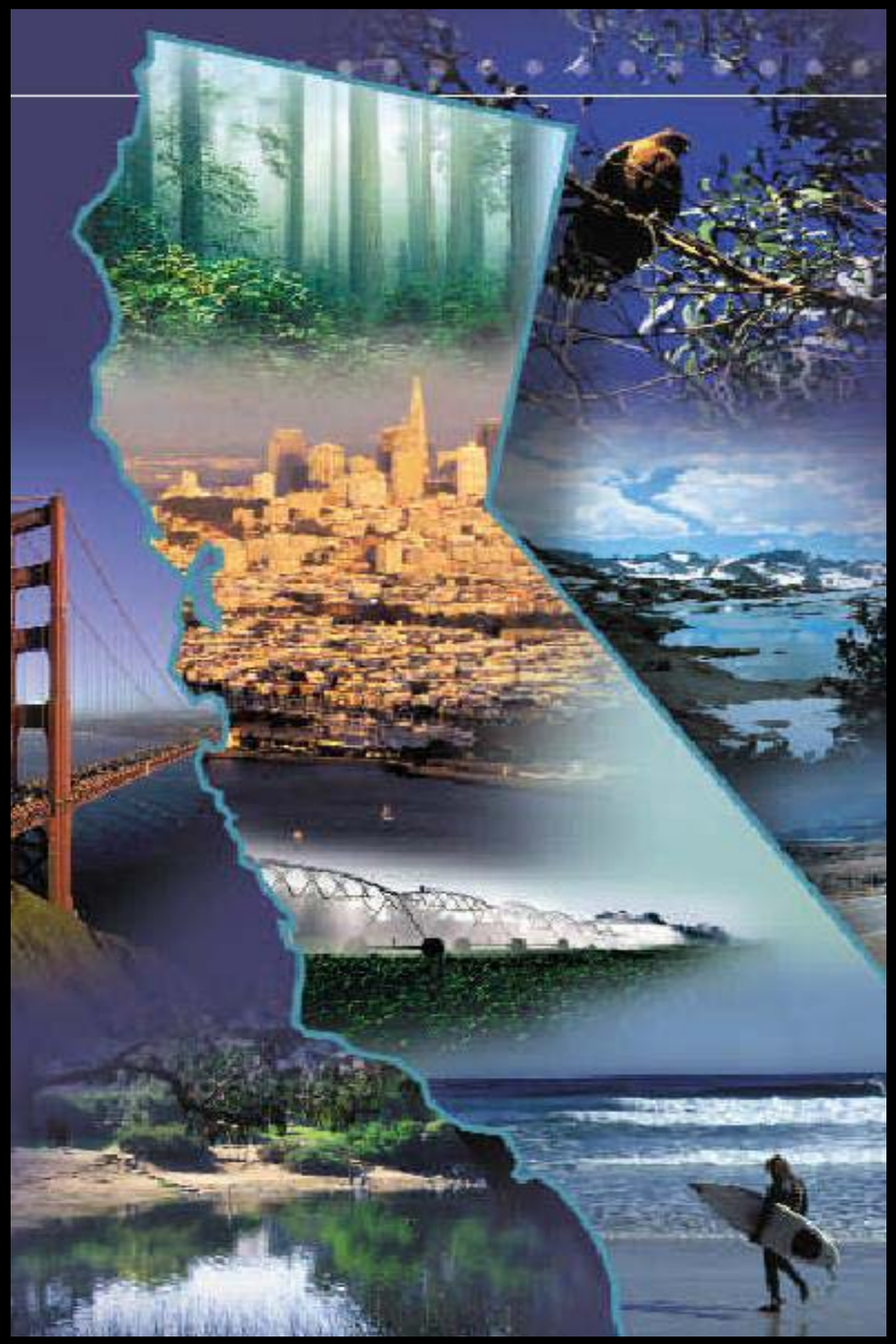
International Conference on Carbonaceous Particles in the Atmosphere
Lawrence Berkeley National Laboratory
August 12-14, 2008



Climate Impact Assessment of Carbonaceous Aerosols for California's Climate Protection Plan

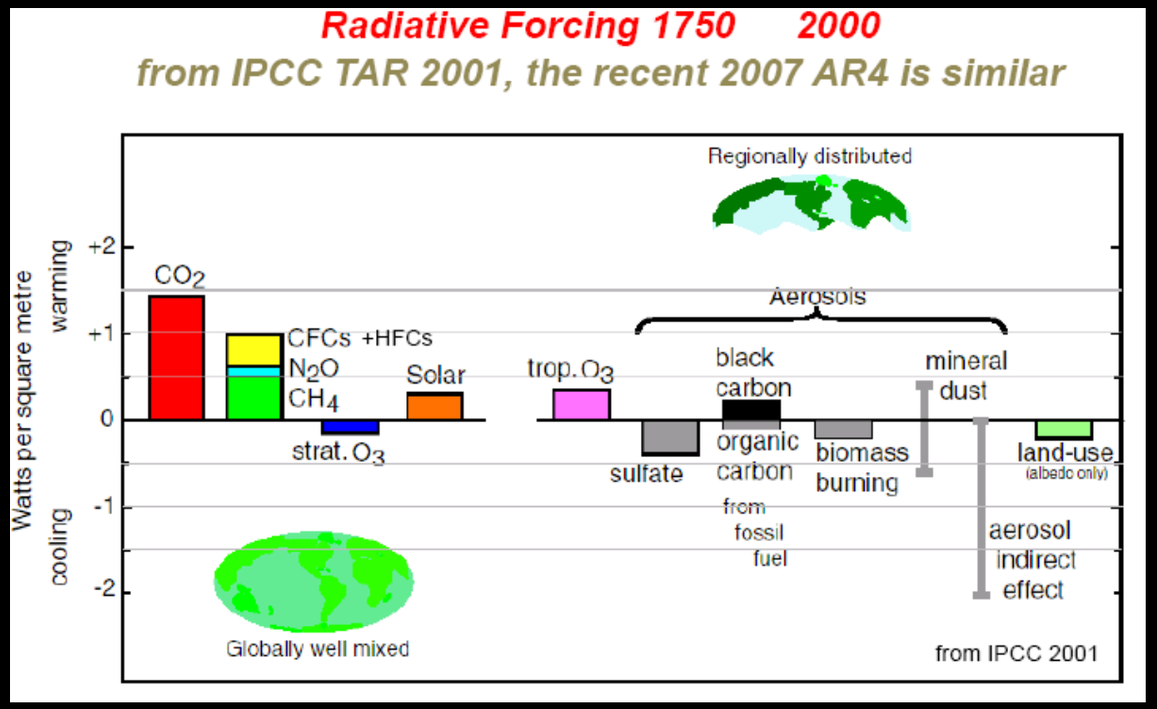
Nehzat Motallebi, Dongmin Luo, and Alberto Ayala

California Air Resources Board

California Environmental Protection Agency

Key Message

- **California has long standing interest in the role that non-Kyoto climate species play in climate change**
- **They have not been the specific focus of legislation**
  - But some are included in climate protection program
- **State has concerted and aggressive efforts to reduce PM (and the fraction that is BC)**
  - Emission reductions for health protection
- **Pursuing closing remaining knowledge gaps that may impede additional policy action on basis of climate protection**
  - Tracking international research progress
  - Sponsoring California-centric research

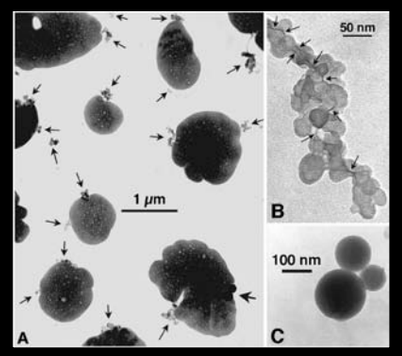


The Role of Aerosols in the Current Climate Picture

- Global: **Change radiative balance (<GHGs)**
  - IPCC concluded that PM in general has an overall cooling effect

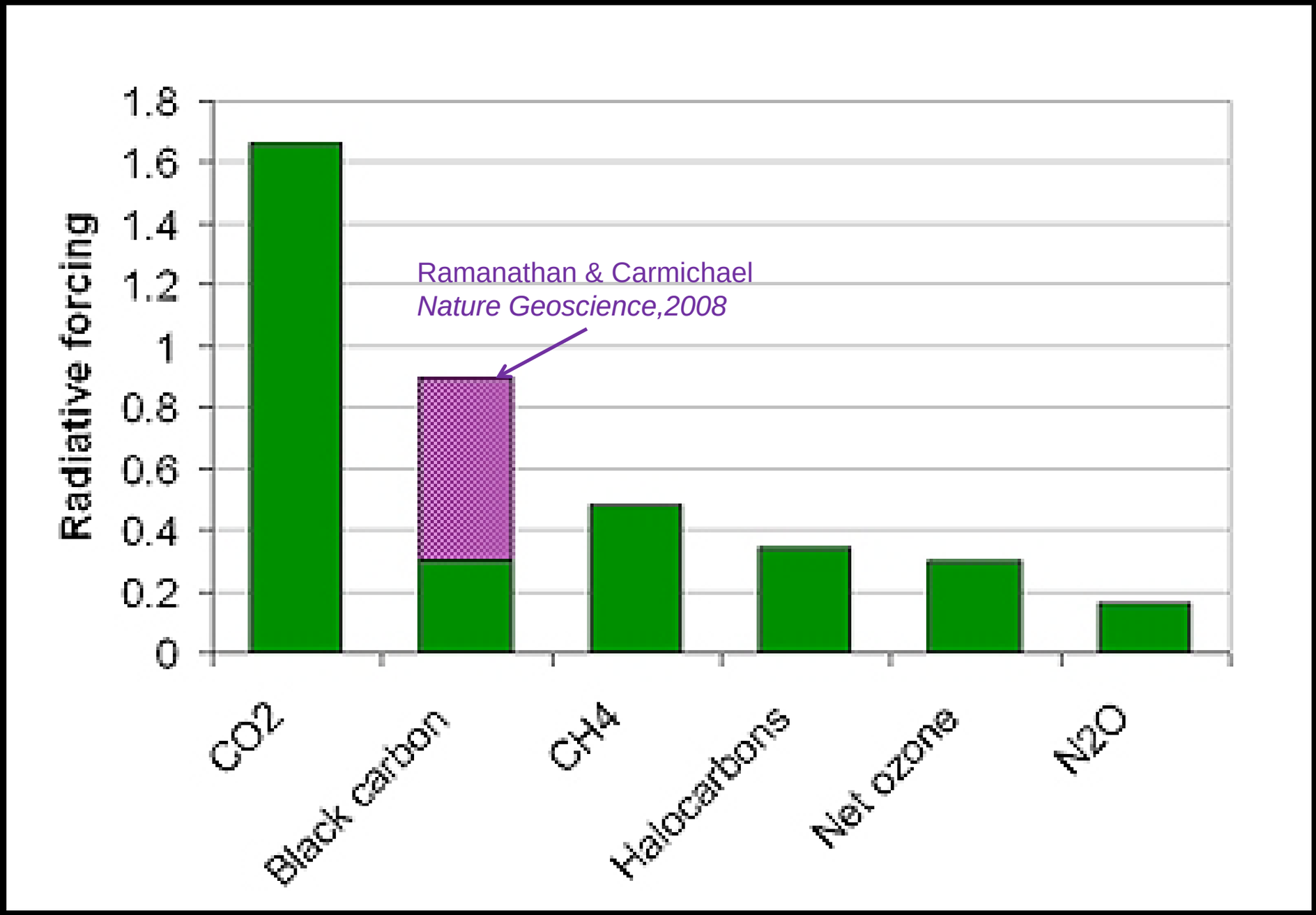
- Regional: **Change radiative balance (>>GHGs) & clouds**

- Soot particles: **Most efficient aerosol species at absorbing solar radiation,**
  - ➢ New estimate says heating potential of black carbon is three to four times greater than prevailing estimates



Soot particles (arrows) coated by ammonium sulfate

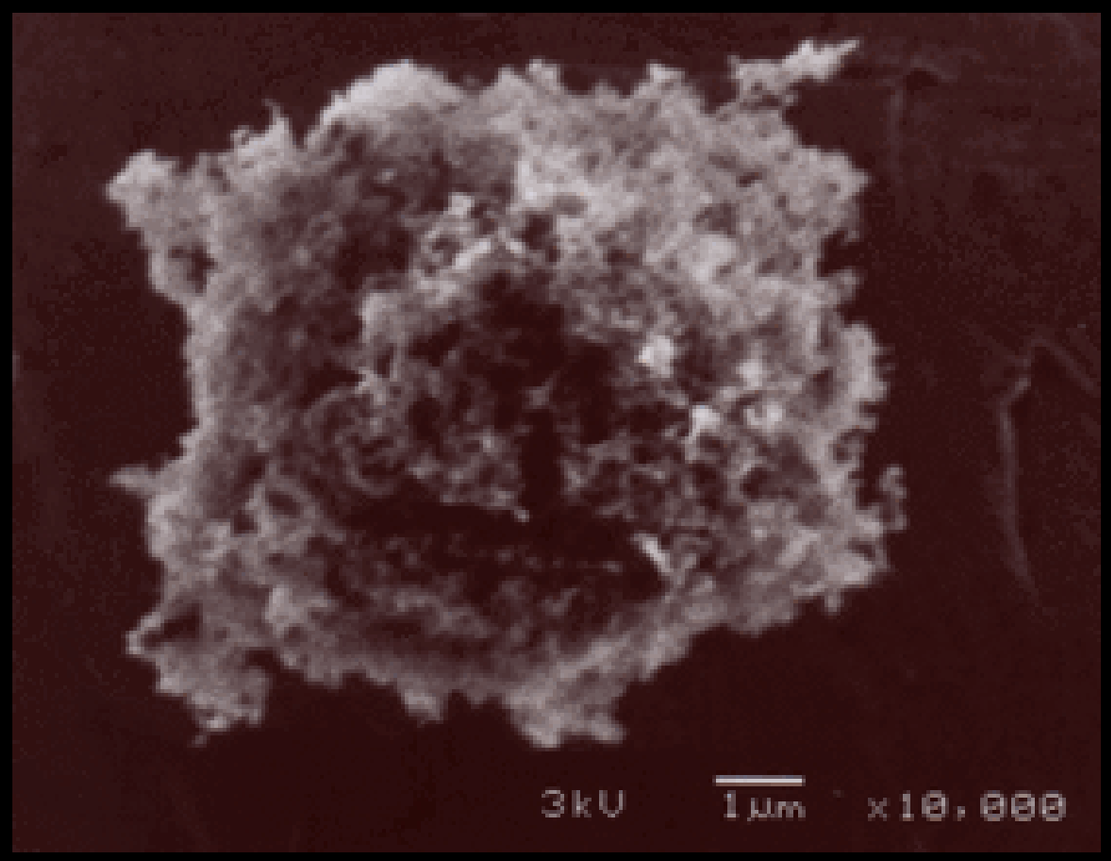
Warming Effects of Various Climate Species



Source: EarthTrends, 2008 using data from IPCC, 2007

Ramanathan & G. Carmichael. Global and regional climate changes due to black carbon, *Nature Geoscience*, Published online: 23 March 2008 | doi: 10.1038/ngeo156 March 23, 2008.

CARB On-Going and Planned Research



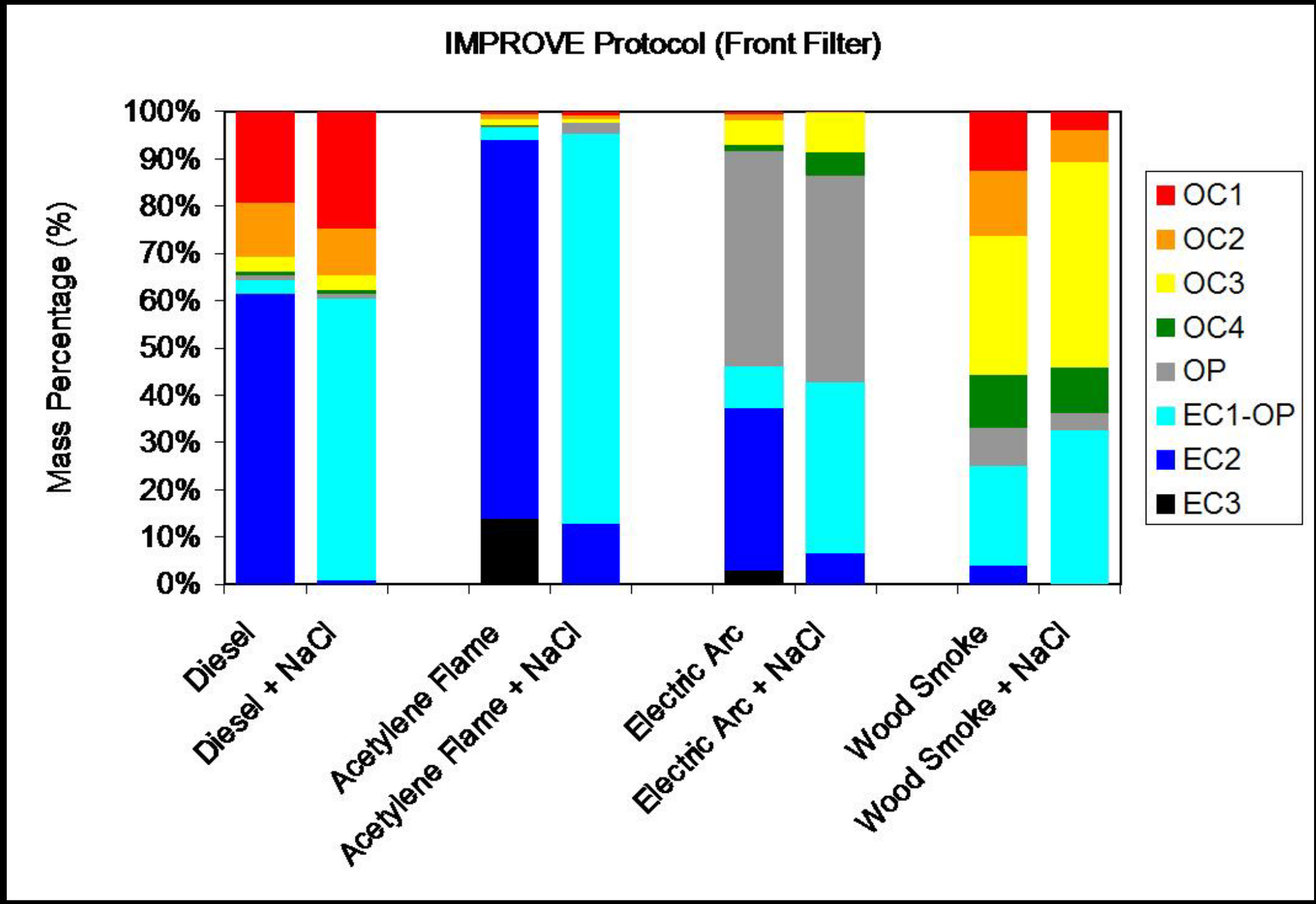
Soot Particle Under a Microscope Image credit: D.M. Smith, University of Denver

CARB-sponsored research to evaluate C measurement methods and inventories

- Compare continuous vs. filter-based BC/EC measurements
- Examine seasonal and diurnal variations of BC/EC
- Quantify equivalence, comparability, and predictability of different methods for BC/EC
- Determine the causes of differences in BC/EC

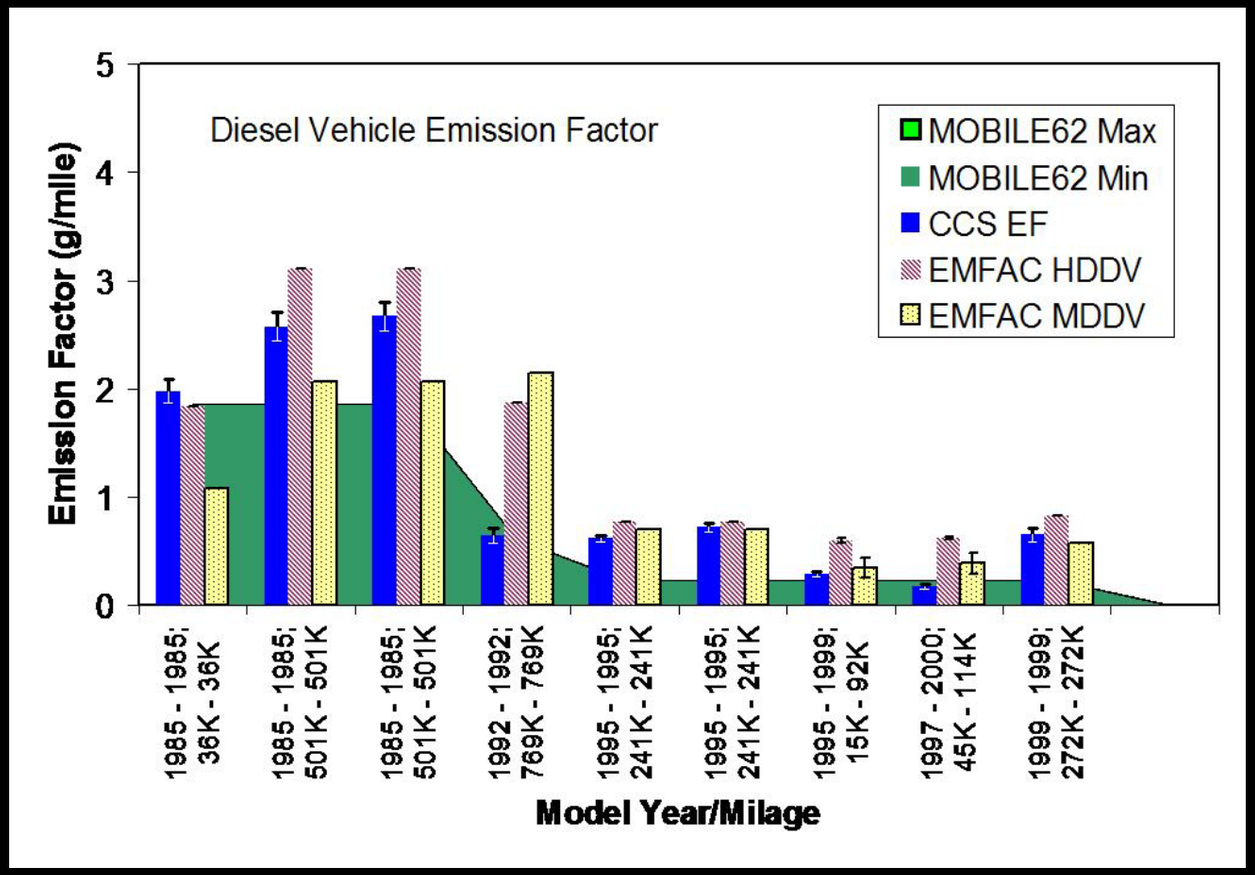
Ref.; Chow, J.C. and Watson, J., DRI, “Characterization of Black Carbon and Organic Carbon Air Pollution Emissions and Evaluation of Measurement Method”. CARB Contract.

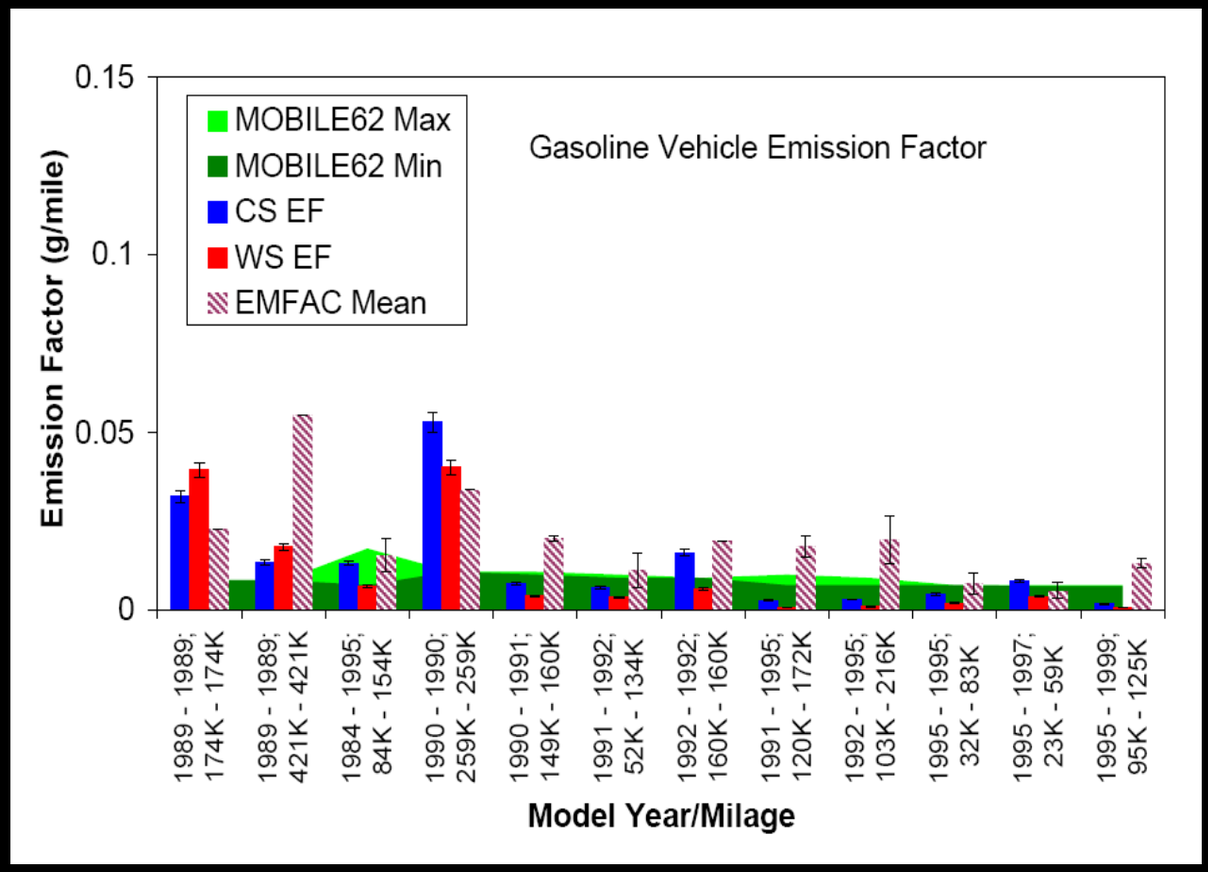
Comparisons of carbon fractions (in TC) by IMPROVE_A_TOR protocol of different samples with or without additional NaCl



Chow et al. (2006)

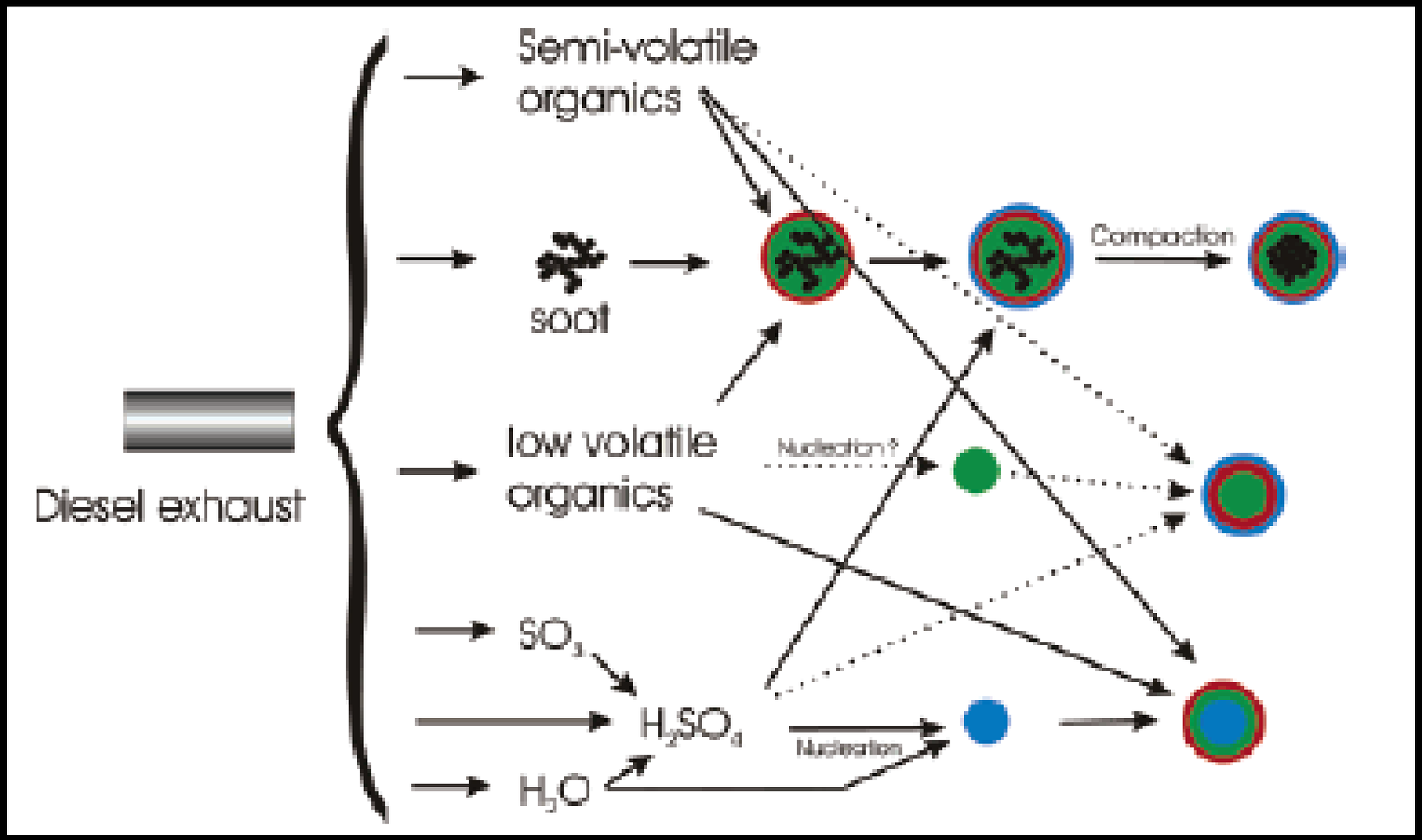
Comparisons of Model and Measured $PM_{2.5}$ Emission Factors for Diesel and Gasoline Vehicles





Chow et al. (2008)

Diesel PM formation



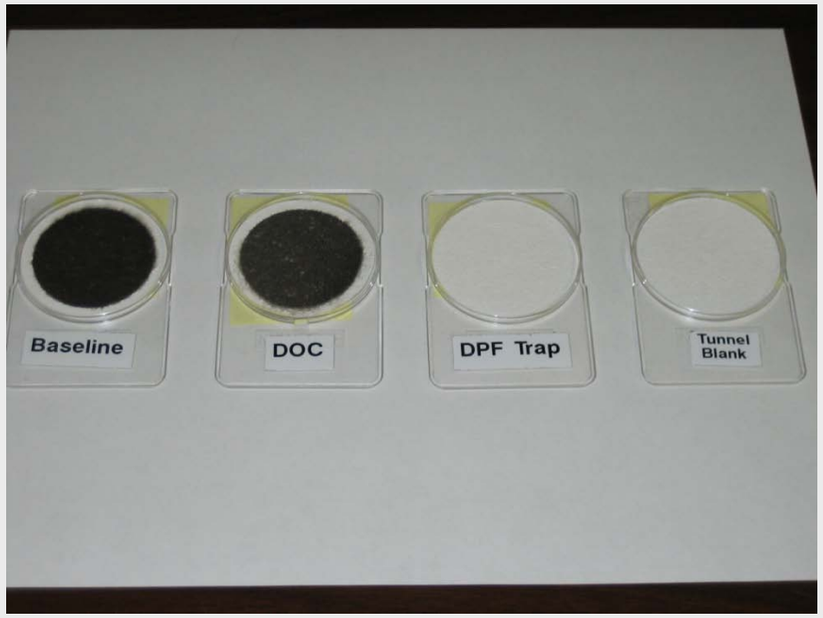
Accumulation mode

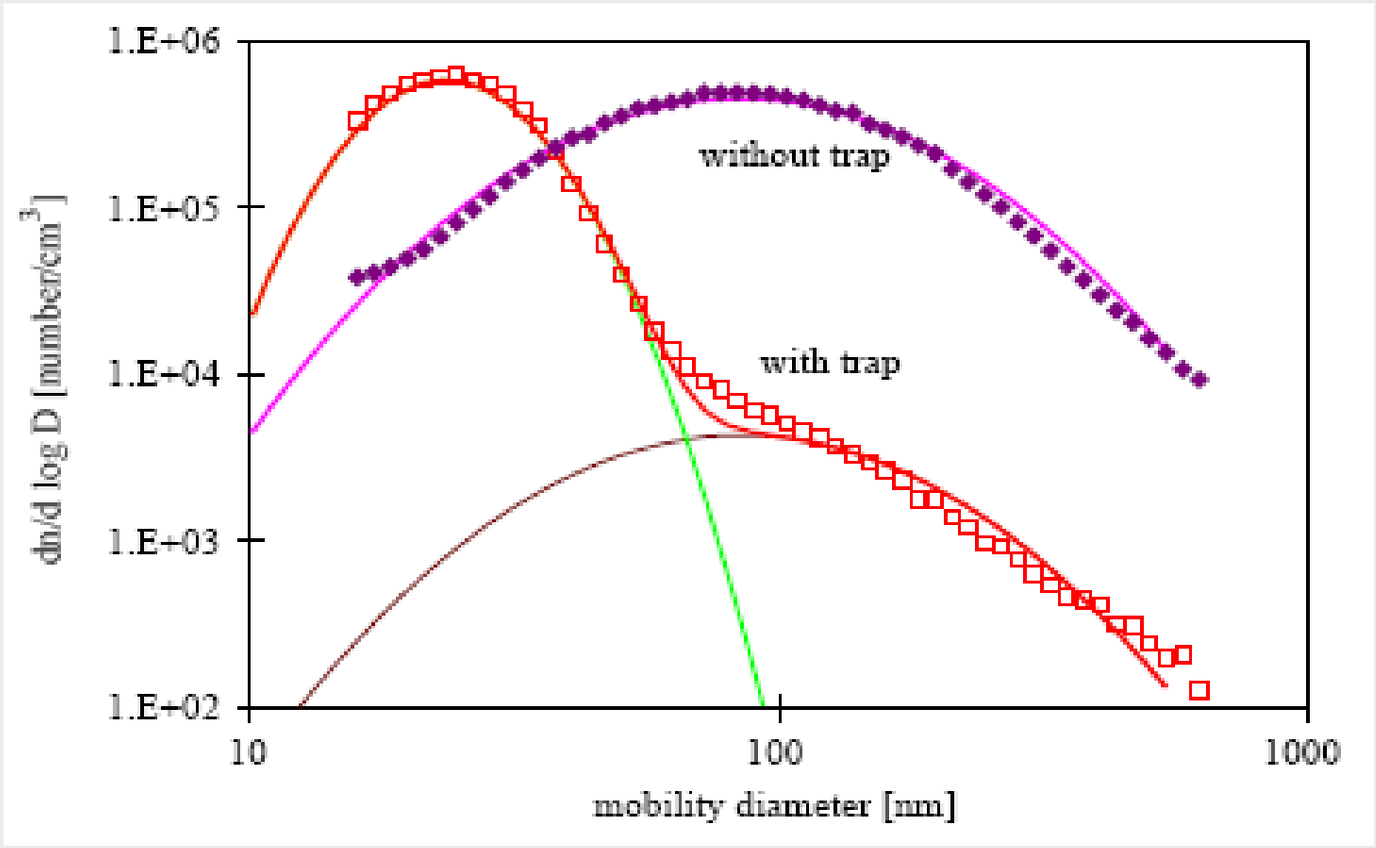
Nucleation mode

Schematic of the emissions and particle formation mechanisms in diesel exhaust. Solid lined indicate well established processes, dotted lined indicate processes under discussion

Schneider et al., Environ. Sci. Technol., 2005, 39, 6153-6161

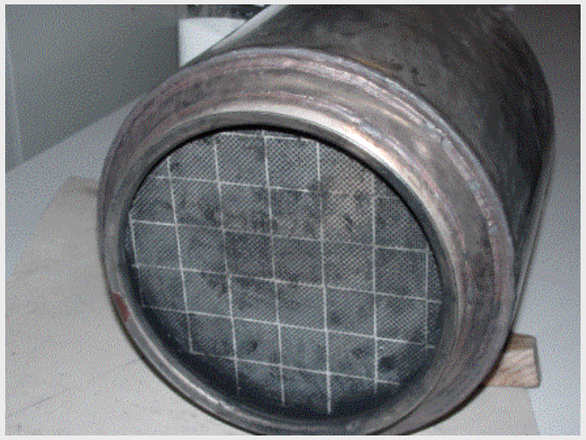
Effect of a Diesel Particle Filter

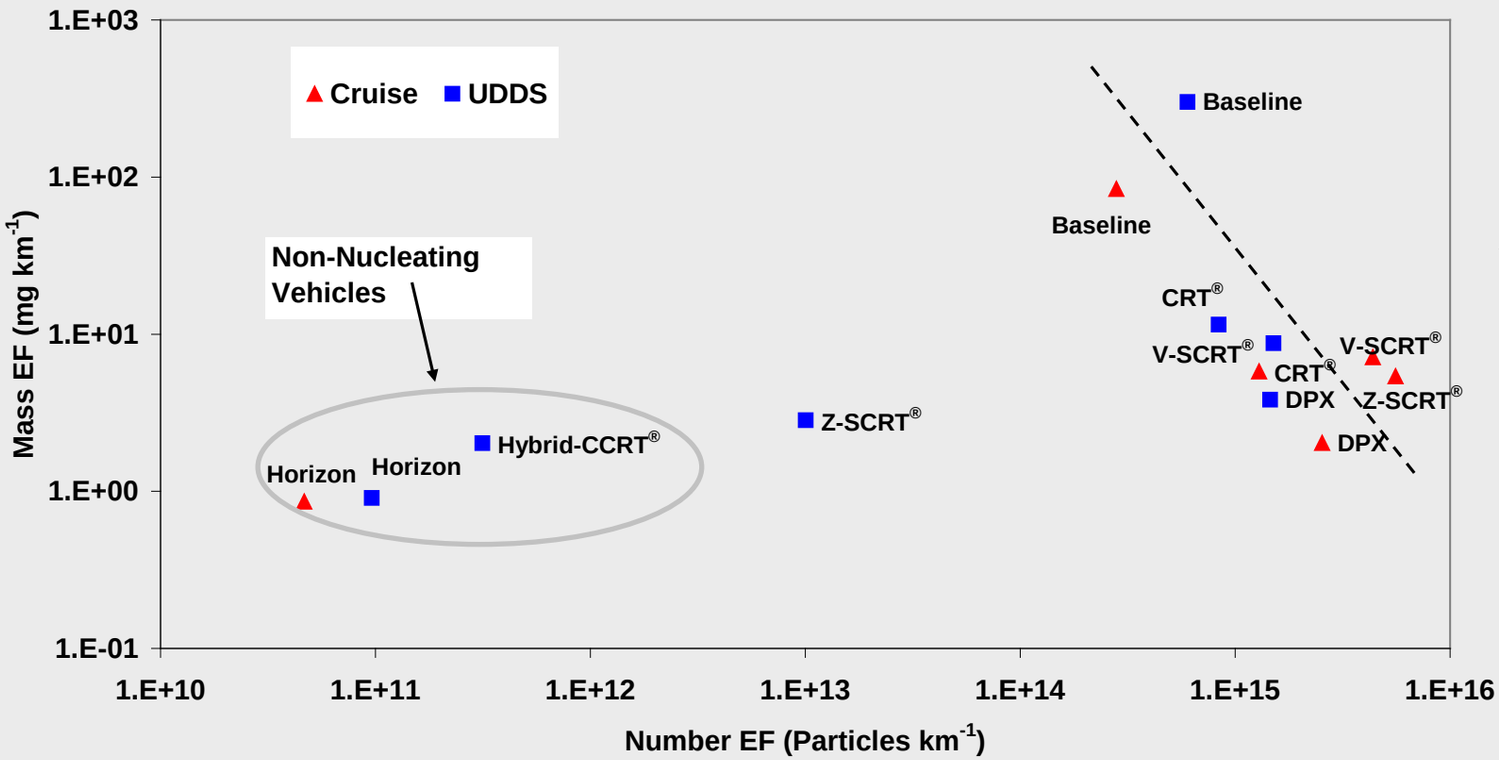




H. Burtscher / Aero.Sci. 36 (2005) 896-932

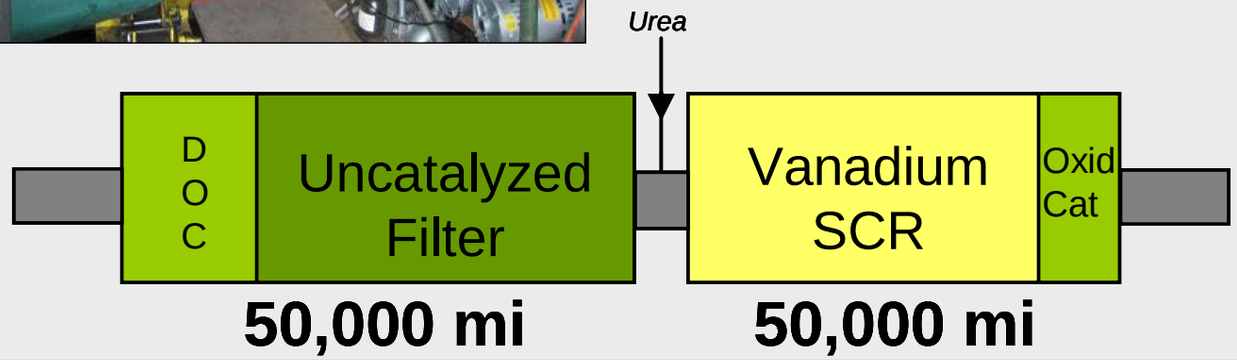
Number vs Mass Emission Factors

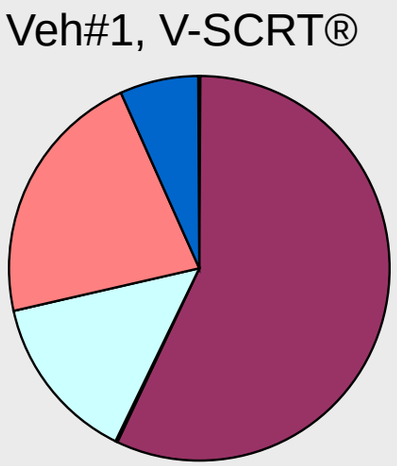


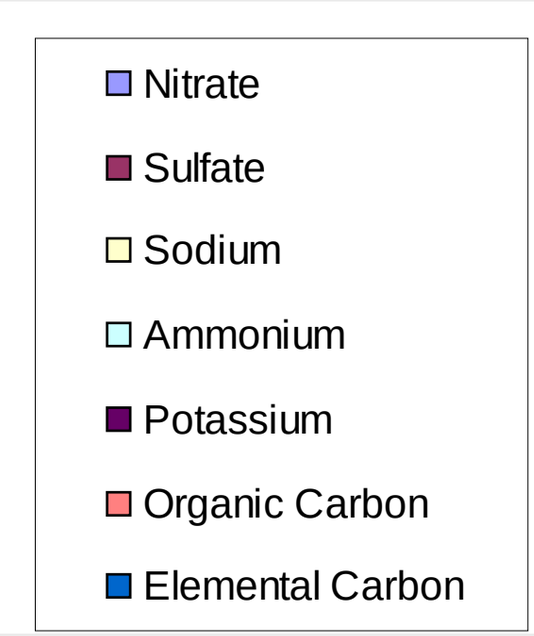


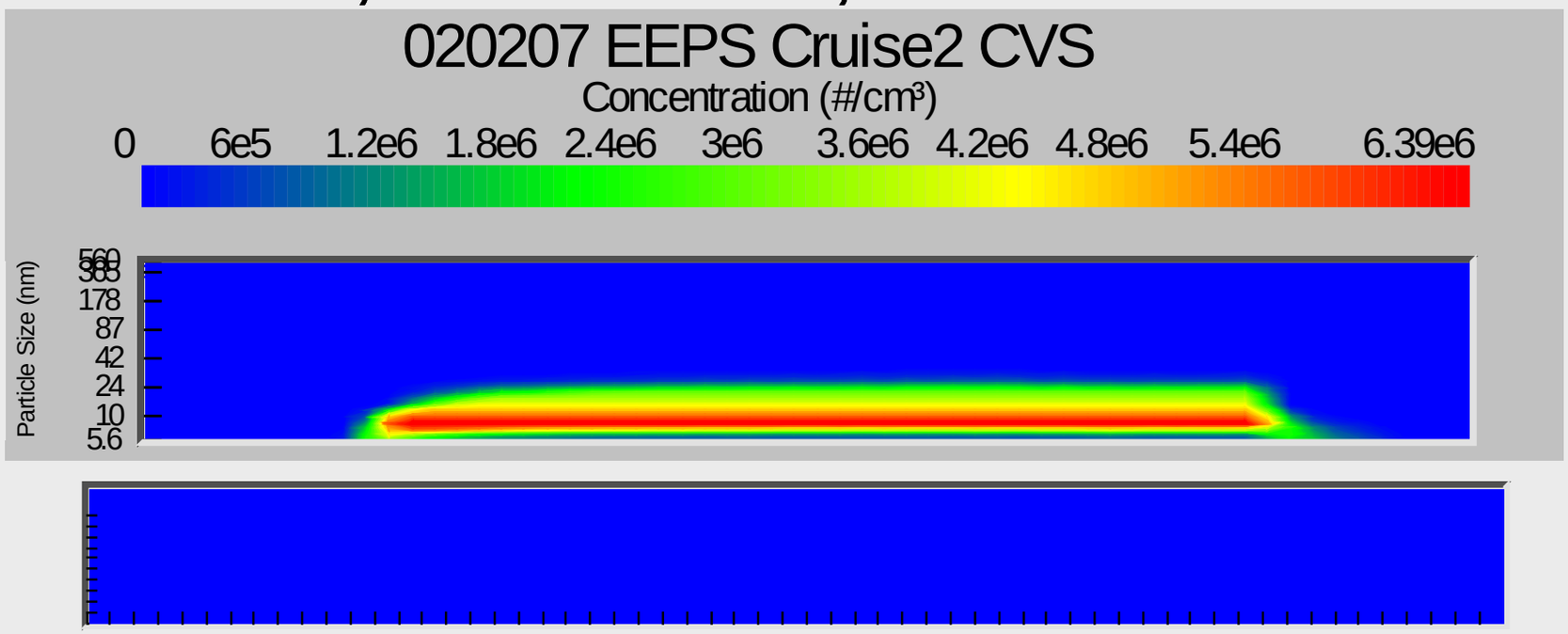
Biswas et al., Atmos.Env.42 (2008) 5622-5634

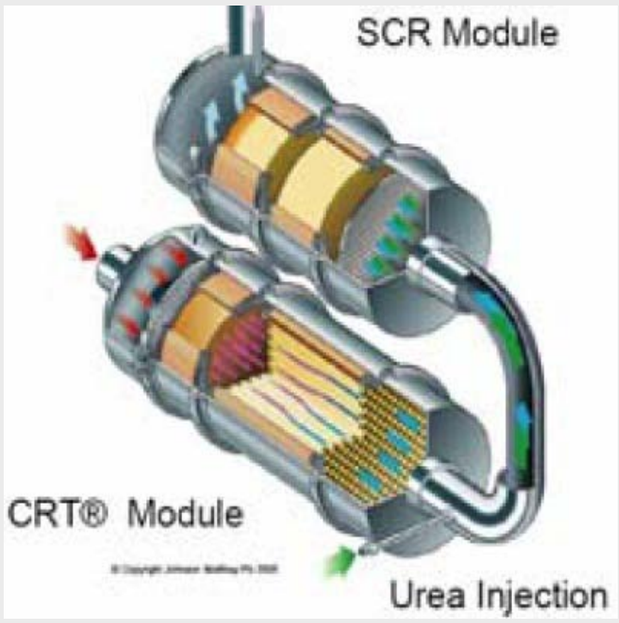
DPF + SCR for NO_X and PM reduction











Remaining Scientific Questions about Aerosols and Climate Impact

- Despite significant progress to date, understanding of sources, source strength, regional impacts, and global distributions of particles is still rudimentary
- How to resolve/understand differences of BC emission inventories?
- What is the overall magnitude of aerosol energy absorption?
- How to improve calculation of albedo changing BC impacts?
- What are the effects of all anthropogenic GHGs and aerosols on climate?

New research idea for FY08-09

Improve understanding the role of BC aerosols for climate change at the California regional level

- **Reduce uncertainty of BC levels on climate forcing**
- **Improve understanding of aerosol aging: role of BC mixing state against other particles**
- **How much of regional radiative forcing is due to local, regional, global sources of BC?**

Implications of Climate Change for Air Quality

“ significant synergies and co-benefits are possible through a concerted consideration of air quality and climate change policies”

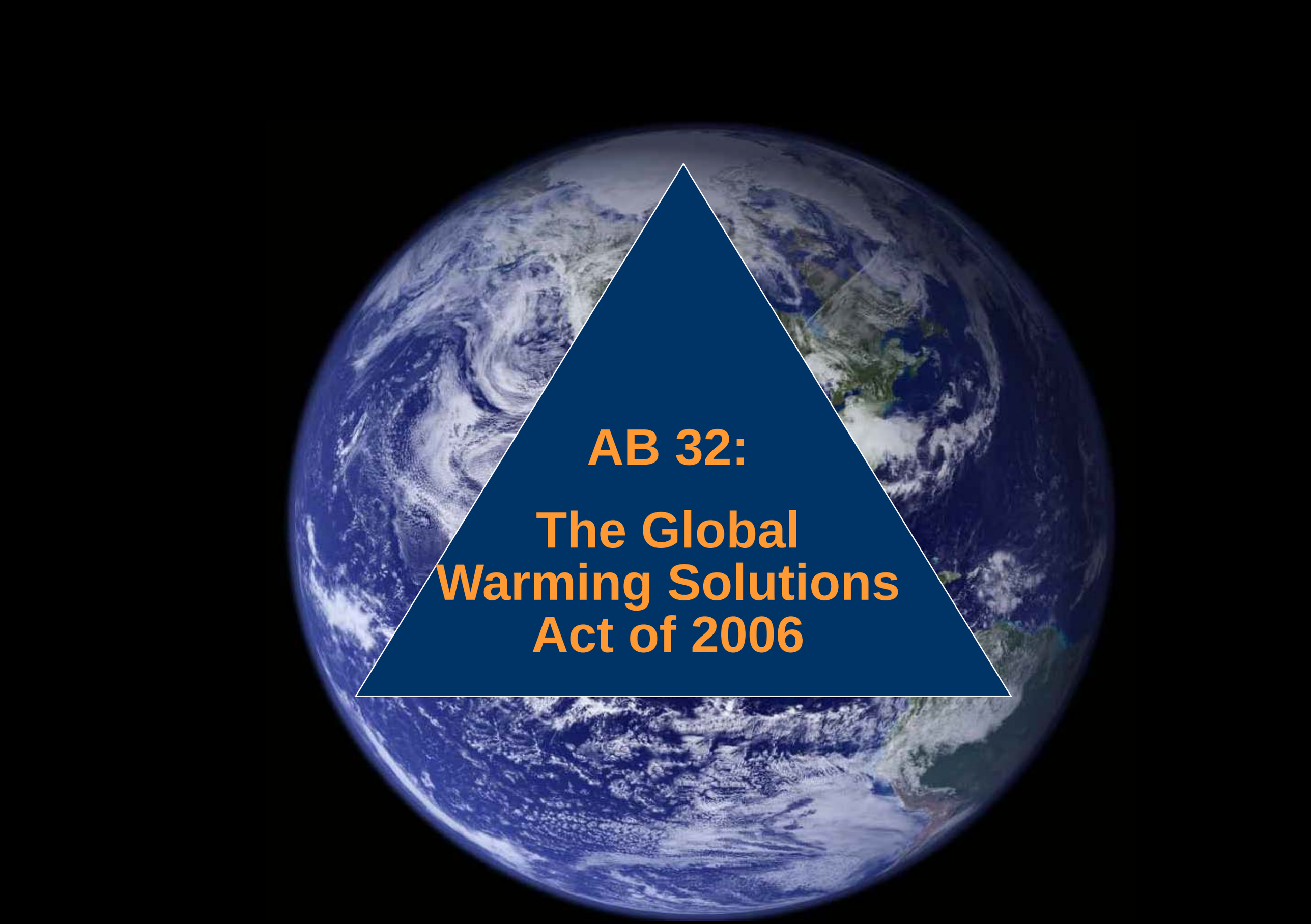
Williams, M.L.,”UK air quality in 2050-synergies with climate change policies,” Env.Sci.&Policy, ***2006***

Climate Forcers in California

Preliminary Calculations

Climate Forcer	$MMTCO_2E$	2005-2020 Change [a]
Kyoto (CO_2, CH_4, N_2O, HFC, PFC, SF_6)	~500	-15%
Ozone (CO, VOC, NO_X)	-5 – 25	-30%
Diesel PM	15 – 35	-85% [b]
Other PM	unknown	--
Montreal (CFC, HCFC)	~50	unknown

[a] CO_2 etc.: AB 32 target. CO, ROG, NO_X: CARB emission inventory for rules already adopted.
[b] Diesel PM: 2000 to 2020 Diesel Risk Reduction Plan target.


AB 32:
The Global Warming Solutions Act of 2006

California Global Warming Solutions Act of 2006 (Assembly Bill 32)

Sept 2006

AB 32 signed into legislation

Air Resources Board charged with monitoring and regulating sources of greenhouse gases in order to reduce emissions

Publish list of early actions in June

2007

Publish market and regulatory scoping plan

2008

Inventory baseline and reporting

2009

GHG limits and measures adopted

2010

Adopt enforceable early action regulations

2011

GHG limits and measures operative

2012

Reduce GHG emissions to 1990 levels

2020

~174 MMTCO2E of reductions needed

Reduce GHG emissions to 80% of 1990 levels

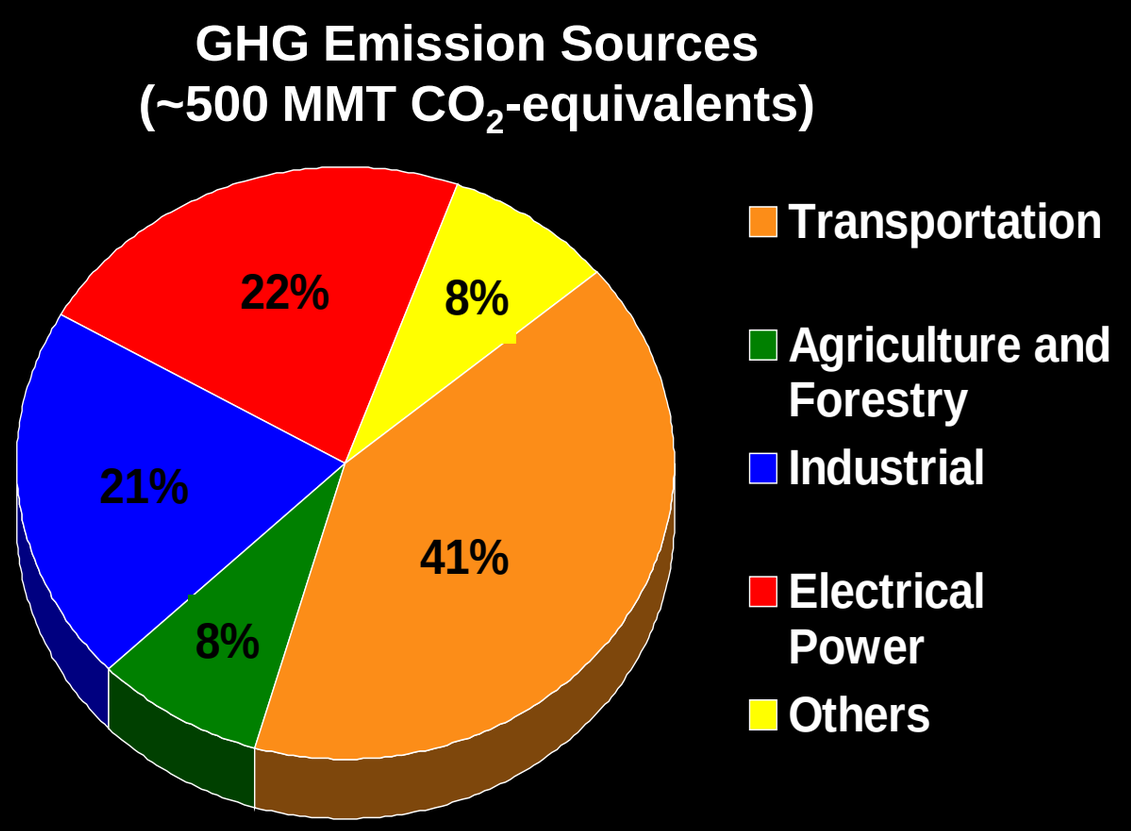
2050

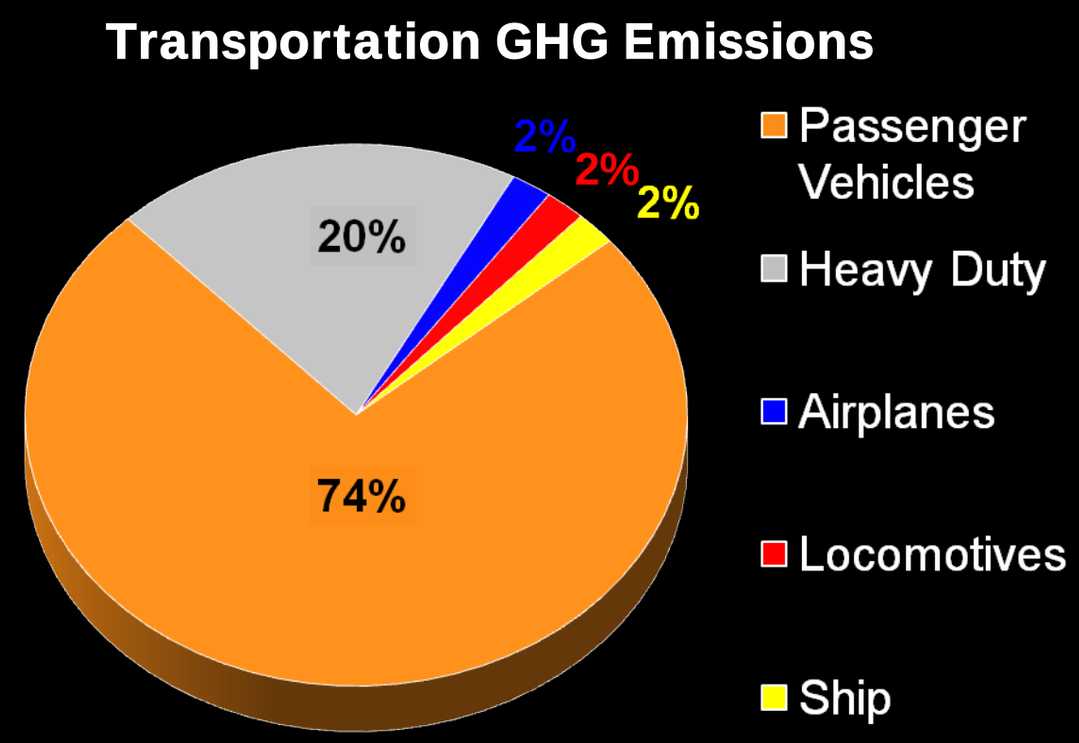
AB 32 Scoping Plan

- **Overall policy framework**
- **Describe how California will reduce GHG emission levels to 1990 levels by 2020**
- **Provide vision for a low carbon future – 2050**
- **Being developed by ARB and other State agencies**
- **All sectors to be evaluated**

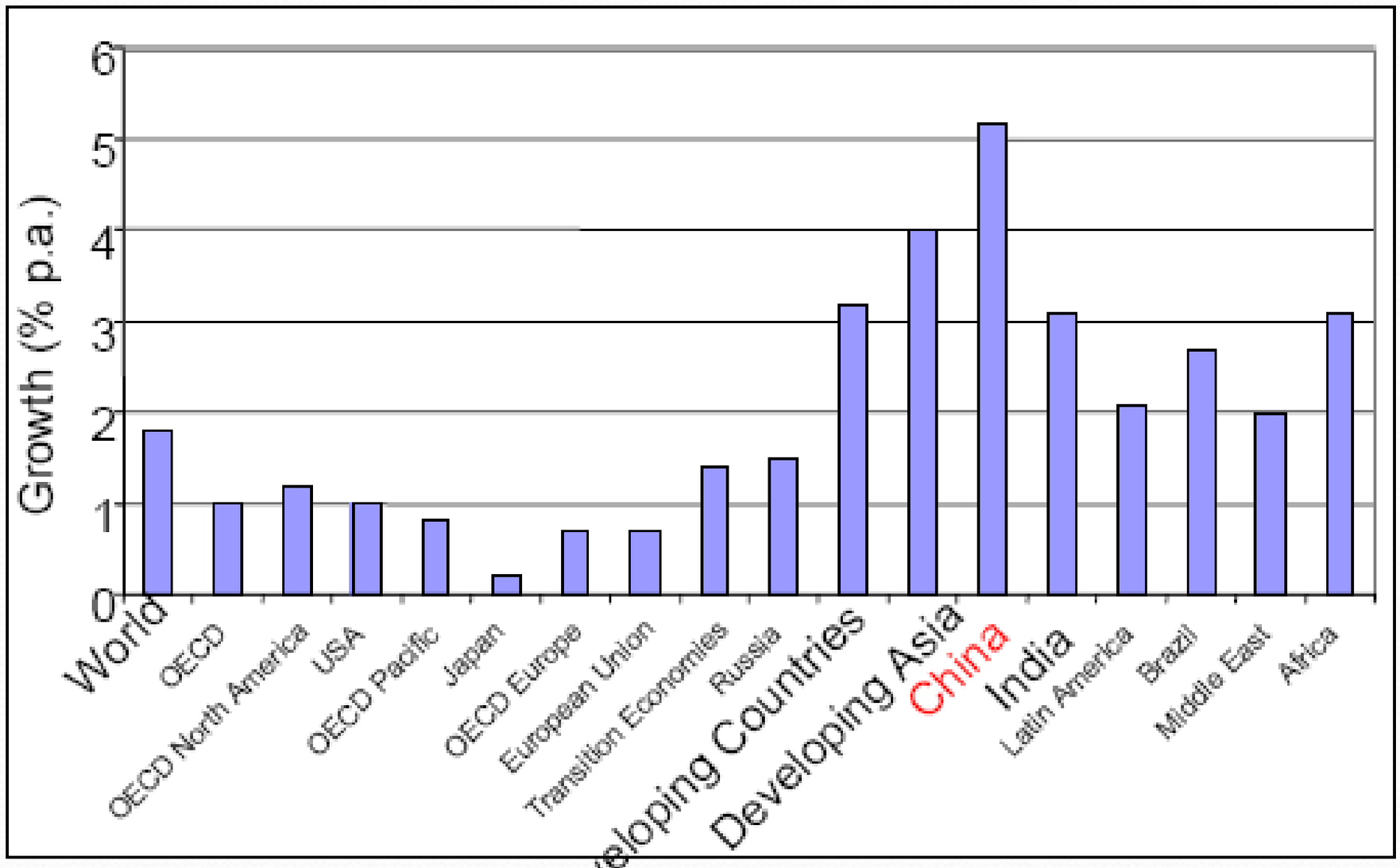
Electricity and natural gas
Transportation (vehicles and fuels)
Business and industry
High-GWP gases
Land use
Agriculture and forests

BROOKS


GHG Emission Sources
(~500 MMT CO_2-equivalents)
22%
8%
21%
41%
8%
Transportation
Agriculture and Forestry
Industrial
Electrical Power
Others


Transportation GHG Emissions
2%
2%
2%
20%
74%
Passenger Vehicles
Heavy Duty
Airplanes
Locomotives
Ship

Energy Demand in the Transport Sector: Annual Average Growth Rate (%) by Region 2004 - 2030

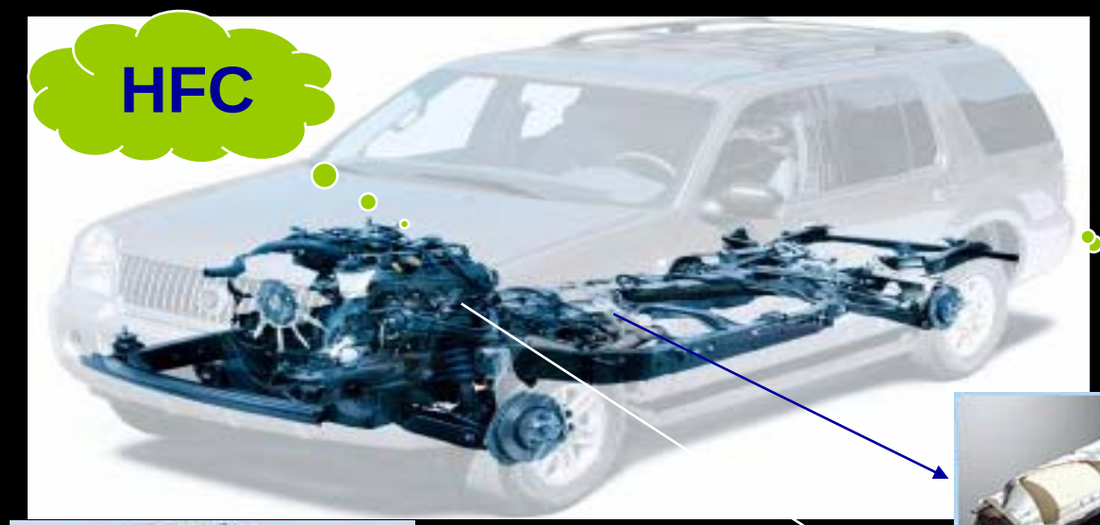


In 2004, 94 % of transport energy was based on fossil oil.

The share will only slightly decrease to 93 % in 2030.

Source: IEA WEO 2006

First-in-the-world motor vehicle GHG emissions regulation (AB1493-Pavley)



Engine

Transmission

A/C compressor

CO_2

Methane

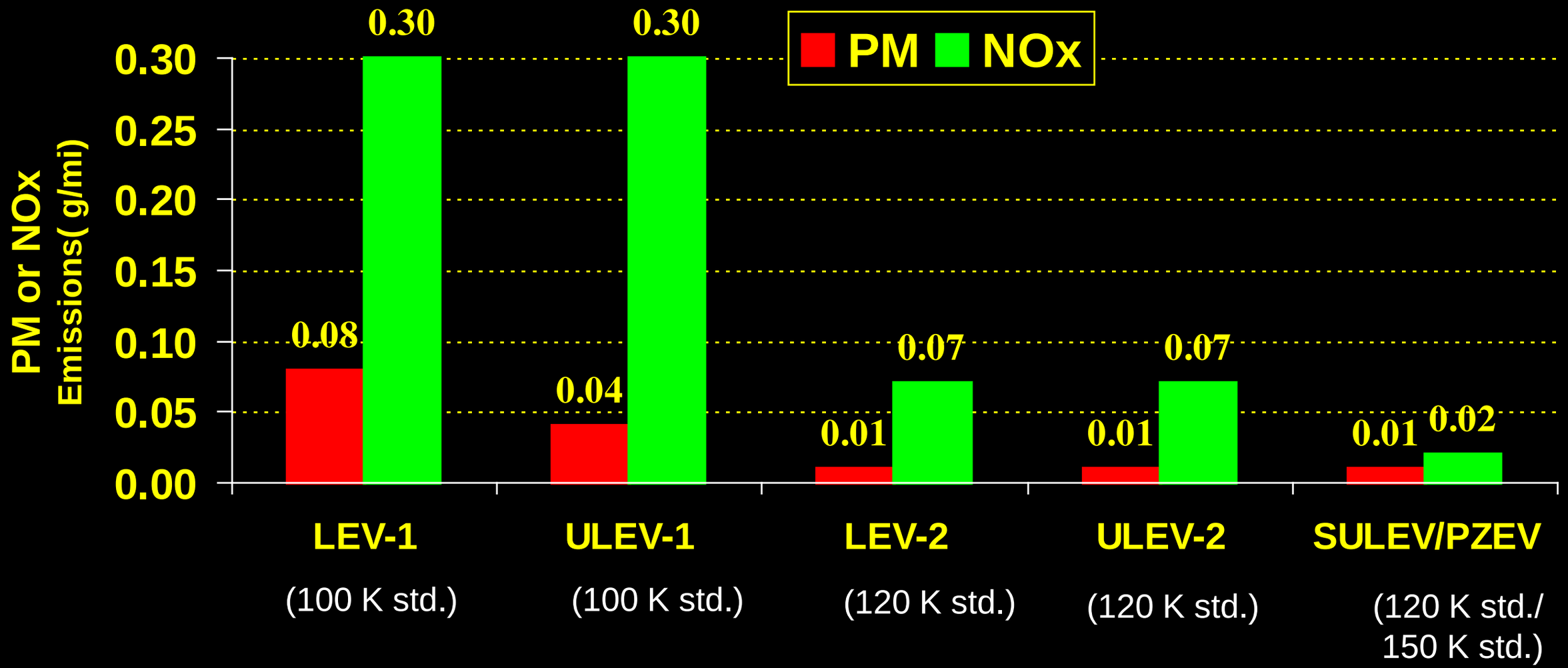
Nitrous Oxide

HFC

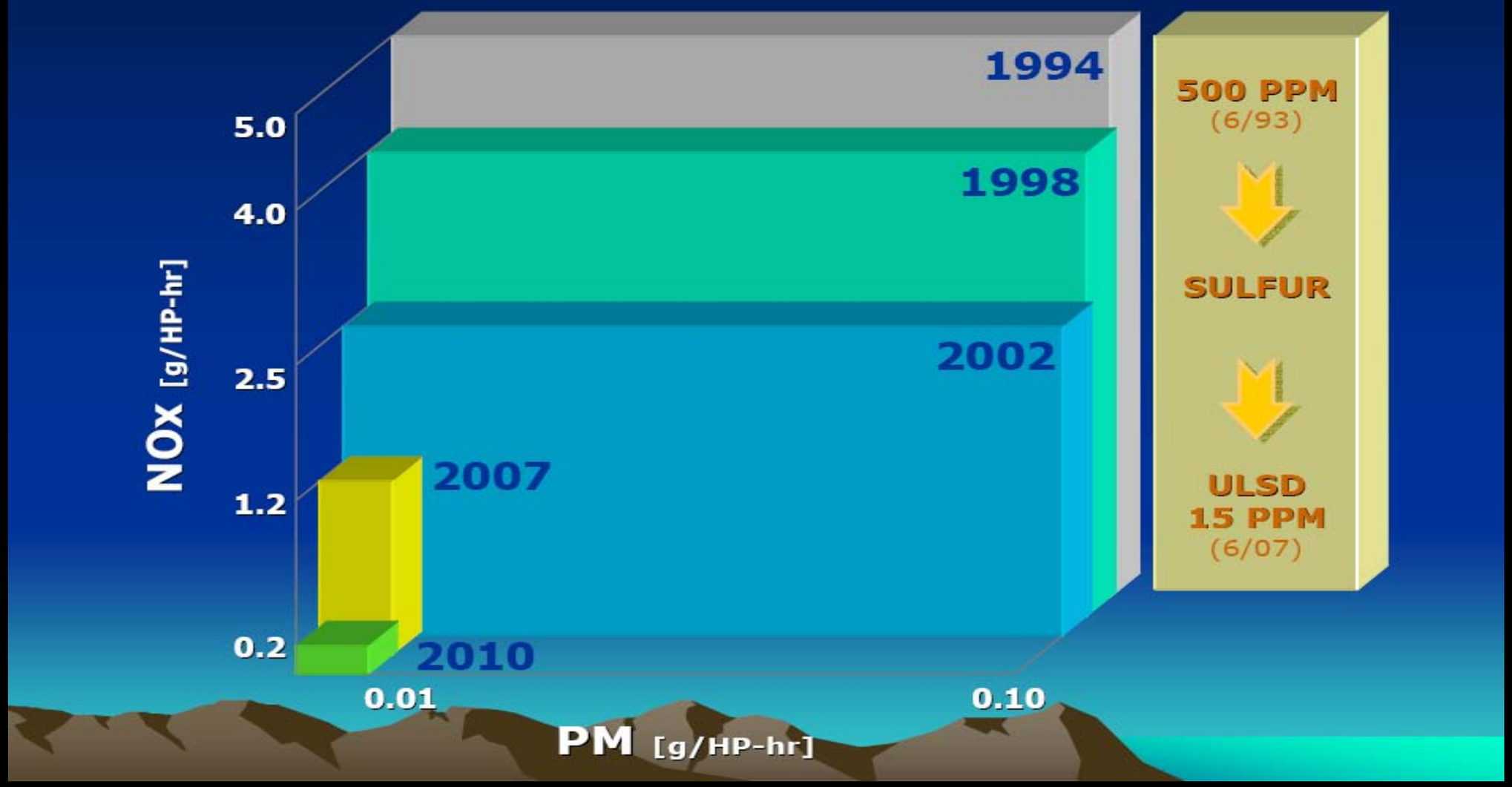
CO_2

- Mandates the reduction of GHG emissions from passenger vehicles. Expected reductions approximately 30 $MMTCO_2E$ by 2020

Future Emission Standards Continue March to Near-Zero Emission Categories for Light-Duty Vehicles



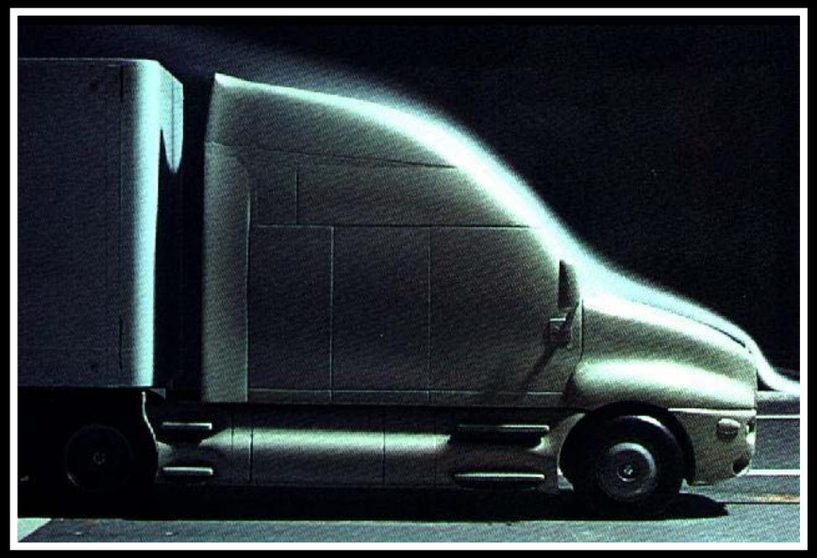
Evolution of US On-Highway Heavy Duty Standards



M. Walsh, Global Trends in Diesel Vehicle Pollution Control and Fuel Development, A 2006 Update," Motor Vehicle Emissions Control Workshop, Honk Kong, China, May 2006

AB 32 Early Actions

SmartWay Truck Efficiency



Reduction potential ~ 1.3 $MMTCO_2E$ by 2020

Anti-Idling

Reduction potential ~ 0.7 $MMTCO_2E$ by 2020

Transportation Efficiency

Reduction potential ~ 9 $MMTCO_2E$ by 2020

Port Electrification

Reduction potential ~ 0.5 $MMTCO_2E$ by 2020

Sector Responsibilities under Cap-and-Trade Program
(MMTCO2E in 2020)

Sector	Projected 2020 Business-as-Usual Emissions		Projected 2020 Emissions After Implementation of Other Recommended Measures		Preliminary 2020 Emissions Limit under Cap-and-Trade Program
	By Sector	Total	By Sector	Total	
Transportation	225	512	163	400	365
Electricity	139		94		
Commercial and Residential	47		42		
Industry	101		101		

Summary

- **Consensus on integration of non-Kyoto climate species into future climate protection policy as research closes data gaps**
- **The California Global Warming Solutions Act of 2006 (AB 32) provides a significant opportunity to leverage co-benefits of GHG and air pollution mitigation**
- **Program addresses Kyoto GHGs and some ODSs for the climate forcing**
- **New scientific evidence can inform and influence policy direction**