Motor Vehicle Pollution Control
A Global Overview

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Prevalence of obesity in the United States

- United States
- 44% of adults are obese
- 8.4% of children are obese
- 21.3% of children are overweight

GBD 2015
Premature Deaths: Air Pollution among top-ranked global risk factors

Outdoor PM contributed to 4.2 million premature deaths

Air pollution combined - ambient plus household - contributed to 10% of global mortality in 2015 – the 4th ranked global risk factor
Historical High Growth Has Offset Many Improvements. Vehicles Remain Important Contributor to Local, Regional and Global Pollution.
Exposure To Vehicle Emissions is Very High
In Your Face! Literally!
Melt descending into a moulin, a vertical shaft carrying water to ice sheet base.

Source: Roger Braithwaite, University of Manchester (UK)
Carbon Dioxide Getting the Most Attention Appropriately

For 650,000 years, atmospheric carbon dioxide had never been above this line.

1950 level

Current level
Black Carbon (BC)

Diesel PM Identified as Prime Candidate for BC Control:
- A Leading environmental cause of poor health and premature death
- As a warming agent:
  - Absorbing solar radiation and converting it to heat
  - Increasing the melting rate of ice and snow
IPCC Calls For 80% Reduction By 2050
Vehicle Emissions Have Become One Of The Major Sources Of Urban Air Pollution

Beijing PM$_{2.5}$ source apportionment results published in April 2014

Source: Beijing News; Beijing government

9 large cities published their results. Transportation source ranked the first in 5 of them (Beijing, Shanghai, Guangzhou, Shenzhen, and Hangzhou).
China Is Now Most Important Motor Vehicle Market

- 2015 – 24.61 M Total Sales
- 21.16 M Light Duty
- 3.45 M Commercial trucks and buses
- Through November 2016, LDV Sales up 16% over 2015
- Stimulated by 50% tax cut on vehicles with engines 1.6 L or less
- Relatively Few Light Duty Diesels
The Growth Of Vehicle Population Of China Will Likely Continue Over The Next 15 Years

Lots of domestic and international research shows:

- Vehicle population of China will overtake the level of U.S in 2030!
- Vehicle population of China will reach 210~250 million in 2020 and 350~500 million in 2030, 20~30 times the number in 2000!

Source: Prof Hao, Tsinghua
Major Global Developments in Recent Years

- LEV3/Tier 3
- Euro 6/VI and Real Driving Emissions
- China Fuels Roadmap/Move to China 6/VI
- China’s New Clean Air Law
- India’s **Leapfrog** to Bharat 6/VI
- USEPA Stage 2 Truck GHG Standards
- VW “Dieselgate” Scandal
- Global Focus on Marine Sector
U.S. and Euro Light-Duty Vehicle Emission Standards

Note: U.S. Tier 2, Bin 5 is equivalent to CARB LEV II - LEV
- 50 ppm S cap
- 10 ppm S cap
- 15 ppm S cap on diesel
- 30 ppm S ave. on gasoline
- 10 ppm S ave. on gasoline

Euro 5+ (2011) and 6 include $6 \times 10^{11}$/km diesel particle number limit;
Euro 6c includes PN limit for GDI
Useful Life of Emissions Control Systems Increasing

- Euro 4, 5, 6: Useful Life (km) = 150,000, Useful Life (years) = 5
- Tier 2/LEV II: Useful Life (km) = 200,000, Useful Life (years) = 8
- Tier 3/LEV III: Useful Life (km) = 300,000, Useful Life (years) = 16

Graph shows the comparison of useful life in kilometers and years for different standards.
European Stage V regulation goes further than US Tier 4, and will require a diesel particulate filter on all non-road diesels from 2020 onwards.
Phase 1 and 2: HEI 2007 and 2010 Engine ACES Results

Compared to earlier Engines (rigorous 16-hour cycle)

2007 Dramatic Reductions
98% reduction in mass
90% - 99% reduction in Ultrafine Particles, air toxics

2010 Further Reductions
(even compared to 2007)
>90% reduction in NOx
>70% reduction in Particles

PM Composition (1998 vs. 2007)
~ 50-fold reduction in mass; shift from carbonaceous to sulfate composition

Emissions Reduction Relative to 2007 ACES Engines
-94% -94%
-72%
-100%
-71%
-92%
-33%
More Stringent New Vehicle Emissions Standards Are Spreading Around The World

Fraction of New Vehicles or Engines Adopting Euro 6 Standards Or Better

<table>
<thead>
<tr>
<th>Model Year</th>
<th>2015</th>
<th>2025</th>
</tr>
</thead>
<tbody>
<tr>
<td>Light Duty Gasoline Cars</td>
<td>41.4%</td>
<td>78.9%</td>
</tr>
<tr>
<td>Light Duty Diesel Cars</td>
<td>65.4%</td>
<td>87.9%</td>
</tr>
<tr>
<td>Heavy Duty Diesel Trucks</td>
<td>24.9%</td>
<td>78.9%</td>
</tr>
</tbody>
</table>

India and China Are Moving Quickly
Recently Daimler and VW announced that they also will use particle filter in their GDI cars in the future.
A Comparison Of Laboratory Vs. On-road Test Results For 3 Diesel Cars In The US Triggered “Dieselgate” and Has Focused Global Attention on Compliance and Enforcement Programs

Source for photos: AVL / ERMES
Vehicles shown on photos are not related to test results shown

Source: http://www.theicct.org/use-emissions-testing-light-duty-diesel-vehicles-us
On-road NO$_x$ : Euro 6 Diesel Cars Are (On Average) Worse Than They Should Have Been 15 Years Ago

Real Driving Emissions Testing Is Critical

Source: ICCT
Summary of VW Settlement

- Vehicle Recall: choice of buyback, lease termination, Emissions Modification (up to $10B)
- Mitigation Projects Across Nation ($2.7B)
- Zero Emission Vehicle Investments ($2.0B)

- Up to $14.7B to stop the pollution, clean up the pollution, and invest in clean transportation
Scope of Settlement

- This is a partial resolution
- This is injunctive—fixing the pollution problem is our first priority
- Parties: United States (EPA & DOJ); California (ARB & Attorney General); Volkswagen AG, Audi AG, Volkswagen Group of America, VW’s Chattanooga Plant
- Agreement considered and coordinated with class action and Federal Trade Commission resolutions
- Included: 2.0 liter diesel vehicles since 2009 (Jetta, Golf, Passat, Beetle, Audi A3); recall and mitigation
- Excluded: 2016 certification; civil penalties; criminal charges; 3.0 liter vehicles
- Timing – Court entered final Consent Decree on October 25, 2016
Light-Duty Vehicle Compliance Program

- **Vehicle Design and Build**
  - Vehicle May Enter Commerce
  - Low-mileage In-Use Verification Testing Performed by Manufacturer
  - Warranty Tracking and Emission Warranty Reports (EWIRs) to CARB
  - Emission Defect Information and Voluntary Emission Recall Reports (EDIRs/VERRs) to EPA

- **EPA Review of Manufacturer Application**
  - EPA Issues Certificate of Conformity
  - EPA Certification Preview and Pre-model Year Reports
  - EPA Confirmatory Testing (Random and Targeted)
  - EPA In-Use Surveillance Testing

- **EPA Follow-Up**
  - Defect and Recall Reports, Mfr. In-Use Testing, EPA Testing
  - EPA Test Data Review/Analysis
  - CARB Coordination (Warranty Reporting)
  - OECA Coordination (Enforcement)

- **Manufacturer Action**
  - Manufacturer Emissions Vehicle Prototype and Durability Testing
  - End of Useful Life (per CAA)

- **EPA Action**
  - EPA Certification Preview and Pre-model Year Reports
  - EPA Confirmatory Testing (Random and Targeted)
  - EPA Follow-Up (Defect and Recall Reports, Mfr. In-Use Testing, EPA Testing)
  - EPA Test Data Review/Analysis
  - CARB Coordination (Warranty Reporting)
  - OECA Coordination (Enforcement)

- **Durability Review and Approval Process**
  - End of Useful Life (per CAA)

- **Vehicle May Enter Commerce**

- **Low-mileage In-Use Verification Testing Performed by Manufacturer**

- **High-Mileage In-Use Verification Testing Performed by Manufacturer**

- **End of Useful Life (per CAA)**
China’s Major Reform Of China Clean Air Law Strengthens Authority For Compliance And Enforcement

• Clear authority to enforce standards
  – Recall authority is established for motor vehicles and off-road engines
  – Clear authority of central and provincial environmental agencies to impose large fines (1-3 times product value) for producing, selling or importing non-compliant vehicles
  – Clear authority of the industry ministry (MIIT) to suspend or discontinue the production of violating vehicles/engines

• Clear authority to perform compliance testing
  – Authority for MEP and provincial EPBs to investigate and test newly produced and sold vehicles and engines
  – Authority of local EPBs to perform random onsite and roadside emission inspection and testing, including remote sensing tests.

• Highlighted shared burden among government, industry, and consumers
  – Manufacturers of vehicles and engines shall test their products to ensure emission compliance before introducing the products into commerce
  – Manufacturers shall publish their emission compliance test result information to the public
  – Manufacturers shall recall their vehicle/engine products if they are found not in compliance with standards due to design, manufacturing defects
  – Consumers are prohibited from tampering/modifying emission control devises (incl. OBDs)
Historical Fleet CO₂ Emissions Performance And Current Or Proposed Standards

[1] China’s target reflects gasoline fleet scenario. If including other fuel types, the target will be lower.
US EPA Recently Adopted Phase 2 Heavy Duty CO2/ Fuel Economy Rule
Total Annual GHG Trends for Phase 2 (Fuel Savings are Proportional)

In the face of sustained growth, Phase 2 achieves a 13-year period of net decreasing GHGs and fuel consumption.

Final program will reduce 1.1 billion tons of CO₂ (more than the NPRM) and up to 2 billion barrels of fuel savings.
Global electric vehicle sales since 2009

- Sales of electric vehicles through 2015
  - There were approximately 530,000 electric vehicle sales in 2015
  - The 1 millionth electric vehicle was sold in September 2015
  - Sales mostly in China, Europe, the U.S. (and concentrated in particular markets)
Role of Advanced Clean Cars

- **Mid-term GHG Target**
  - 2020 GHG Emission Target
  - 0.075 ppm 8-hr Ozone Attainment

- **Future Ozone Standard**
  - 2050 GHG Emission Target

- **Healthy Air Quality**
  - Ozone and PM2.5 Attainment

- **Stable Global Climate**
  - LEV III – Criteria and GHG: Improving Conventional Vehicle Technology

- **ZEV Program:**
  - Accelerating Advanced Technology Development

- **Advanced Clean Cars 2.0??
  - Technology Commercialization and Fleet Transformation

- **2015 2020 2025 2030 2035 2040 2045 2050**

- **100% ZEV Sales by 2050**
Very Serious Challenges Remain But We Have Learned That Strong Actions Can Lead To Progress

Los Angeles Then and Now

Source: New York Times
Transportation Problems
Not Limited To Land Based Vehicles and Engines
Thank You