Diesel Retrofit Experience for Heavy-Duty Diesel Vehicles

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Joint Taskforce on Supporting Businesses in Reducing Diesel Emissions
Oregon Senate Committee on Labor and Business
November 21, 2019
Manufacturers of Emission Controls Association

- Representing emission control and efficiency technology manufacturers since 1976
- 37 member companies commercializing clean mobility technologies
- Supply over 90% of the diesel retrofit and aftermarket catalysts and DPFs in North America
Outline

• Existing Diesel Retrofit Programs
• Verification Programs
• Retrofit Technologies
• Importance of Maintenance
• Insuring compliance
• Summary
U.S. Diesel Retrofit Programs

- **> 19 million in-use diesel engines** of all types throughout the U.S. – significant source of PM and NOx; long service life
  - 15 years of U.S. retrofit programs and 2007 “clean diesel” turnover have impacted < 4 million engines

- **Mandatory Efforts**
  - California – all existing diesel engines impacted
  - New Jersey, New York State, New York City, Chicago metropolitan area (public fleets or public projects)
  - Green construction contracts/requirements spreading

- **Highly Incentivized Voluntary Programs**; mostly with available local, state, or federal funding; mostly focused on PM reductions
  - Everywhere else in the U.S.
Elements of EPA/CARB Retrofit Programs

**U.S. EPA**
- Voluntary program, no fleet reduction regulations, emission reduction credits
- **Absolute** technology performance designation with 1000 h durability demo
- 20% max. NO$_2$ increase; SCR reductant inducements
- Approved application scope & testing plans - designated third party test lab(s)
- Defined in-use testing requirements

**CARB**
- **Mandatory** fleet emission reduction regulations, mandated retrofit warranty
- Technology verification performance bands (3 PM levels, 5 NOx levels) with 1000 h durability demo
- 20% max. NO$_2$ increase; SCR reductant inducements
- Approved application scope, testing plans, & test lab
- Defined in-use testing requirements
Significant Funding in California for Heavy-duty Upgrades/Replacements and Retrofits

<table>
<thead>
<tr>
<th>Program</th>
<th>Funding Details</th>
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<tbody>
<tr>
<td>VW Mitigation Trust</td>
<td>NOx mitigation</td>
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<td></td>
<td>$423M for 2017+</td>
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<tr>
<td>Low Carbon Transportation</td>
<td>GHG reductions</td>
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<td>$330M for FY 17-18</td>
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<td>Zero-Emission Warehouse Program</td>
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<td>AB 617</td>
<td>Criteria and toxics reductions to support community action goals</td>
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<td>Carl Moyer</td>
<td>SIP emission reductions</td>
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<tr>
<td></td>
<td>$69M for FY 17-18</td>
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<tr>
<td>Prop 1B</td>
<td>PM and NOx reductions in goods movement corridors</td>
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<tr>
<td></td>
<td>$267M for 2015+</td>
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<tr>
<td>Funding for Agriculture</td>
<td>Criteria pollutant, toxics, and GHG reductions</td>
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<td></td>
<td>$135M for FY 17-18</td>
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U.S. Federal Clean Diesel Incentive Funding Examples

- Federal funding through the **Diesel Emissions Reduction Act** - over $730 million since 2007 (administered by U.S. EPA)
- Specific federal funding for select non-attainment areas (e.g., California, Utah have received these funds)
- EPA Clean Air Act enforcement settlements (called “Supplemental Environmental Projects”)
  - $2.83 billion **VW environmental (NOx) mitigation trust fund** ($423 million for California) to be spent over the coming 10 years
- Federal Transportation Congestion/Mitigation (CMAQ) funds
- Federal Transit Agency Low/No Emission Vehicle program funding for transit agencies
- Federal Aviation Administration Voluntary Low Emissions Program funding available to upgrade airport equipment
- Department of Agriculture Environmental Quality Incentives Program funds available for farm equipment upgrades/retrofits
DOCs Offer PM Reductions from Older Engines

Diesel Oxidation Catalysts: 20-40% PM

- Millions of DOC retrofits worldwide on on-road and off-road vehicles and equipment.
- Less sensitive to engine-out PM
- Can be applied to older equipment.

CO Aldehydes HC PAH \( \text{SO}_2 \) \( \text{NO}_x \) Flow through monolith with catalytic coating

\( \text{CO}_2 \) \( \text{H}_2\text{O} \) \( \text{SO}_2 / \text{SO}_3 \) \( \text{NO}_x \)
Wall-Flow Diesel Particulate Filters Offer the Highest (>90%) PM Filtration Efficiency

- Passively regenerated DPFs employ catalysts and available exhaust heat to burn soot
- Require specified exhaust temperature
- Large reduction in toxics from catalyzed DPFs
- Same technology as on U.S. MY 2007 and newer trucks
Range of Active DPFs Available for Low Exhaust Temperature Applications

- Suited for on- and off-road applications with low exhaust temperatures.
- Uncatalyzed or catalyzed wall-flow filter with electrical regeneration.
  - Catalyzed filter + electrical element combines passive and active functions
  - On or off vehicle regeneration possible
- Wall-flow filter with a fuel burner for regeneration.
Retrofit Systems that Provide PM + NOx Reductions

DPF + Urea-SCR Retrofit System

60-90% NOx Efficiency

DPF + HC-SCR Retrofit System

25-40% NOx Efficiency
Current List of Available U.S. EPA-/CARB-Verified Level 3 Retrofit Technologies (as of November 2019)

• U.S. EPA (https://www.epa.gov/verified-diesel-tech/verified-technologies-list-clean-diesel)
  – 5 on-road passive DPFs (includes 2 DPF+SCR)
  – 4 on-road active DPFs
  – 4 off-road passive DPFs (includes 1 DPF+SCR)
  – 2 off-road active DPFs
  – 2 off-road SCR systems
  – 1 locomotive SCR system

• California ARB (www.arb.ca.gov/diesel/verdev/vt/cvt.htm)
  – 13 on-road passive DPFs (includes 1 DPF+LNC and 1 DPF+EGR)
  – 7 on-road active DPFs
  – 1 off-road passive DPF
  – 7 off-road active DPFs (includes 1 DPF for RTG crane)
  – 8 Level 3 devices for TRUs or APUs
  – 15 Level 3 devices for stationary engines
Experience with Diesel Particulate Filter Retrofits Spans a Variety of On-Road Vehicle Applications
Non-Road Retrofits Pose Installation Challenges
U.S. Clean Diesel Locomotive Demonstrations

Passive DPF Retrofits on Tier 2 Gen-Set Switcher Loco

Tier 2 Loco Retrofit with EGR and DOCs/DPFs

Tier 4 Gen-Set Switcher with DPFs

GE Tier 4 Line Haul Loco with EGR
U.S. Clean Diesel Marine Demonstrations

- SCR Retrofits on 2 Staten Island Ferries
- DPF+SCR Retrofit on LA Port Tug
- DOC + Crankcase Filter Retrofits On Mississippi Barge Tugs
- Long Beach Hybrid Tug Retrofit
DOC and Filter Stationary Installations
Diesel Retrofit Sales Survey Results for U.S. (On-Road and Off-Road, 2009-2017)

Source: MECA, 2018
# Diesel Retrofit Technology Cost Estimates

<table>
<thead>
<tr>
<th>Retrofit Technology</th>
<th>Cost Range ($)</th>
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<tbody>
<tr>
<td>DOC</td>
<td>500-2,000</td>
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<tr>
<td>Passive DPF</td>
<td>8,000-20,000</td>
</tr>
<tr>
<td>Active DPF</td>
<td>12,000-30,000</td>
</tr>
<tr>
<td>SCR+Passive DPF</td>
<td>20,000-30,000</td>
</tr>
<tr>
<td>Crankcase filter</td>
<td>&lt;1,000</td>
</tr>
</tbody>
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Source: ICCT and MECA, 2017
Successful Retrofit is Partnership Between Manufacturer, Installer and Owner
Key Considerations for Successful Retrofit Projects

Manufacturer’s Responsibility

- **Application engineering** – match the right technology to the vehicle or equipment
  - Vehicle must be well maintained before considering retrofit - gross emitters are not good retrofit candidates
  - Vehicle duty cycles and exhaust temperature define retrofit options
  - Use only verified retrofit technologies with **proven** performance/durability

- **Professional installation**

Owner’s Responsibility

- **Maintenance** – vehicle/equipment and retrofit device require **regular inspections and maintenance**

- **On-vehicle monitors** – provide important user feedback on performance and mustn't be ignored.
Heavy-Duty I/M is Critical For Compliance
Proper Truck Maintenance is Important

• To operate as designed, all engines require proper maintenance

• Benefits of conducting preventive maintenance:
  – Maintains low emissions
  – Helps save fuel costs
  – Maximizes truck performance
  – Maximizes engine life
  – Reduces down-time

• DPF not a “fit-and-forget” device

• Improper care of engine and emission controls can lead to:
  – Expensive repairs and replacement parts
  – Voided warranty
  – Engine malfunction or breakdown
  – Loss of horsepower and de-rated engine

Need to Improve Effectiveness of Existing State Heavy-Duty I/M Programs

• Currently, 19 states in U.S. have heavy-duty I/M programs

• State I/M test criteria have changed little over past 20 years
  – Regulations for new heavy-duty engines have become increasingly stringent over same period
  – Current I/M test criteria used by states (i.e., smoke opacity limits) out of date for modern trucks

• More stringent I/M test criteria needed to ensure benefits of new trucks maintained throughout vehicle intended service life
Truck Inspection Programs insure Compliance

- Current smoke inspection requirements for older Heavy-Duty trucks in the US:
  - SAE J1667 snap acceleration smoke test procedure
  - 40% opacity limit for 1991 and newer, 55% for 1990 and older
  - Current smoke meters are adequate to measure opacity levels in 5% range
  - Opacity above 3-5% is an indication of a damaged DPF
Potential Concepts for Future Heavy-Duty I/M Programs

- CARB discussing potential concepts for future, comprehensive heavy-duty I/M program (proposal in 2020; implementation post-2021)
  - Focus on OBD for 2013+ MY engines, multiple pollutants (NOx, PM, GHGs?)
  - Potential for both physical inspections and remote inspections (telematics)
  - Testing requirements for non-OBD vehicles (2012 MY and older)
  - Heavy-duty repair shop licensing/mechanic competency
  - Program verification elements (roadside testing)

- CARB funding multi-year heavy-duty I/M research study at UC-Riverside CE-CERT (began in Summer 2016)
  - Evaluate potential test methods for identifying vehicles with broken emission controls and assessing cost of repairs

- Other states have expressed interested in ARB’s heavy-duty I/M development efforts: New Jersey, Massachusetts, Wisconsin, Colorado, Utah, others
Diesel Retrofit Summary

• Diesel retrofit programs provide an important tool for cleaning-up in-use fleet and accelerating air quality improvements

• A variety of proven retrofit technologies have been verified for reducing PM and NOx emissions from existing on-road and off-road diesel engines

• Pre-installation inspections are critical to insuring that a vehicle is a good retrofit candidate and matching the vehicle with the correct retrofit solution

• Engine and retrofit device maintenance is essential for achieving emission reductions and proper operation.

• Truck inspection and maintenance programs are important to prevent tampering and insure compliance