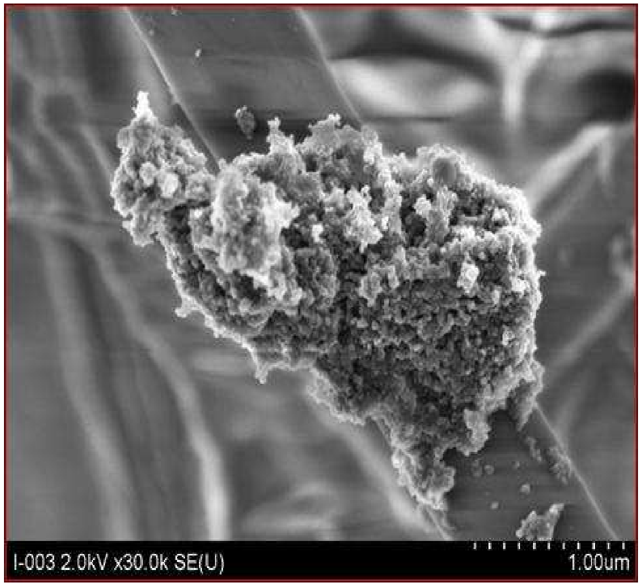
2009 International Workshop on Black Carbon in Latin America
October 19, 2009
Mexico City



Black carbon controls in California:

emissions, abatement, and knowledge gaps

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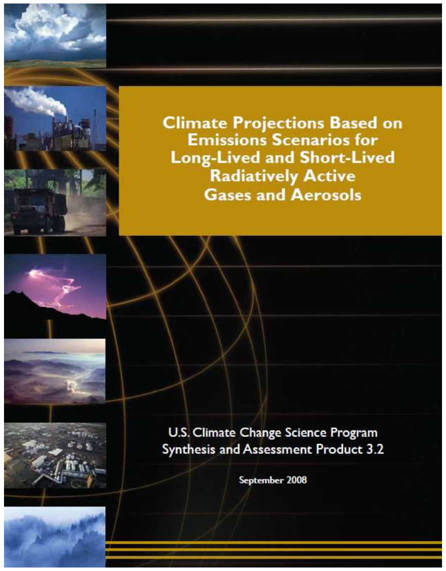
[2]Mechanical Engineering, West Virginia University

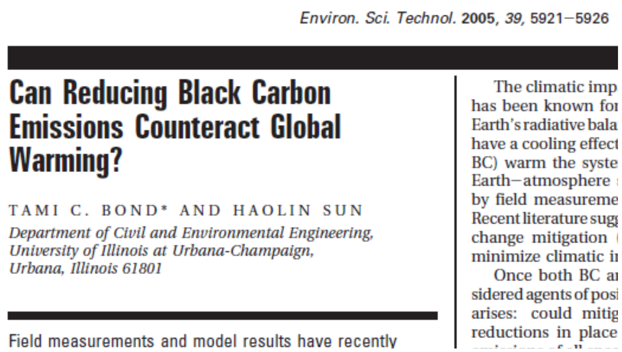
Picture courtesy of Dr. D. Su, Fritz-Haber Institute

The case for BC abatement is well made in the scientific/policy mainstream



Air Quality and Health

Reduction of emissions from surface transportation offers greatest potential for substantial, simultaneous improvement in local air quality and reduction of global warming in North America, US CC Sci. Program, Synthesis and Assess. Product 3.2, 2008



Environ. Sci. Technol. 2005, 39, 5921–5926

Can Reducing Black Carbon Emissions Counteract Global Warming?

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Field measurements and model results have recently

The climatic imp
has been known fo
Earth's radiative bala
have a cooling effect
BC) warm the syste
Earth–atmosphere
by field measureme
Recent literature sug
change mitigation
minimize climatic i
Once both BC a
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arises: could mitig
reductions in place

NEWS FEATURE

CLIMATE'S SMOKY SPECTRE

With their focus on greenhouse gases, atmospheric scientists have largely overlooked lowly soot particles. But black carbon is now a hot topic among researchers and politicians. **Jeff Tollefson** investigates.

American Clean Energy and Security Act 2009 (House)
Carper's Amendment to Interior Appropriations Bill (Senate)

– direct EPA to find the most cost-effective ways to reduce BC emissions

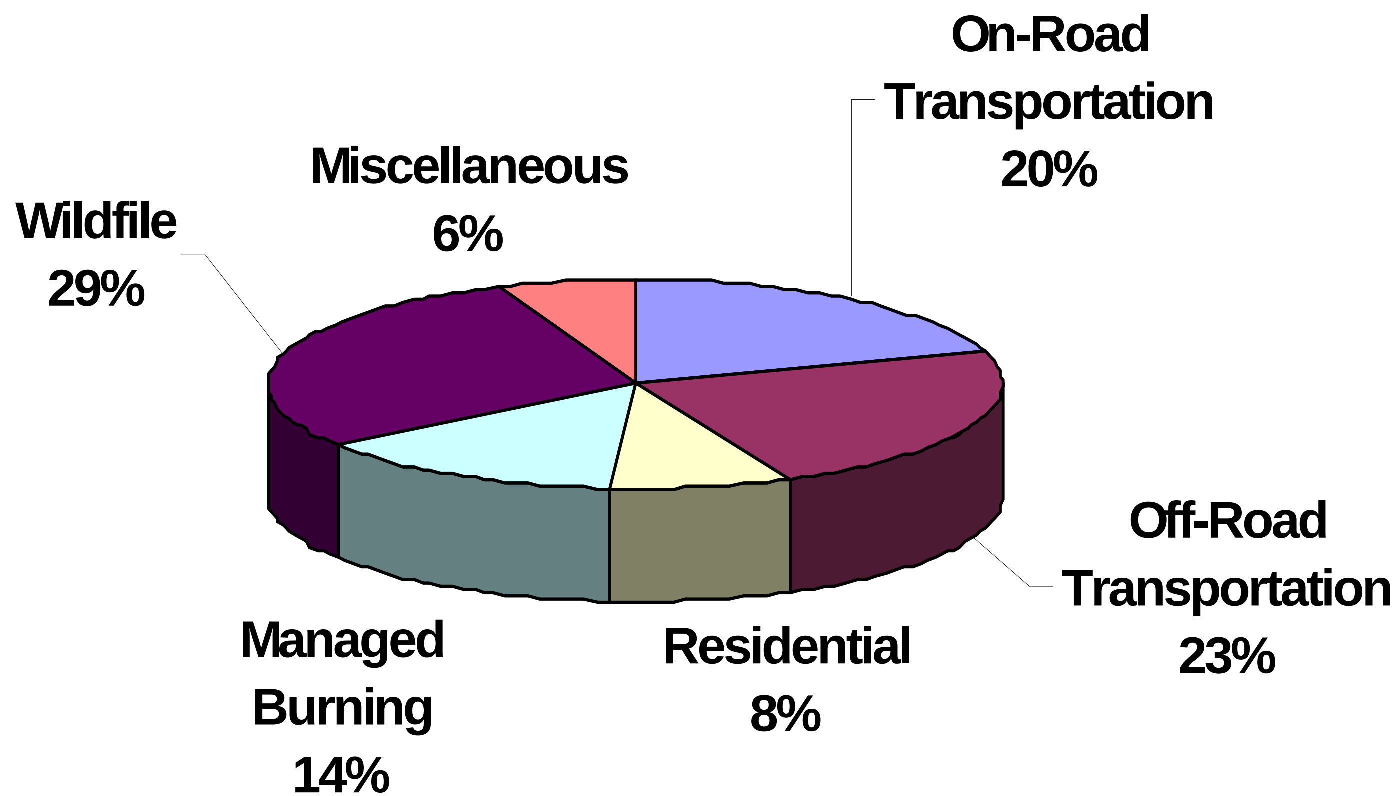
First, the caveats

- **You can't manage it if you can't measure it**
  - Optical and thermal methods (to measure BC and EC) in contradiction
  - No single universally accepted standard (yet!) for BC or EC measurement
  - Separation of organic carbon (OC) from EC is difficult
  - Discrepancies due to local aerosol characteristics and meteorology
- **Properties most relevant to climate**
  - Optical (absorption), mixing state (aged aerosol), size distribution not yet measured consistently
- **BC climate impacts differ at global, regional, and local scales**
- **Principal uncertainties: projection of future emissions and indirect BC effects***
- **Preferred inventories are bottom-up approaches**
  - Experimental data scant for specific emission factors and activities
- **California-specific emission factors account for**
  - Unique mix of fuels, combustion technology, operating conditions, and aggressive emission control programs

References:

1) Bond, T.C., Bergstrom, R.W. (2006). Light absorption by carbonaceous particles: An investigative review, Aero Sci and Tech 40, 27-67.
2) M. Moffet, R. C., and Prather, K. A.(2009): In-situ measurements of the mixing state and optical properties of soot with implications for radiative forcing estimates, PNAS, 106(29), 11872-11877, doi: 10.1073/pnas.0900040106.
3) CARB study (04-307) by Chow et al. (2008).
*4) US Climate Change Science Program, Synthesis and Assess. Product 3.2, 2008

California BC emissions



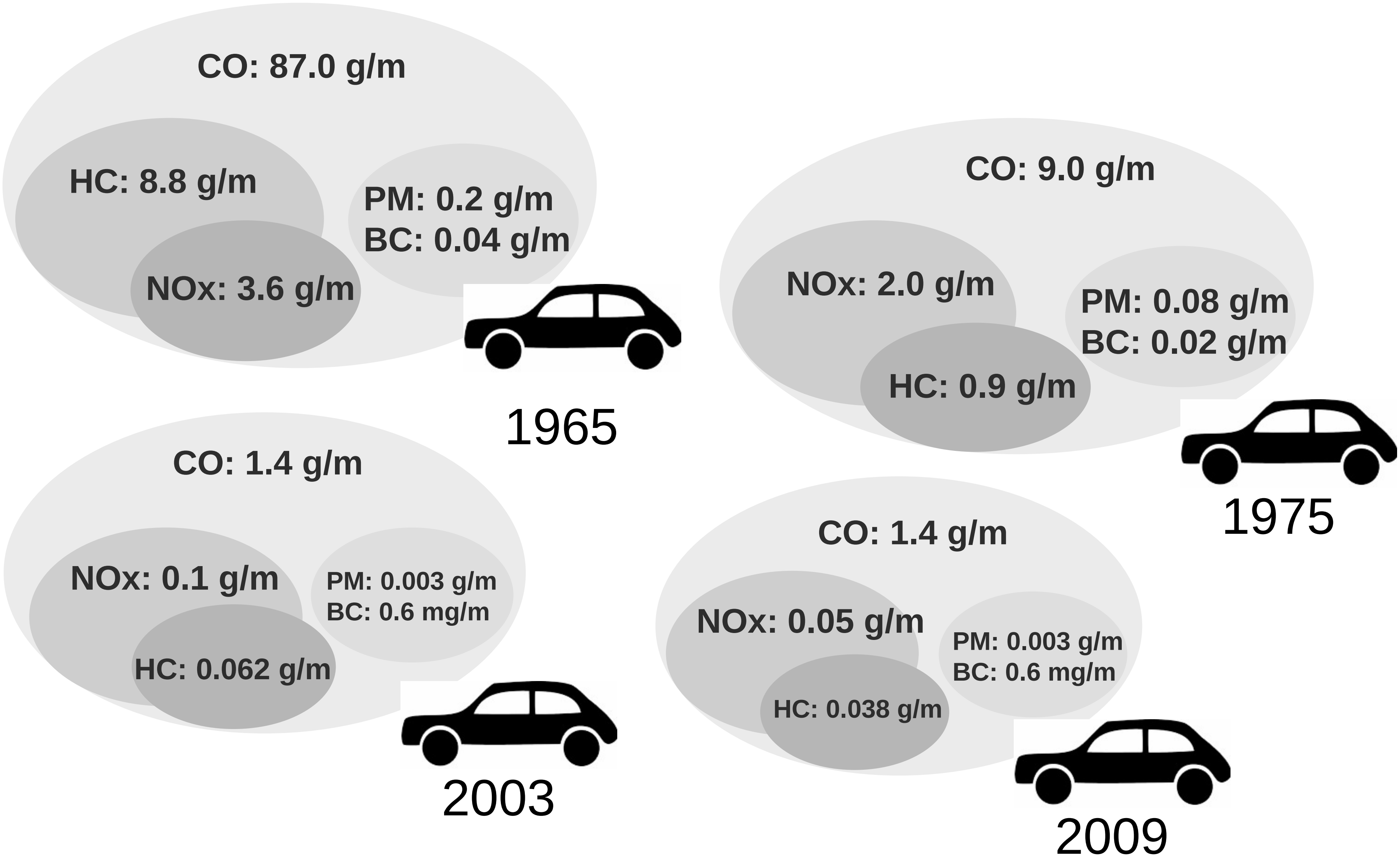
2006

- PM2.5$_i$ from emissions inventory
- PM2.5$_i$ X [BC/EC and OC]$_i$
- BC/EC and OC for source$_i$ (i.e, source profile)

Sources: Chow, J.C., Watson, J.G., Lowenthal, D.H., and Chen, L.W.A., "Climate Change – Characterization of Black Carbon and Organic Carbon Air Pollution Emissions and Evaluation of Measurement Methods," CARB study (04-307), 2008; CARB emissions inventory: www.arb.ca.gov/ei/ei.htm

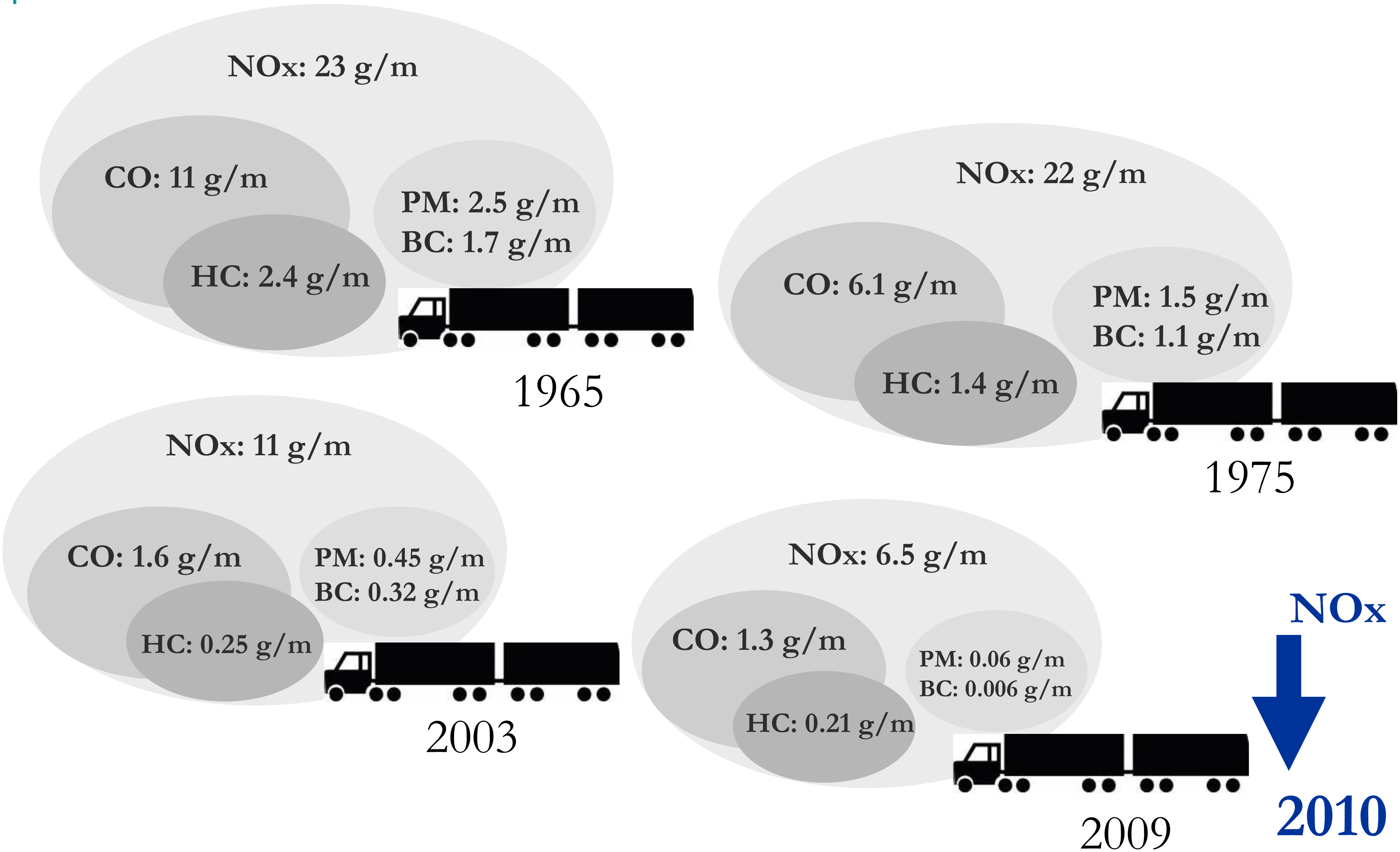
Transportation emissions are key focus for air quality and climate

Trends in gasoline car emissions



Source: PM emission factors from US EPA Kansas City Study

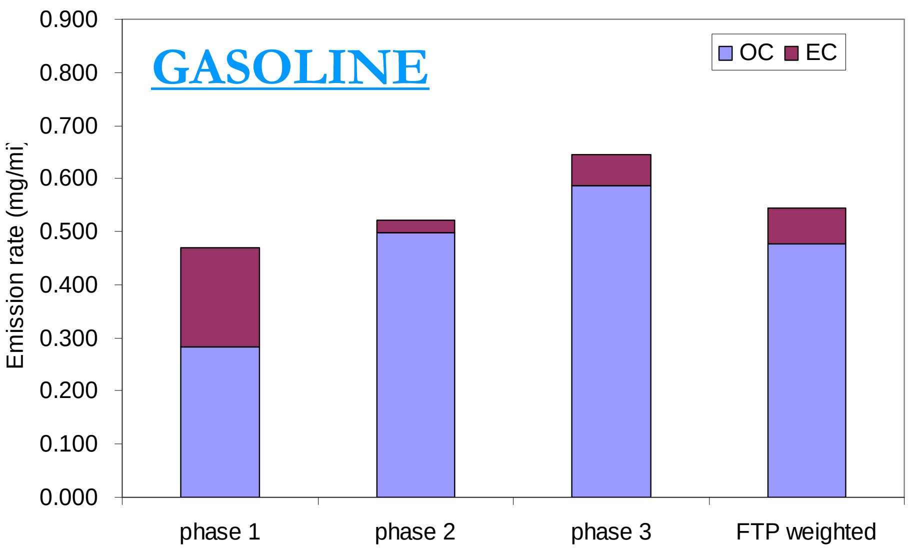
Trends in diesel truck emissions



Data source: CARB's EMFAC model

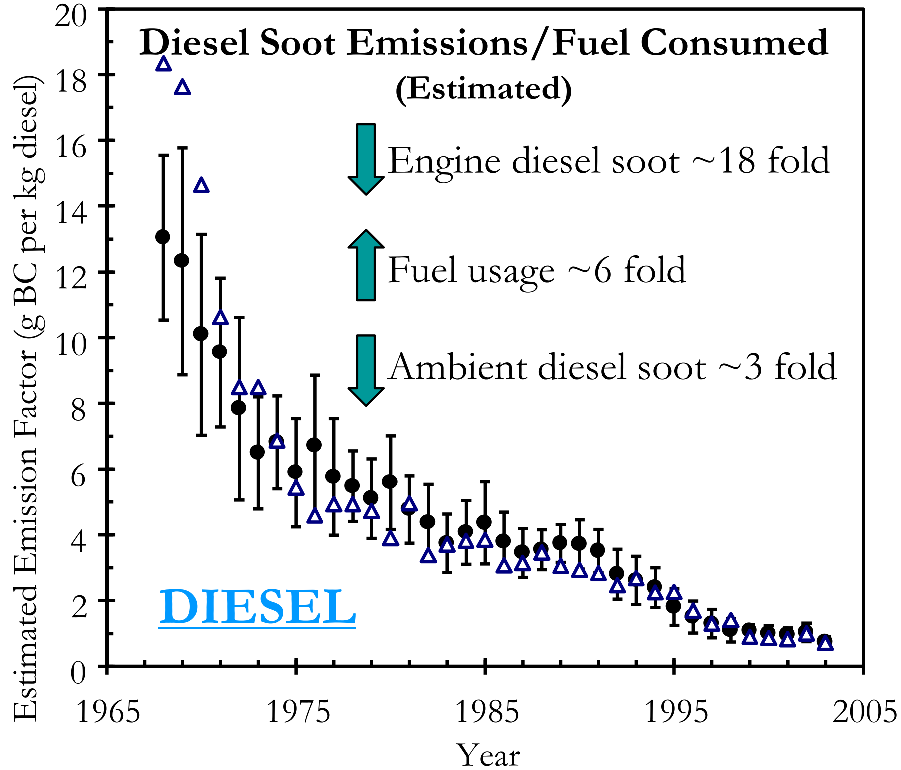
Research confirms progress on PM reductions

SULEV limit = 10mg/mi



Fleet averaged emission rates of OC and EC for SULEVs, not corrected with background.

Li, W., Collins, J.F., Norbeck, J.M., Cocker, D.R., and Sawant, A., "Assessment of Particualte Matter Emissions from a Small Fleet of In-Use ULEV and SULEV Vehicles," SAE Tech. Paper 2006-01-1076



Kirchstetter,T.W., Aguiar, J., Tonse, S., Fairley, D., and Novakov, T., "Black carbon concentrations and diesel vehicle emission factors derived from coefficient of haze measurements in California: 1967-2003," Atmospheric Environment, 42(3): 480-491, 2008

Diesel control

Health = #1 policy driver for diesel PM/BC control

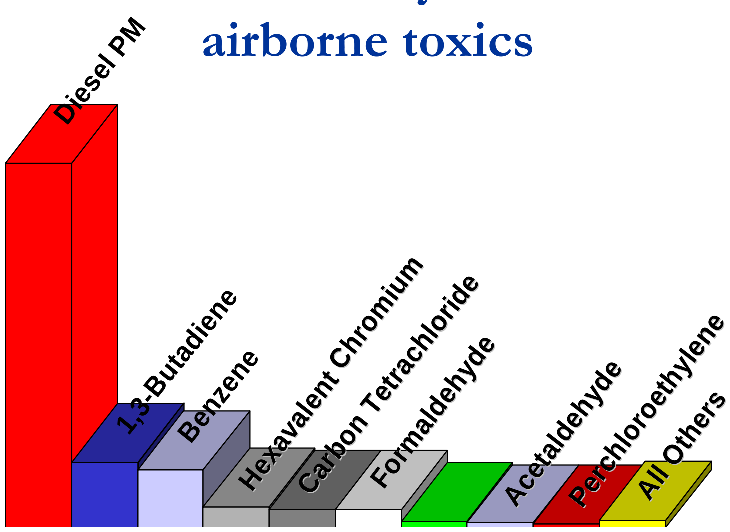
Air pollution and premature death*

California estimates for 2005

Pollutant	Annual Deaths*
PM2.5	18,000
Ozone	540
Toxic Air Contaminants	400

* At least a factor of two uncertainty.

Relative cancer risk by inhalation from airborne toxics



Impact of diesel PM on California*

Premature death (3500 per year*)

Lung cancer (250 per year)

Decreased lung function in children

Chronic bronchitis

Increased hospitalizations

Aggravated asthma

Increased respiratory symptoms

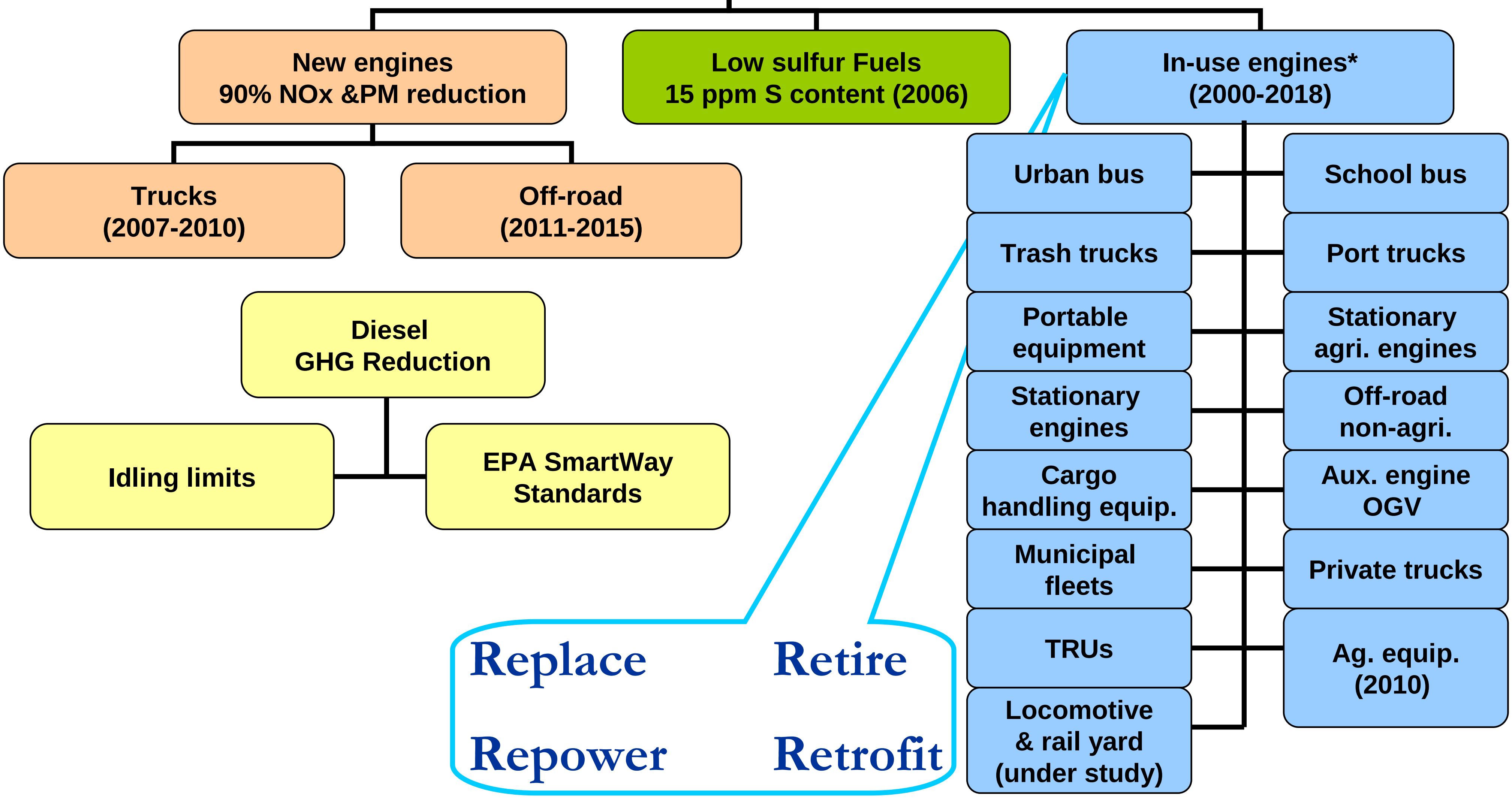
Lost work days

Reduction in visibility (10-75% of total)

* www.arb.ca.gov/research/health/pm-mort/pm-mort.htm

*Source: California Air Resources Board. Methodology for Estimating Premature Deaths Associated with Long-term Exposures to Fine Airborne Particulate Matter in California. May 22, 2008. Staff Report. http://www.arb.ca.gov/research/health/pm-mort/pm-mortdraft.pdf

CARB's Diesel Risk Reduction Plan (DRRP)
(Diesel PM 85% below 2000 in 2020)



*With millions $ per year in incentive funding provided

www.arb.ca.gov/diesel/dieselrrp.htm

Diesel engine applications covered by DRRP

On-road Vehicles


On-road Truck


Passenger Bus


Concrete Mixer


Hay Squeeze


Water Truck


Fuel Tank Truck


Reefer Van


Drill Rig


Dump Truck


Tow Truck

Off-road Vehicles


Aerial Lift


Loader


Backhoe Loader


Ground support equipment


Skid Steer


Belt Loader


Dozer

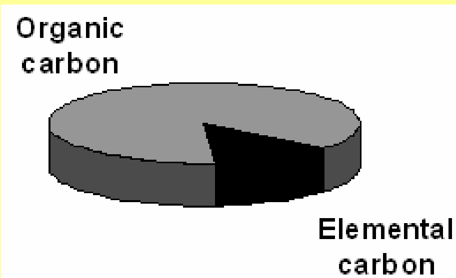

Mast Forklift


Telescopic Forklift

BC fraction in PM vehicle emissions

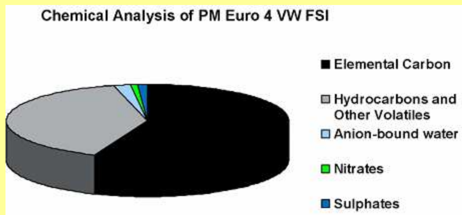
Gasoline Car

Conventional



- PM emissions < 1 mg/mile
- << current SULEV PM standard of 10 mg/mile
- Most PM is OC
- BC increases for high PM emitters

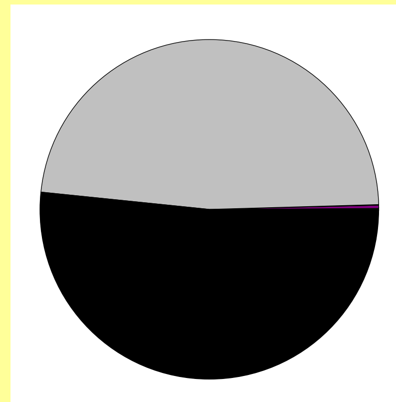
Direct injection



- Very good for CO_2 reduction
- still < current SULEV PM standard
- But PM > conventional gasoline
- Also > particle counts
- Most PM is BC or soot like diesel

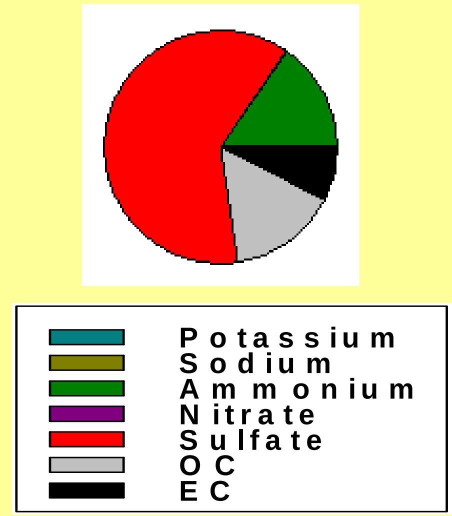
Diesel Truck

Pre-2007



- PM standard at 100 mg/bhp-hr
- Most PM is EC or soot

2010

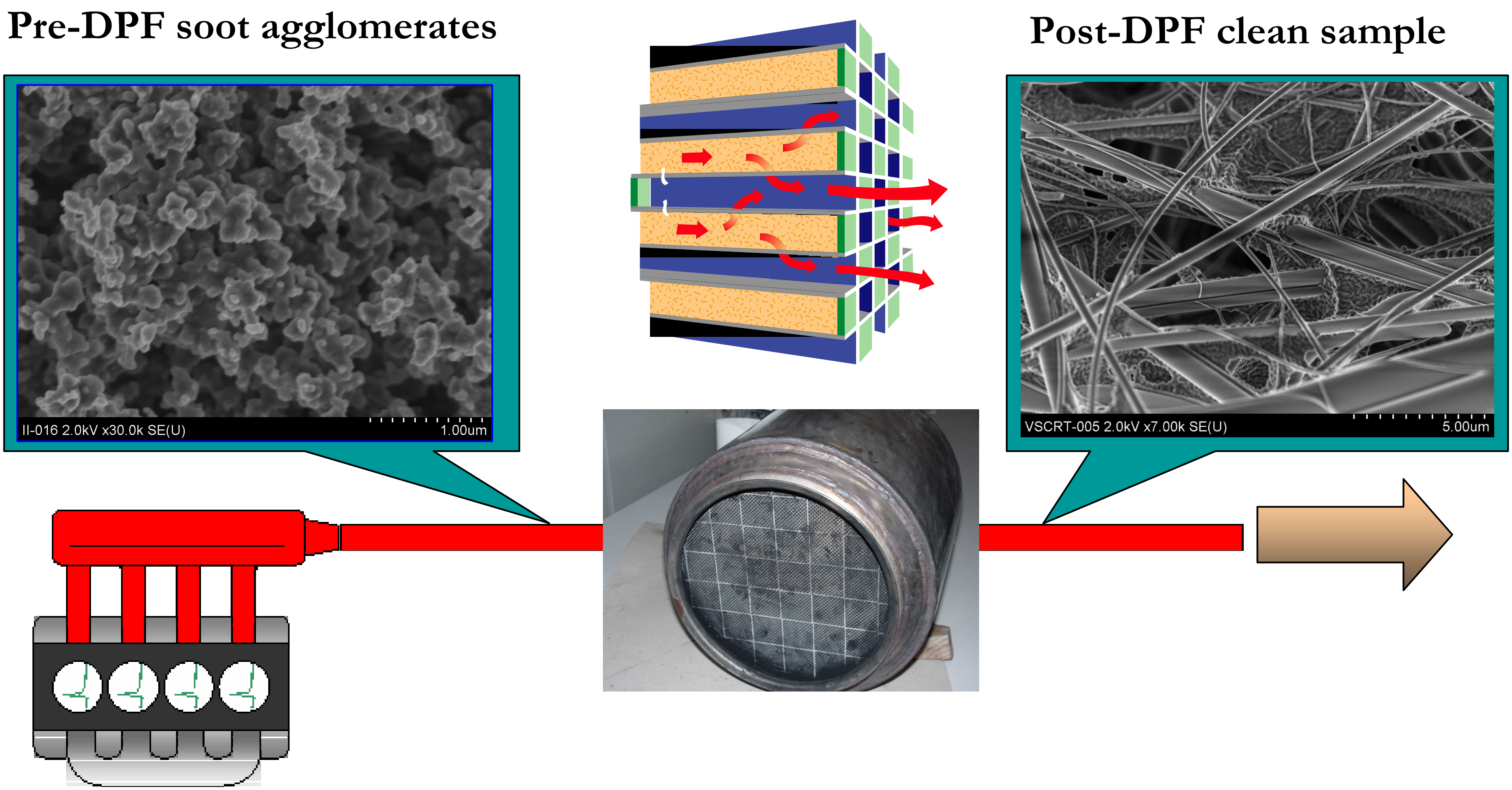


- PM emissions << standard 10mg/bhp-hr
- Little BC (EC or soot)

CARB evaluating LEV III (more stringent PM standard)

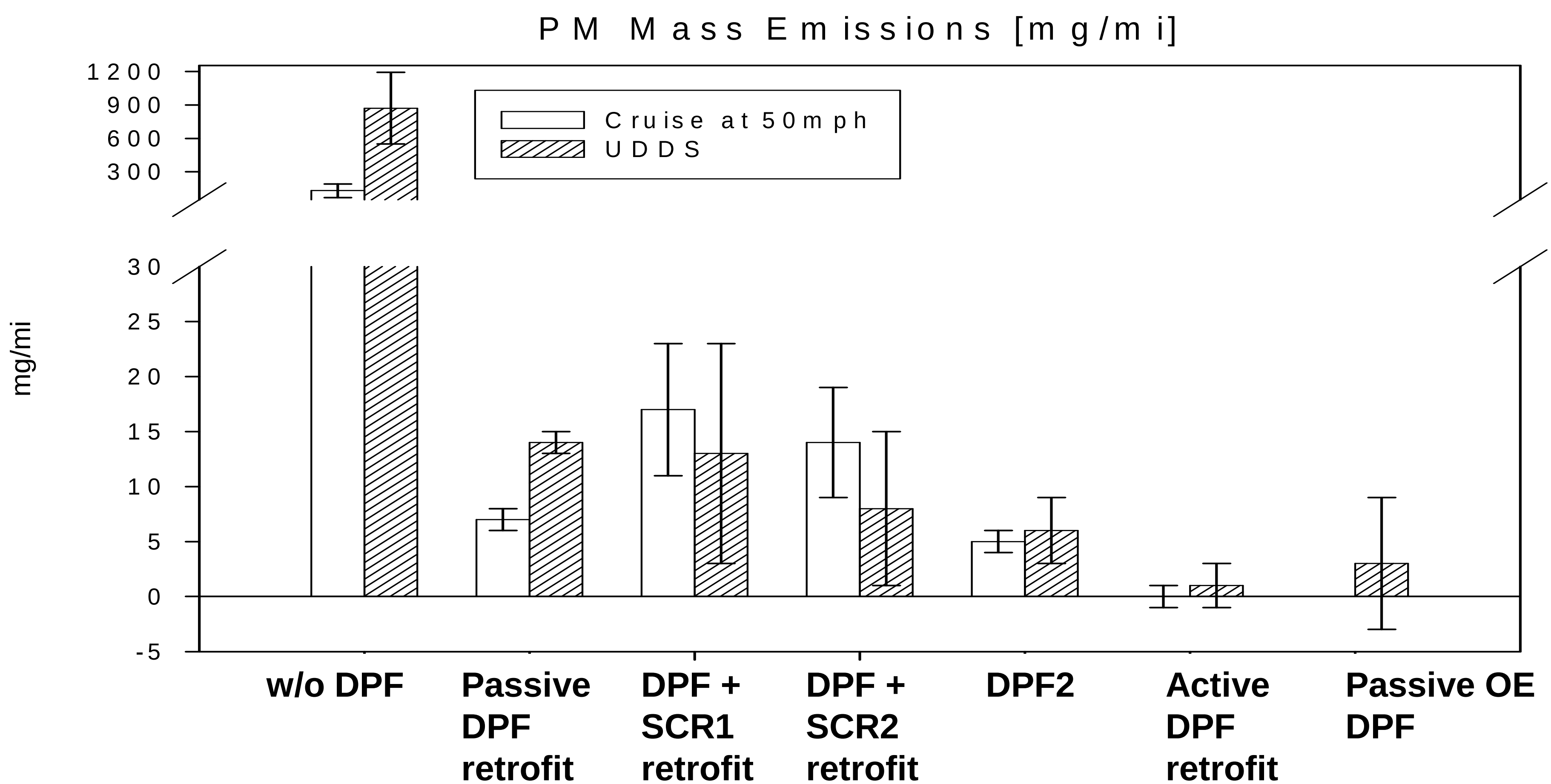
Sources: CARB's Phase II HDV emissions study, Ricardo/UK; Li, W., Collins, J.F., Norbeck, J.M., Cocker, D.R., and Sawant, A., "Assessment of Particualte Matter Emissions from a Small Fleet of In-Use ULEV and SULEV Vehicles," SAE Tech. Paper 2006-01-1076

DPF (for retrofit or OE installation) is game changing solution



SEM images courtesy of Dr. D. Su, Fritz-Haber Institute

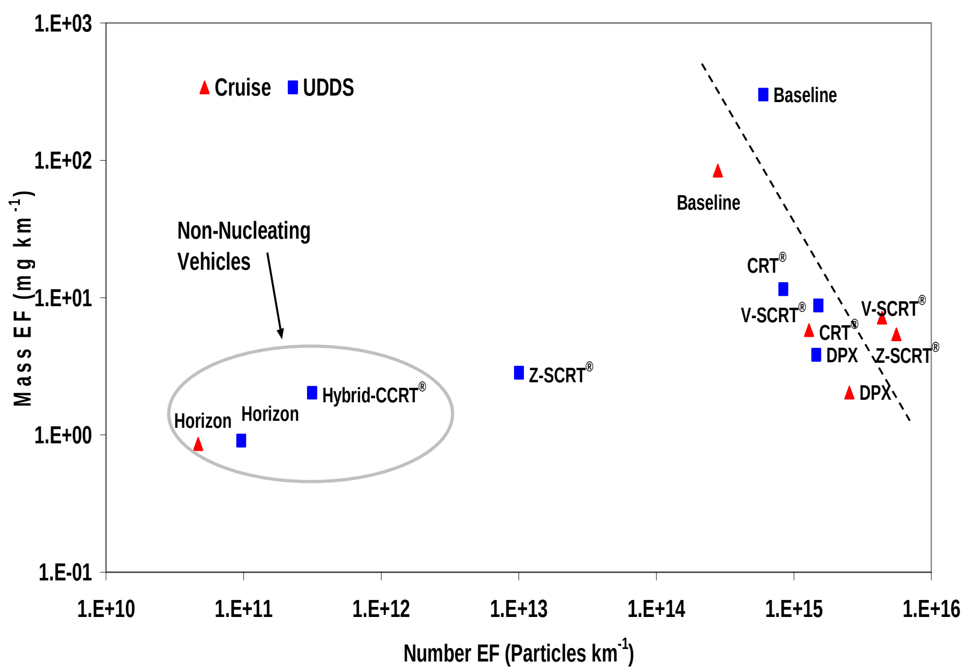
Significant PM(BC) reductions by various types of DPFs

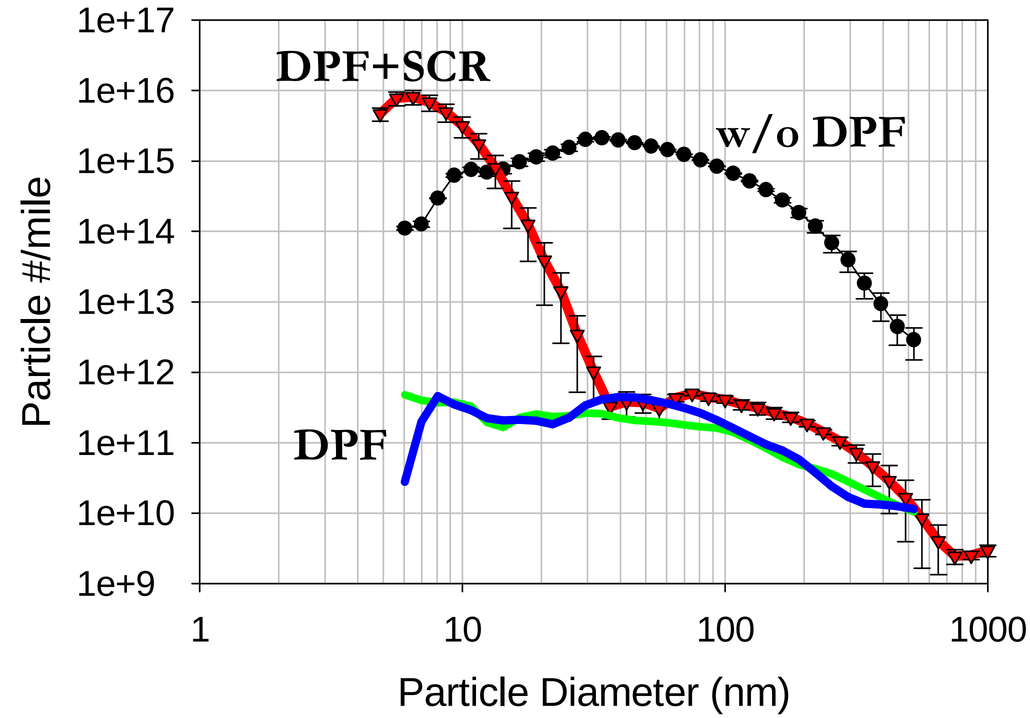


Source: Herner, J.D., Huai, T., Collins, J., Robertson, W., Dwyer, H., Hu, S., and Ayala, A., "The effect of advanced aftertreatment for PM and NOX control on heavy duty truck emissions," *Environmental Science and Technology,* **2009**, 43, 5928-5933

Clean diesel exhaust (Post-DPF particles)

EC(soot or BC) is eliminated; if particles present, they are mostly very small sulfate

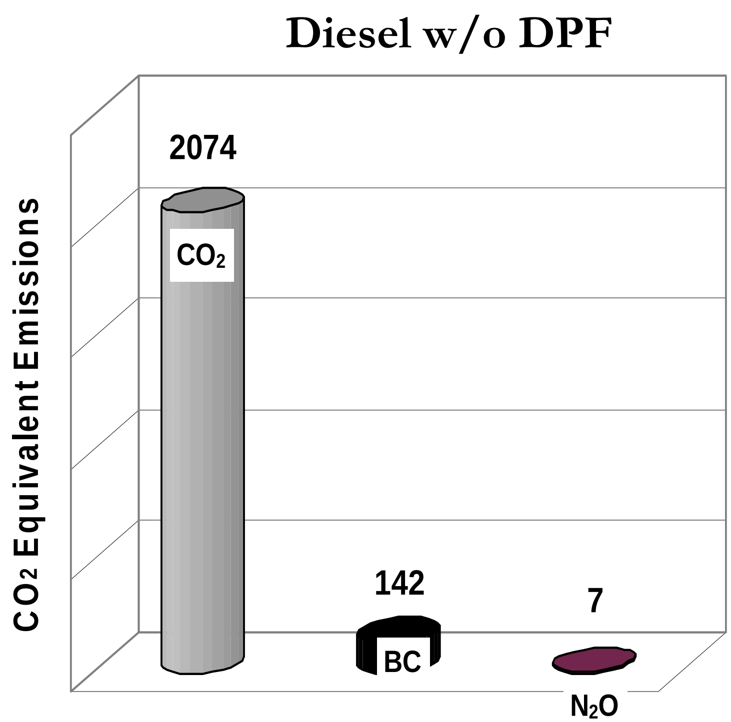


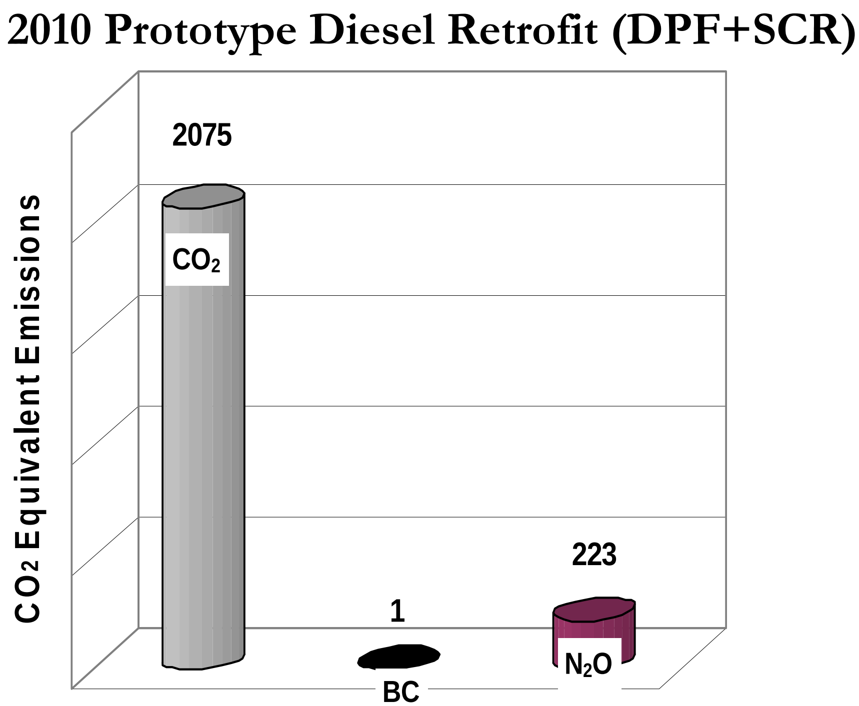


Biswas, S., Hu, S., Verma, V., Herner, J.D., Robertson, W.H., Ayala, A., and Sioutas, C., "Physical Properties of Particulate Matter from Newer Heavy-Duty Diesel Vehicles Operating with Advanced Emission Control Technologies," *Atmospheric Environment*, 42 (**2008**) 5622-5634.

Hu, S., Herner, J.D., Robertson, W., Huai, T., Collins, J., Dwyer, H., and Ayala, A., "Nucleation Mode Particle Emissions from In-use Heavy Duty Vehicles Equipped with Diesel Particulate Filter (DPF) and Selective Catalytic Reduction (SCR) Retrofits," *Environmental Science and Technology,* **2009**, In preparation

Global warming emissions





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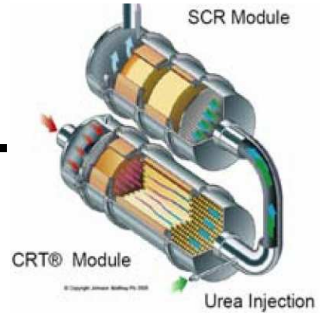

Other BC sources

Southern California Wildfire

Managed Burning

Residential -Fireplace

Residential wood burning

- Mandatory wood burning curtailment when air quality is poor in winter (e.g., in Bay Area, Sacramento, San Joaquin Valley, South Coast)
- Wood stoves & fireplace change out incentive program to replace older polluting units with cleaner units (e.g., $150-750 voucher in the Sacramento County)

Managed burning

- ARB Smoke Management Program provides guidelines for agricultural and prescribed burning operations in California (effective in 2001)
- Agricultural burning prohibited unless no economically feasible alternatives available (e.g., in San Joaquin Valley)
- Working groups involving different stakeholders to find alternatives to burning (e.g., use as a fuel in biomass plants)

Closing remarks

- Science supports co-benefits of BC reductions for air quality and climate protection
- California implementing clear policies
- Taking aggressive action for reducing PM (and BC)
  - Major programs in place for mobile sources (gasoline, diesel, etc.)
  - Tangible progress
  - Diesel PM reductions is key focus for air quality and health
  - Concurrent climate benefit from BC reductions
- New policies will emerge
  - California's LEVIII program
  - US Congress directs EPA to look into BC