California’s Diesel Control Program and its Black Carbon Co-benefits

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Many Areas of State Do Not Meet Federal Air Quality Standards

- Federal 8hr Ozone
- Federal PM2.5

Map of California showing nonattainment areas for Federal 8hr Ozone and Federal PM2.5.
Diesel trucks are largest mobile source

### Particulate Matter
- Marine, rail, aircraft: 30%
- Trucks: 40%
- Cars: 2%
- Off-Road: 28%

### NOx
- Marine, rail, aircraft: 19%
- Trucks: 32%
- Cars: 29%
- Off-Road: 20%

2010 Mobile Source Emissions
Progress in Reducing Ambient PM2.5 Pollution

- Since 2000, annual PM2.5 has dropped by 50% in the South Coast Air Basin and the San Joaquin Valley.
- Both regions will attain annual 15 µg/m³ and 24-hr 35 µg/m³ standards by 2014 and 2019 deadlines.
- Diesel fleet regulations and state and regional incentives are rapidly cleaning up fleet.
- These actions are most significant strategy for attainment demonstration.

California’s Success in Reducing PM2.5 Pollution

California has made remarkable progress in reducing fine particle pollution in the nation’s most challenging nonattainment regions, the South Coast Air Basin and the San Joaquin Valley. This article outlines the state’s success.

Since 2000, annual concentrations of fine particulate matter (PM2.5) have dropped by more than 50% in both regions. The South Coast Air Basin (SCAQMD) has achieved annual average 15 µg/m³ PM2.5 levels on schedule for the 2015 deadline. The San Joaquin Valley (SJVMD) has reduced PM2.5 concentrations to meet the 35 µg/m³ level by 2019.

Diesel fleet regulations and state and regional incentives are rapidly cleaning up fleet.

These actions are most significant strategy for attainment demonstration.
Climate Pollutant Emissions (2010)

Global

- Carbon Dioxide: 65%
- Black Carbon: 14%
- Methane: 13%
- Nitrous Oxide: 7%
- Hydrofluorocarbons: 1%

California

- Carbon Dioxide: 80%
- Methane: 8%
- Nitrous Oxide: 3%
- Hydrofluorocarbons: 3%
- Wildfire: 3%
- Anthropogenic: 3%
Anthropogenic Black Carbon Sources (excluding wildfires and biogenic)

Statewide
BC ~ 17,000 tons per year

Transportation 57%
Managed Burning 16%
Residential 11%
Cooking 6%
Others 10%

2010
California Actions on Short-lived Climate Forcers

• Black Carbon
  – Diesel engine controls, Advanced Clean Cars, burning restrictions

• Methane
  – Landfill controls, oil and gas regulations, dairy digester offset protocol

• Hydrofluorocarbons
  – Refrigerant Management Program, Advanced Clean Cars, other regulations
## Global Warming Potential for Selected Greenhouse Gases*

<table>
<thead>
<tr>
<th>Pollutant</th>
<th>SLCP</th>
<th>Global Warming Potential (20-year)</th>
<th>Global Warming Potential (100-year)*</th>
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<tbody>
<tr>
<td>Carbon dioxide</td>
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<td>1</td>
<td>1</td>
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<tr>
<td>Methane</td>
<td>Yes</td>
<td>72</td>
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<tr>
<td>Nitrous oxide</td>
<td></td>
<td>289</td>
<td>298</td>
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<tr>
<td>Sulfur hexafluoride</td>
<td></td>
<td>16,300</td>
<td>22,800</td>
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<tr>
<td>Hydrofluorocarbons</td>
<td>Yes</td>
<td>437 – 6,350</td>
<td>124 – 4,470</td>
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<tr>
<td>Perfluorocarbons</td>
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<td>5,210 – 8,630</td>
<td>7,390 – 12,200</td>
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<tr>
<td>Black carbon</td>
<td>Yes</td>
<td>3,200</td>
<td>900</td>
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<tr>
<td>Nitrogen trifluoride</td>
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<td>12,300</td>
<td>17,200</td>
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*The 20 and 100-year global warming potential estimates are from the IPCC 2007 Fourth Assessment review, except for the black carbon global warming potential estimate, which is based on a major scientific assessment of the black carbon radiative forcing published early this year (Bond et al.).
### 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**
- Organic carbon
- Elemental carbon
- Very good for CO₂ reduction
- still << current SULEV PM standard
- But PM > conventional gasoline
- Also > particle counts
- Most PM is BC or soot like diesel

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#### 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)

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Sources: CARB's Phase II HDV emissions study, Ricardo/UK; Li, et.al., SAE Tech. Paper 2006-01-1076
California Tailpipe PM Standards
(passenger cars, light trucks < 8,500 lbs. GVW)

Gasoline vehicles subject to PM standard beginning in 2004

LEV III
Reducing Diesel PM is a Public Health Priority

• 1998 identification as Toxic air contaminant
• 2000 Diesel Risk Reduction Plan
  ▪ Reduce cancer risk by 85% by 2020
  ▪ 2007 new engine standards
  ▪ Clean fuel standards
  ▪ In-use controls (retrofits/re-power)
  ▪ Anti-idling
  ▪ Public investment - incentives ~ $100s of millions/year
  ▪ Enforcement
• Mitigate other health impacts
  ▪ Hospital admissions
  ▪ Asthma rates
  ▪ Acute bronchitis
  ▪ Work days lost
• Children/elderly most vulnerable
**In-Use Diesel Regulations**

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<tr>
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<tbody>
<tr>
<td>Portable Engines (2004)</td>
<td>Agricultural Tractors and Equipment (under development)</td>
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<tr>
<td>Transit Fleet Vehicles (2005)</td>
<td></td>
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<tr>
<td>Public Fleets &amp; Utilities (2005)</td>
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<tr>
<td>Cargo Handling Equipment (2005)</td>
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</table>
Freight Transport Today:
Contribution to Statewide Emissions

- Diesel Soot (PM/black carbon)
- Nitrogen Oxides (NOx)
- Greenhouse Gases
Adopted ARB Freight Regulations

✓ Cleaner diesel fuel rules
✓ Statewide truck rules
✓ Port and railyard truck rule
✓ Truck/trailer efficiency rule
✓ Truck idling and refrigeration unit rules
✓ Ship fuel and shore power rules
✓ Harbor craft rules
✓ Cargo equipment rule
✓ Locomotive/rail yard agreements
California’s Diesel Program

85% black carbon reductions from 1990 levels

Achieved by:
• Emissions standards
• Fuel rules
• Fleet rules
PM Benefits Already Realized by T&B Regulation

- Baseline
- With Rule Requirements

2,700 tons reduced by 2014
Significant NOx Benefits from Replacements

- Normal turnover
- With Rule Requirements

89 tons/day reduction in 2023
Black Carbon Emission Reductions from Trucks Operating at Port of Oakland

Dallmann et al. (2011) Environmental Science & Technology, 45, 10773-10779
Black Carbon and the Regional Climate of California

- First regional assessment of climate impact of BC
- Based on modeling and observational data (aircraft, satellite, ground monitors)
- Ramanathan et al.
- 3-year study
- Scripps Institution of Oceanography
- University of California at San Diego
- Lawrence Berkeley National Lab
- Pacific Northwest National Lab

Final report: [www.arb.ca.gov/research/single-project.php?row_id=64841](http://www.arb.ca.gov/research/single-project.php?row_id=64841)

Press release: [www.arb.ca.gov/newsrel/newsrelease.php?id=444](http://www.arb.ca.gov/newsrel/newsrelease.php?id=444)
Climate Forcing from BC and BrC (annual mean of 2001 to 2010)

Observationally Constrained Data

Goddard Chemistry, Aerosol, Radiation, and Transport (GOCART) model simulation
Major Findings: Detection

• Statewide BC concentrations in California have decreased from 0.46 µg/m³ in 1989 to 0.24 µg/m³ in 2008 (about 50% reduction)
• Fossil fuel and diesel emissions show a corresponding 50% reduction
• This trend extends further back – a decrease of 72% from 1960s to 2000
• The negative trend is still continuing
Major Findings: Attribution

- BC has decreased even though total fuel consumption has steadily increased
- BC trend is consistent with diesel BC emission trend
- Lack of similar trends in other aerosols indicates: negative trend in BC is not due to meteorology
- Clean-up attributed to reduced tailpipe emissions, improved engines, and low-sulfur fuel as mandated by State policies

Large negative trends in BC and lack of corresponding negative trends in co-emitted cooling aerosols gives compelling observational evidence that mitigation of diesel BC would be effective in mitigating global warming as inferred by modeling studies (e.g., Jacobson, 2010; Bond et al., 2013)
Brown Carbon*: Another Climate Warming Pollutant?

• Brown Carbon adds significant amount to Black Carbon heating
  
  — The direct warming effect of brown carbon, ignored in most models, offsets about 60% to 90% of the direct cooling effects of other organic carbon aerosols

• Bottom-up emission models, including regional models, underestimate the heating of the atmosphere by Black Carbon and Brown Carbon by a factor of about 3

*Produced in lower temperature smoldering combustion from fuel containing biomass and likely from secondary organics from fossil fuels (polycyclic aromatics, tarballs, organonitrates, and likely many others)
Co-Benefit of Diesel Black Carbon Reduction to Climate Change Mitigation

California’s \( CO_2 \) emissions (2009): 393 MMT/yr

- Black carbon contributes to both air pollution health and climate change problems
- California diesel control program effective in reducing black carbon
  - 90% reduction observed over past 45 years
  - 95% control expected by 2020
- California diesel control program provided significant climate co-benefits
  - 21-50 MMTCO2e/year in 2008 (compared to 1989)
Going forward on short-lived climate forcers

• ARB is taking additional action
• Exploring additional emission reductions prior to 2020
• Short-lived climate pollution strategy by 2016
  – Inventories
  – Sources and emissions
  – Research needs
  – Plan for control measures