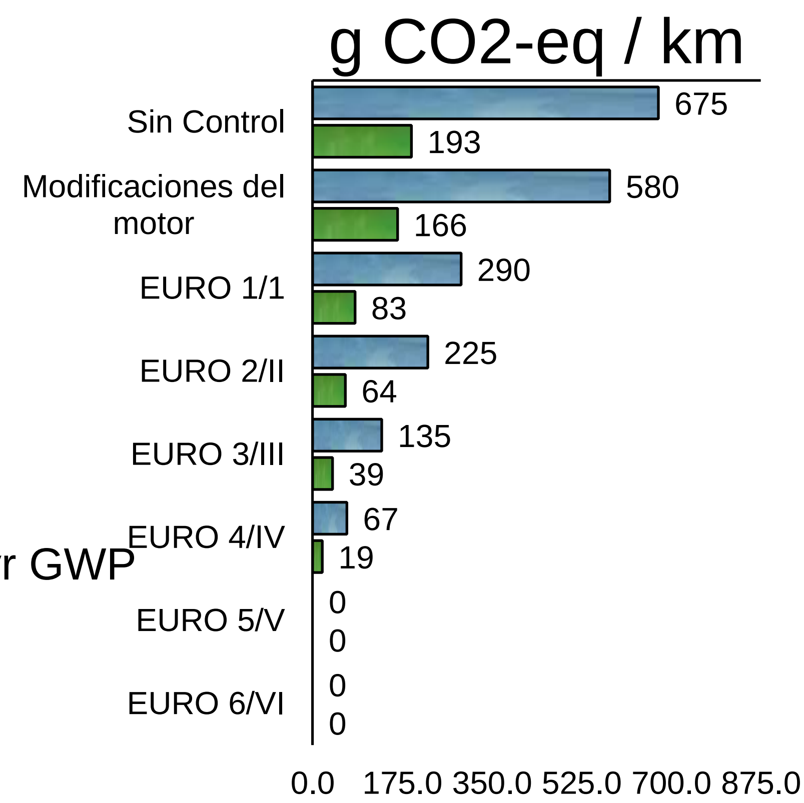
20-year CO2-eq emission factors of new vehicles

Mode	Fuel	Emission Factors (g/km)							
		Uncontrol	Engine Mods	Euro I	Euro II	Euro III	Euro IV	Euro V	Euro VI
LDV	Gasoline	-0.9	-0.8	1.9	1.2	1.2	1.2	1.2	1.2
	Diesel	1025.8	684.1	526.7	221.4	122.5	62.6	2.7	2.7
Bus	Gasoline	-0.8	-0.9	1.9	1.2	1.2	1.2	1.2	1.2
	Diesel	2524.6	1695.1	1150.8	982.4	604.9	304.3	304.3	4.5
LHDT	Gasoline	-0.8	-0.9	1.9	1.2	1.2	1.2	1.2	1.2
	Diesel	696.1	481.1	297.8	275.2	160.1	28.2	8.1	5.5
MHDT	Gasoline	-0.8	-0.9	1.9	1.2	1.2	1.2	1.2	1.2
	Diesel	672.6	556.8	464.1	423.7	251.2	46.9	13.4	8.2
HHDT	Gasoline	-0.8	-0.9	1.9	1.2	1.2	1.2	1.2	1.2
	Diesel	1655.7	1344.5	982.4	773.4	480.8	136.2	136.2	2.7

Las reglas diseñado para proteger la salud tienen un co-beneficio climático

Impacto climático de emisiones de PM diesel





Nota: Valores comunican el impacto climático de PM (carbono orgánico más carbon negro). Valores de Potencial de Calentamiento Global (GWP) para carbono negro son 1830 (20 años) y 520 (100 años) derivado por Rypdal et al 2009 y modificado por efectos indirectos con el método de Hansen et al, 2007. Valores de GWP para carbono organico son -160 (20 años) y -40 (100 años) y tomado de Rypdal et al 2010. Factores de emisiones tomado de Michael Walsh. Porcentaje de PM constituido de carbono orgánico y carbono negro tomado de Chow et al, 2010 y son 32 % para carbono orgánico y 50% para carbono negro.

Costs and Benefits of AFRI-4 Fuels in SSA

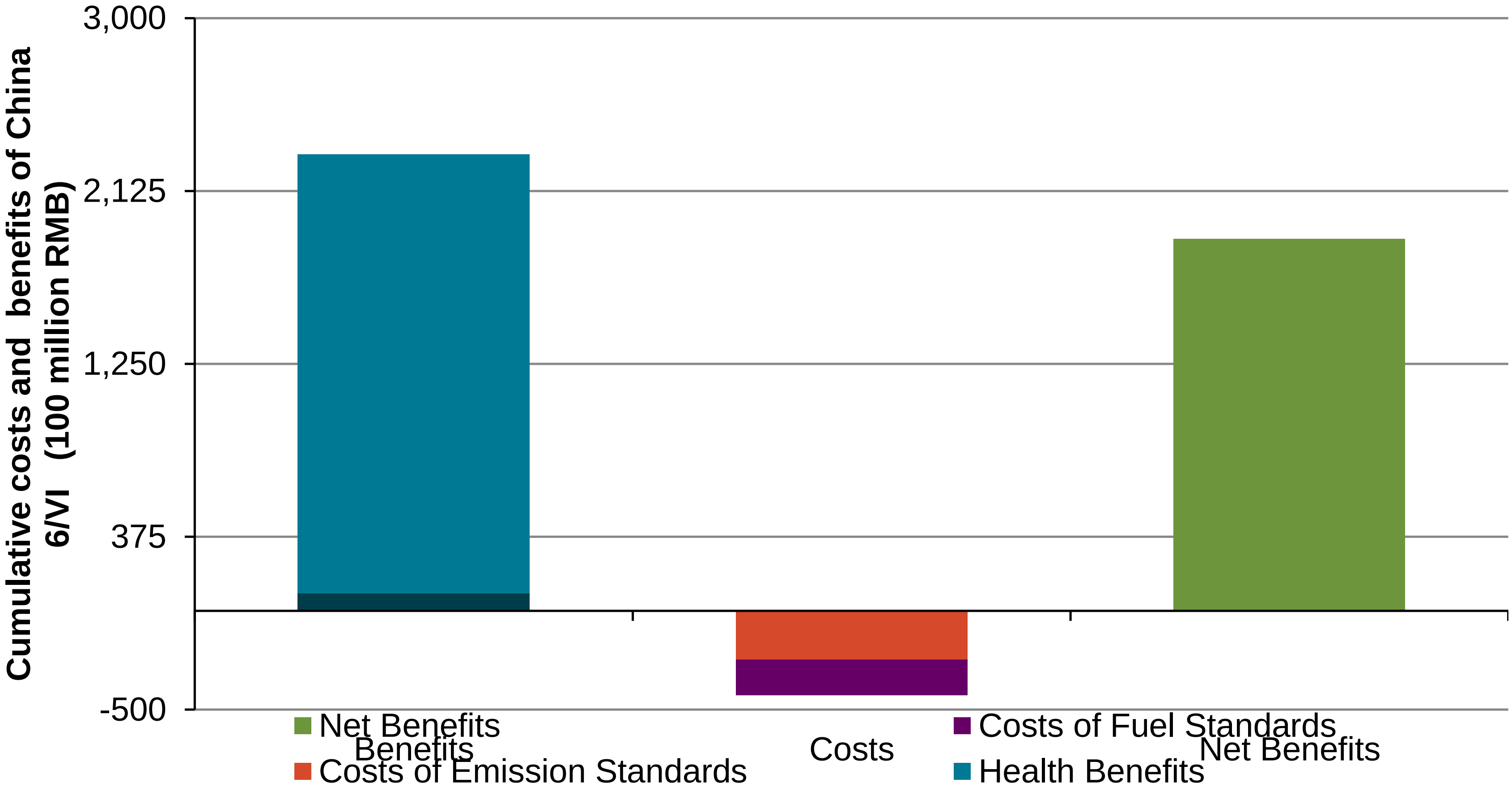
Billions 2007 Dollars	SSA Total	West Africa	East Africa	Southern Africa
5-Year Refinery Investment Costs	$ 2.76 B	$ 0.47 B	$ 2.13 B	0.59 B
Health Benefits over 5 Years[1]	$ 25 B	$ 18 B	$ 5.3 B	$ 1.0 B
10-year Refinery Investment Costs	$ 6.14 B	$ 4.96 B	$ 2.48 B	$ 0.99 B
Health Benefits over 10 Years[1]	$ 43 B	$ 33 B	$ 9.0 B	$ 1.8 B

1. Central value shown for elasticity=1.5; ranges for elasticities of 1.0 and 2.0 are shown in the report. For Scenario 2 (lower sulfur fuel and pollution control equipment) and alternate 2-stroke motorcycle emissions assumptions.

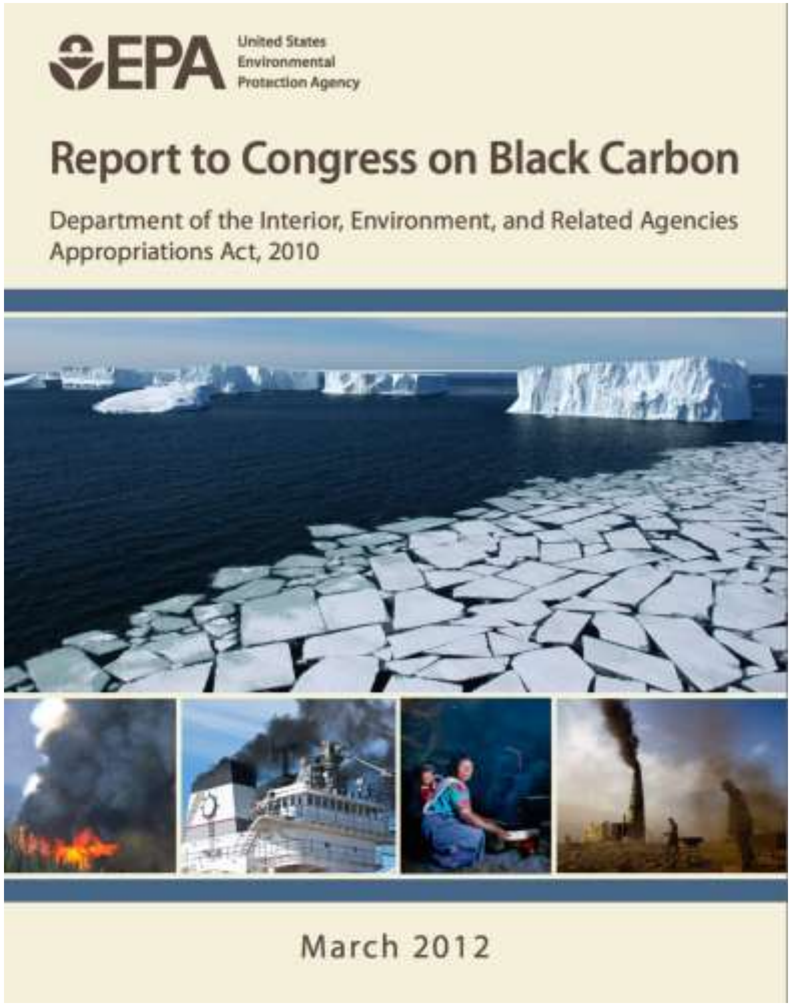
icct THE INTERNATIONAL COUNCIL ON Clean Transportation

ICF International (2009). Final Report: Sub-Saharan Africa Refinery Project Executive Summary. Submitted to the World Bank and the African Refiners Association. June 2009

Details: China – value of moving to Euro VI-equivalent standards



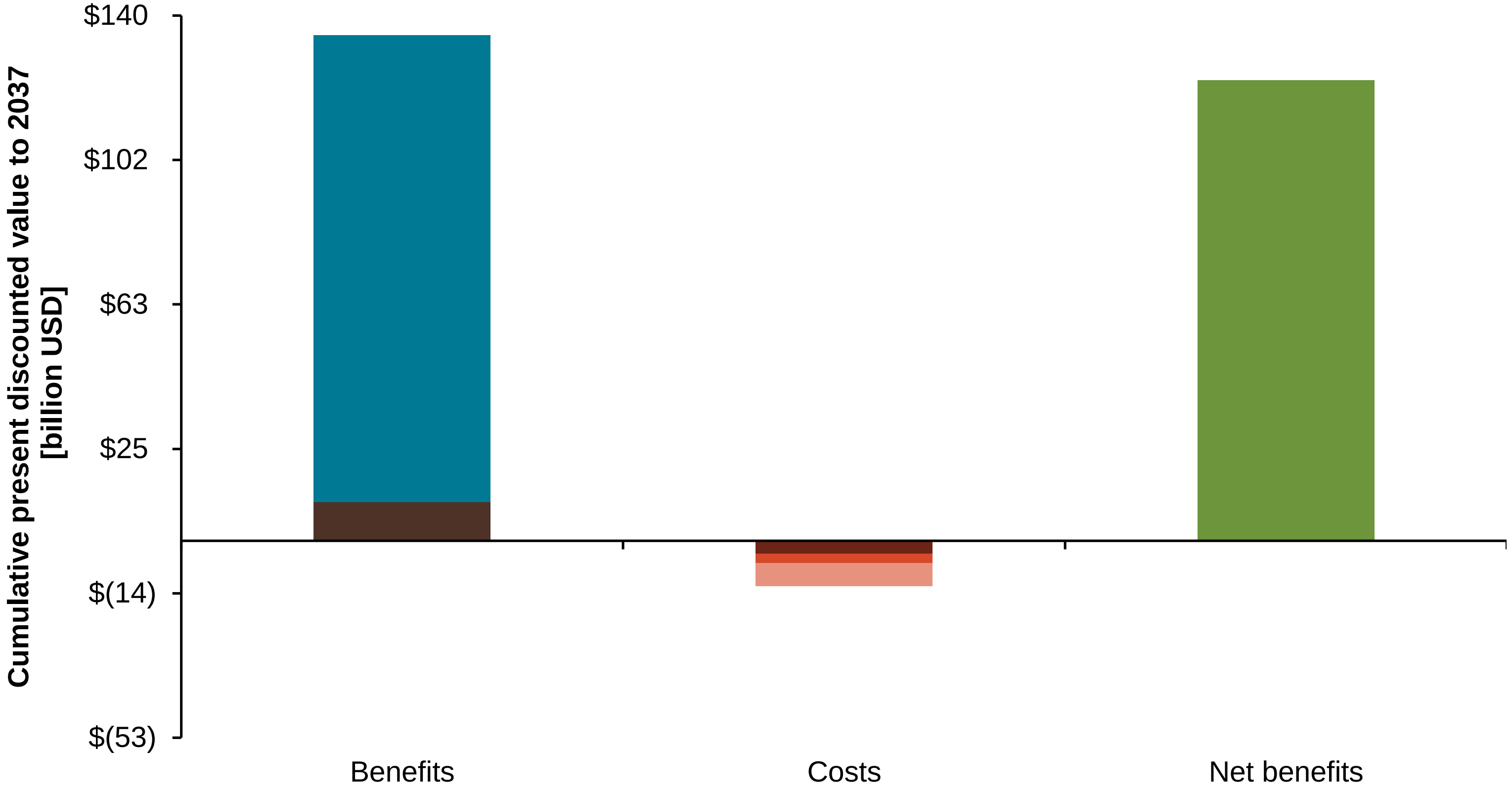
US EPA Report to Congress on Black Carbon (2012)



"**The most important BC emissions reduction opportunities globally include** residential cookstoves in all regions; brick kilns and coke ovens in Asia; and **mobile diesels in all regions.** "

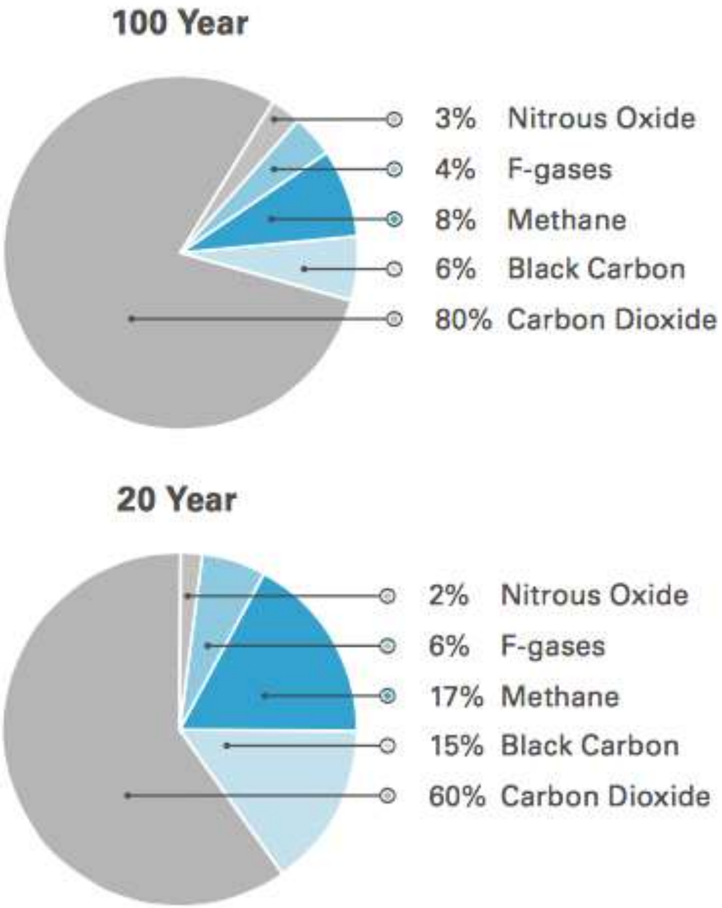
Sasser, E., & Hemby, J. (2012). Report to Congress on Black Carbon (No. EPA-450/R-12-001) (pp. 1–388). US Environmental Protection Agency. Retrieved from http://www.epa.gov/blackcarbon/

Details: Mexico – value of moving to heavy-duty standards equivalent to Euro VI



California adopts law SB 605 to require plan by 2016 to address short-lived climate pollutants

California 2012 GHG Inventory



icct THE INTERNATIONAL COUNCIL ON CLEAN TRANSPORTATION

http://arb.ca.gov/cc/shortlived/slcp_booklet.pdf

Norwegian Environment Agency Presents Action Plan on Short-Lived Climate Pollutants (2014)

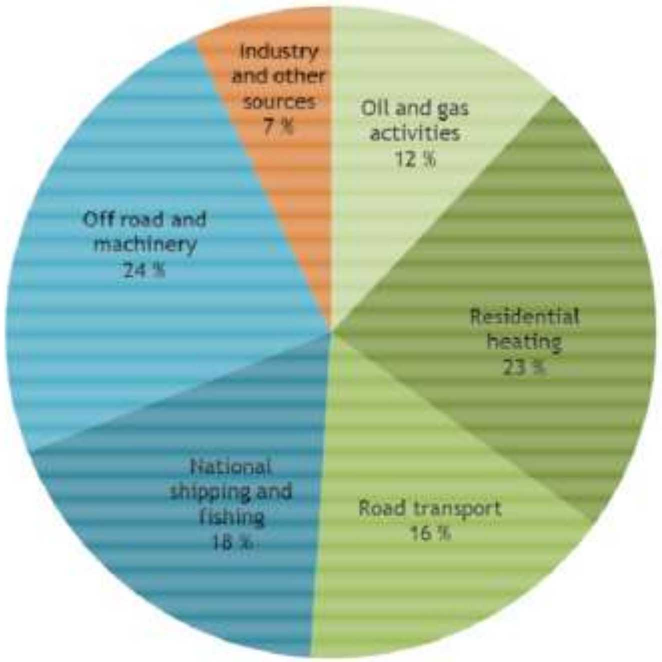


Figure 1: Distribution of sources for Norwegian 2011 emissions of black carbon [7, 8].

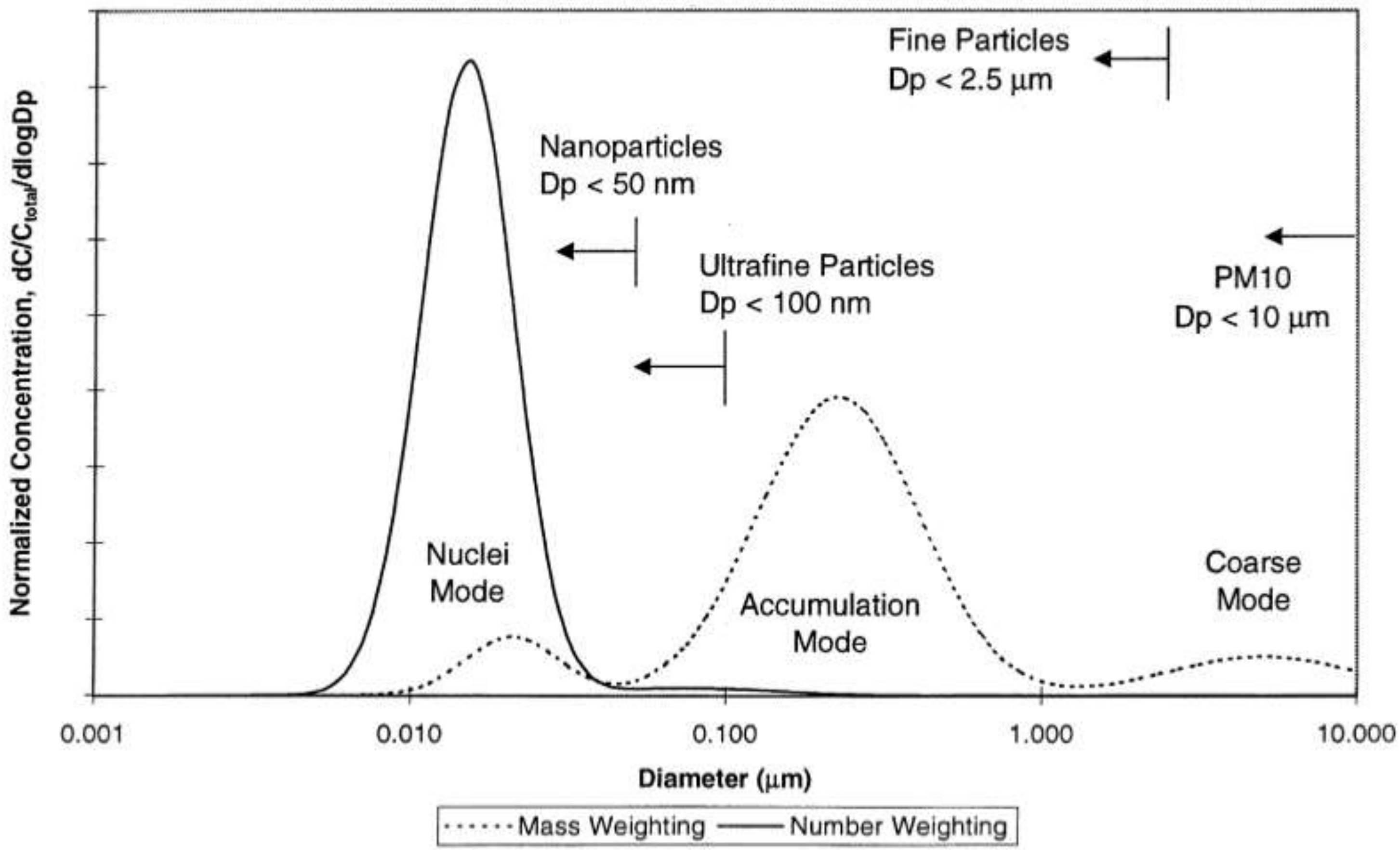
BC Transport-Related Measures

- DPF retrofit on construction machinery, coastal vessels, & fishing boats, mobile rigs, light-duty vehicles, tractors, & heavy-duty vehicles
- Bus fuel switching to food waste biogas

Vestreng, V., Kvalevåg, M. M., Guttu, S., & Skjellum, S. F. (2014). The Norwegian action plan on short-lived climate pollutants (Vol. 1, pp. 299–313). Presented at the AIR POLLUTION 2014, Southampton, UK: WIT Press. doi:10.2495/AIR140251

icct THE INTERNATIONAL COUNCIL ON CLEAN TRANSPORTATION

Schematic of distribution of particles emitted by vehicles



Source: Kittelson, D. (1998). Engines and nanoparticles a review. *Journal of Aerosol Science*, *29*(5-6), 575–588.

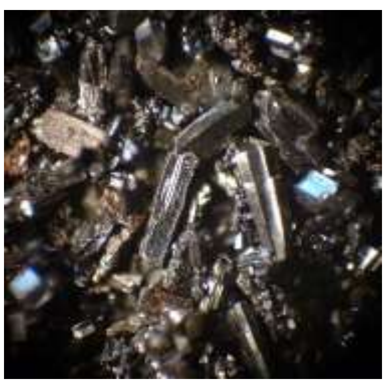
What is black carbon?

Forms of pure carbon

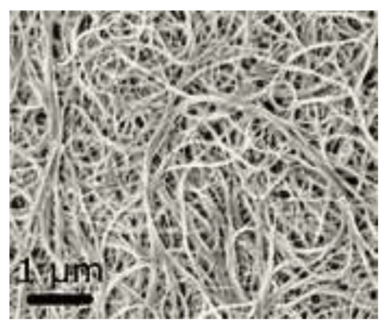
Diamond

Graphite

Lonsdaleite



Fullerenes

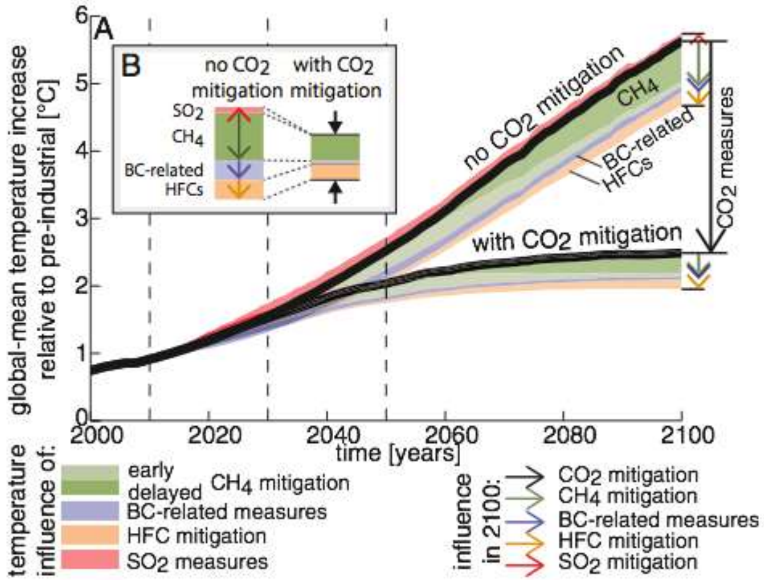


Carbon nanotubes

Soot

BC control is no substitute for carbon dioxide to achieve 2°C target

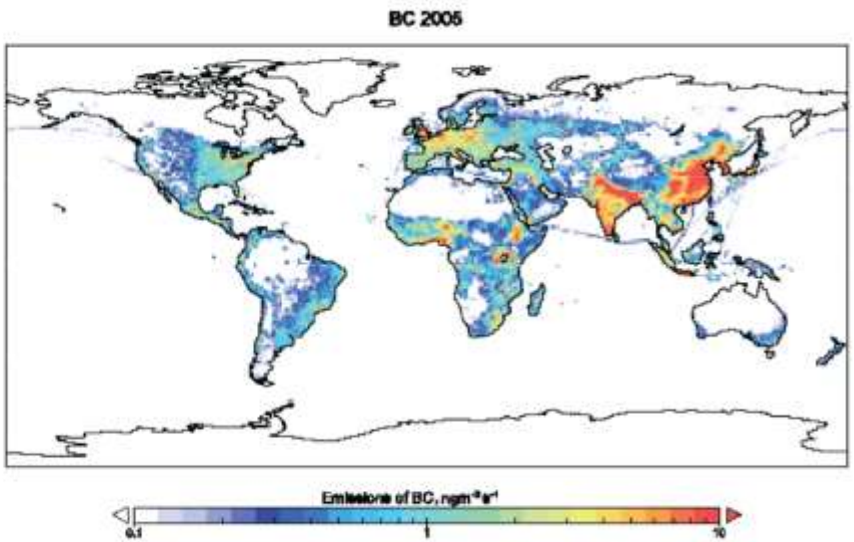
Black Carbon	Carbon Dioxide
• Short-lived • Regionally constrained • Controls year of peak temperature	• Long-lived • Globally well-mixed • Controls magnitude of peak temperature



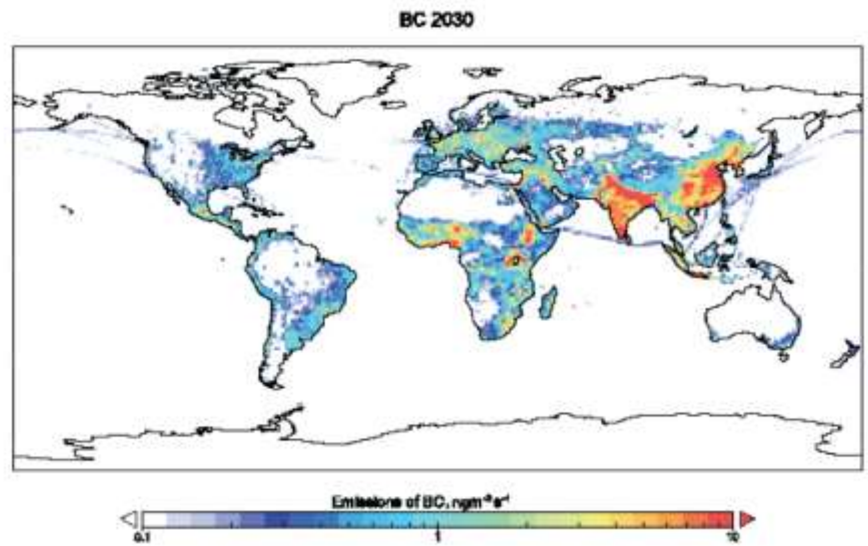
Rogelj, J., Schaeffer, M., Meinshausen, M., Shindell, D. T., Hare, W., Klimont, Z., et al. (2014). Disentangling the effects of CO2 and short-lived climate forcer mitigation. Proceedings of the National Academy of Sciences. doi:10.1073/pnas.1415631111

What are the emission trends for diesel black carbon?

Global Distribution of BC Emissions



Year 2005



Year 2030

Shindell, D., Ramanathan, V., Raes, F., Cifuentes, L., & Kim Oanh, N. T. (2011). *Integrated assessment of black carbon and tropospheric ozone* (pp. 1–285). Nairobi: UNEP and WMO. Retrieved from http://www.unep.org/dewa/Assessments/Ecosystems/ClimateChange/tabid/7002/Default.aspx

Alternative Scenario (Hansen et al, 2000)

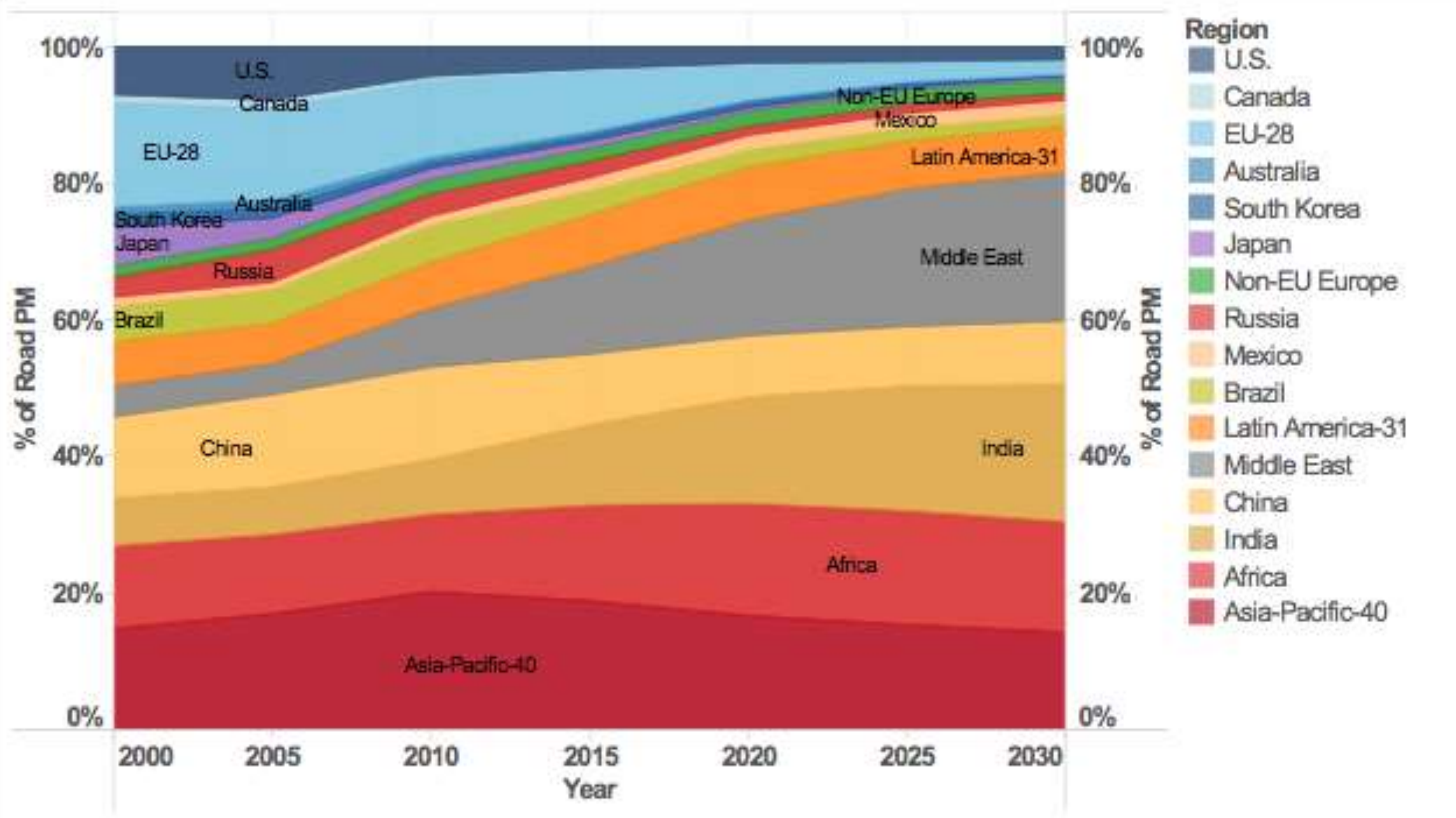
"Concievably a reduction of climate forcing by 0.5 W/m^2 or more could be obtained by reducing **black carbon emissions from diesel fuel** and coal."

" If the World Bank were to support investments in modern technology and air quality control in **India** and China, for example, the reductions in tropospheric ozone and **black carbon** would not only improve local health and agricultural productivity but also benefit global climate and air quality."

icct
THE INTERNATIONAL COUNCIL ON CLEAN TRANSPORTATION

Hansen, J., Sato, M., Ruedy, R., Lacis, A., & Oinas, V. (2000). Global Warming in the 21st Century: An alternative Scenario. Proceedings of the National Academy of Sciences, 97(18), 9875–9880.

Contribution to PM emissions in the transport sector, by region



THE INTERNATIONAL COUNCIL ON CLEAN TRANSPORTATION

Cost of Air Pollution to Society is Dominated by Mortality