Diesel Retrofit Technology Update

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Strategies to Reduce Emissions from In-Use Diesel Engines

- Retrofit – installing a verified emission control device on an existing diesel engine
- Refuel
- Repair/Rebuild
- Repower
- Replace
- Idling reduction

Types of Diesel Retrofit Technologies

PM Reduction

- Diesel Particulate Filter
  - Wall-flow device that physically traps PM in exhaust stream on surface of substrate; PM burned off through regeneration (passive or active)
  - >85% PM reduction
- Flow-Through Filter
  - Wire-mesh substrate or metal foil-based substrate with sintered metal sheets that traps a portion of the PM; passive regeneration with catalyst
  - 50-75% PM reduction
- Diesel Oxidation Catalyst
  - Flow-through device with catalytic coating on substrate that oxidizes soluble organic fraction of PM
  - 25-50% PM reduction
- Closed Crankcase Ventilation System
  - Replaceable filter that reduces engine blow-by emissions
  - >90% PM reduction (crankcase emissions)

Types of Diesel Retrofit Technologies

NOx Reduction

- Selective Catalytic Reduction
  - Flow-through device that reduces NOx with injection of a reductant (urea) over the catalyst
  - 60-90% NOx reduction
- Lean NOx Catalyst
  - Flow-through device that reduces NOx with injection of a reductant (diesel fuel) over the catalyst
  - 25-40% NOx reduction

List of Available EPA-/ARB-Verified Level 3 Retrofit Technologies Continues to Expand (as of September 2013)

- U.S. EPA (epa.gov/cleandiesel/verification/verif-list.htm)
  - 6 on-road passive DPFs (includes 2 DPF+SCR)
  - 2 on-road active DPFs
  - 1 off-road passive DPF
  - 1 off-road SCR (NOx control)
  - 1 locomotive SCR (NOx control)
- California ARB (www.arb.ca.gov/diesel/verdev/vt/cvt.htm)
  - 13 on-road passive DPFs (includes 1 DPF+LNC and 1 DPF+EGR)
  - 9 on-road active DPFs
  - 1 off-road passive DPF
  - 4 off-road active DPFs
  - 7 Level 3 devices for TRUs or APUs
  - 11 Level 3 devices for stationary engines

Benefits of Diesel Retrofit Technology

- Allows continued use of existing diesel engine with all its positive attributes
- Immediate, cost-effective reductions in emissions from in-use diesel fleet
- Filter retrofits provide climate change impacts through reductions in black carbon emissions
  - EPA Report to Congress on black carbon in March 2012

Technical Considerations for Successful Retrofit Projects

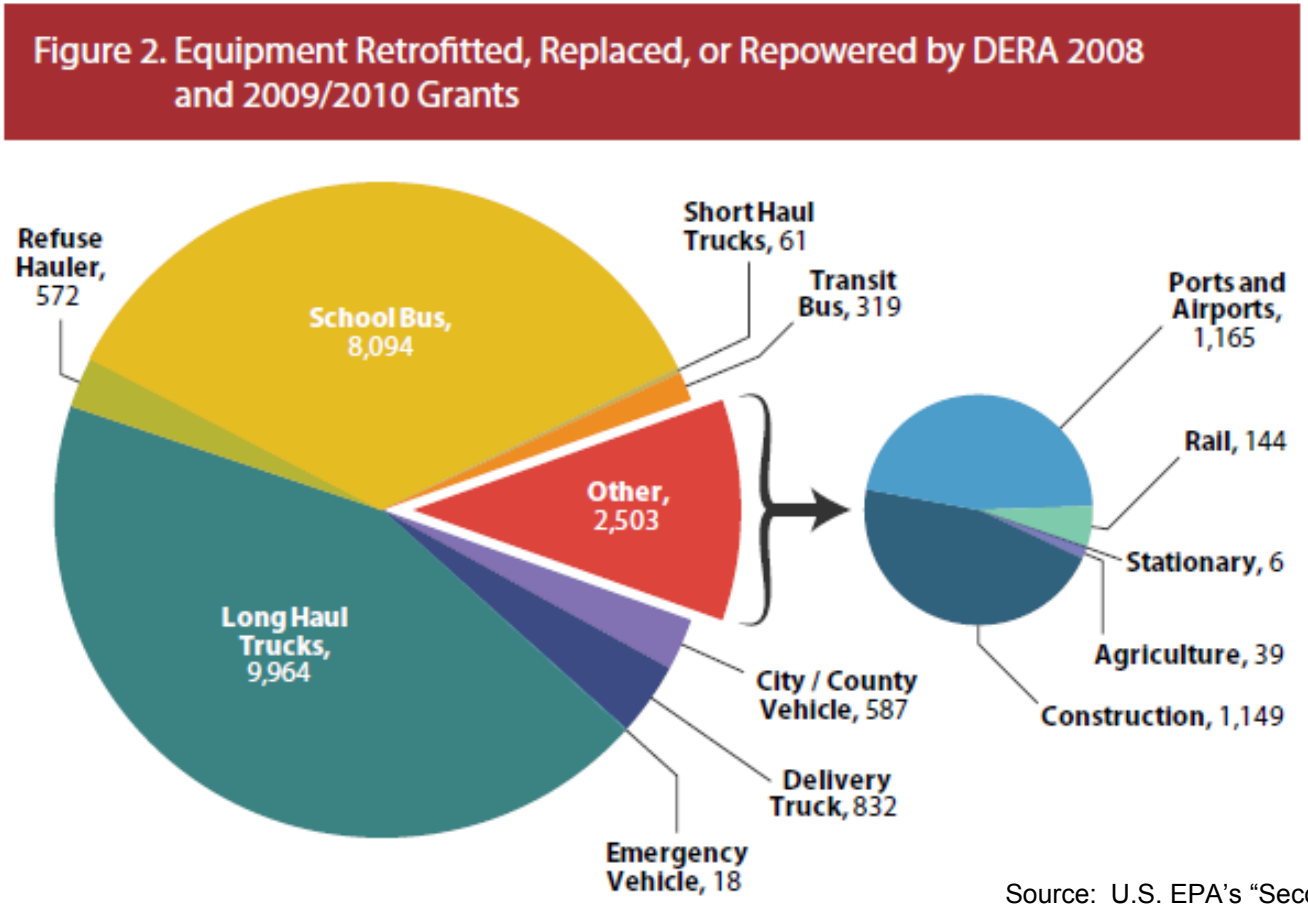
- Vehicle should be properly maintained before considering retrofit
- Application engineering – Matching the right technology to the specific piece of equipment and application
- Proper professional installation – Retrofits can be installed safely (visibility concerns addressed)
- On-vehicle monitors – Provide important user feedback on performance (don't ignore warning lights)
- Maintenance – Vehicle/equipment and retrofit device require inspection and maintenance
- Checklists available on MECA diesel retrofit website

Successful Retrofits Require a Cooperative Effort Between Fleet Owners, Operators, and Technology Providers

Significant On-Road Retrofit Experience, Off-Road Experience Growing

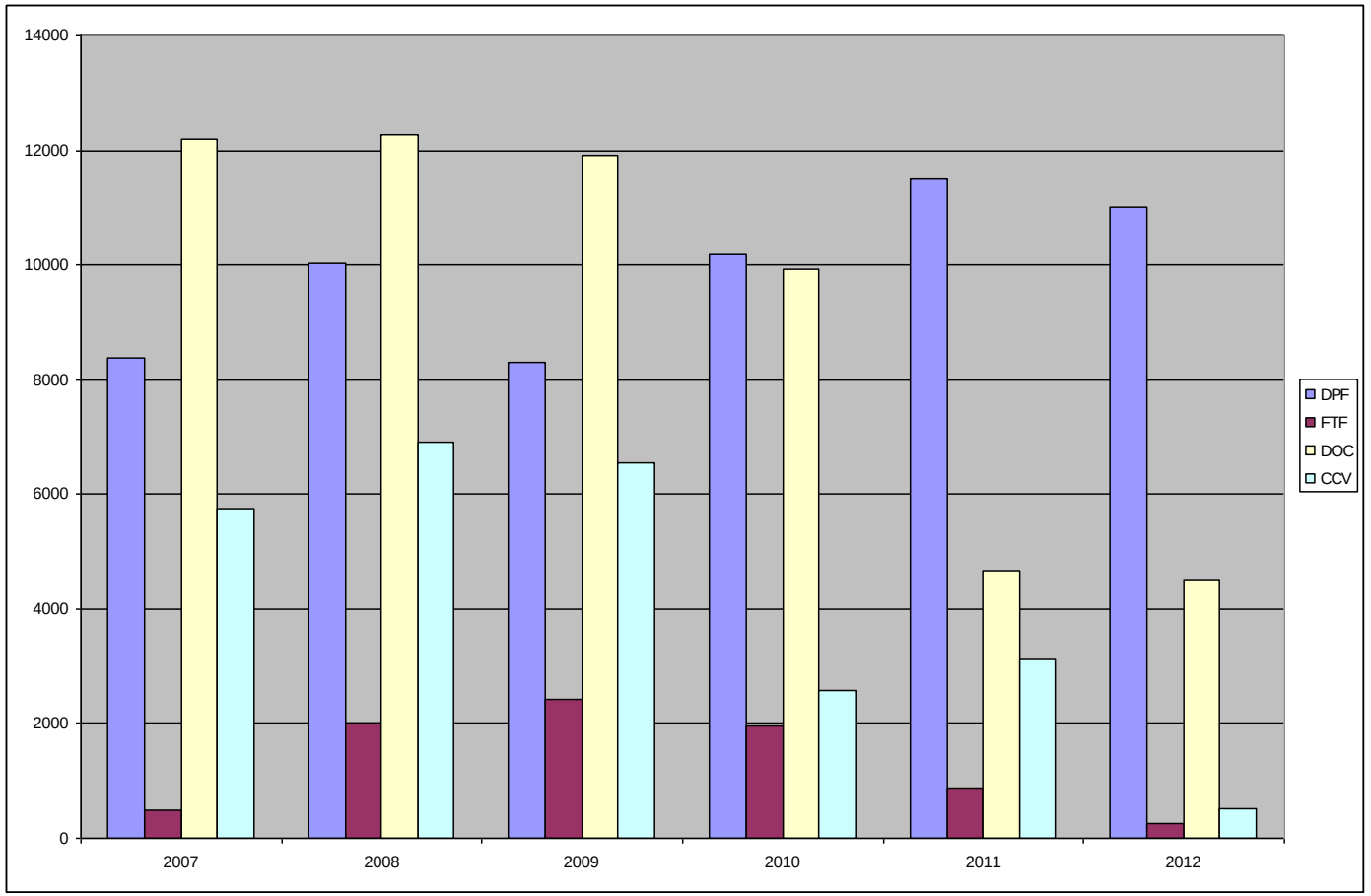
- >300,000 on-road DPF retrofits and >50,000 off-road DPF retrofits worldwide
- >1 million DOC retrofits worldwide
- >40,000 on- and off-road DPF retrofits in California since 2002
- Significant experience with retrofit technologies exists for on-road vehicles
  - School buses, transit buses, long- and short-haul trucks, refuse haulers, utility vehicles
  - Same technology as on new diesel vehicles
    - DOCs and DPFs form technology base for reducing PM emissions from U.S. 2007-10 on-road HD engines and Tier 4 off-road HD engines
    - U.S. 2010 on-road HD engines launched with DPF+SCR systems
- Retrofit experience is growing for many off-road applications
  - Construction equipment, port vehicles/equipment, marine engines and locomotives, stationary IC engines

Significant On-Road Retrofit Experience, Off-Road Experience Growing



Source: U.S. EPA's "Second Report to Congress: Highlights of the Diesel Emissions Reduction Program," April 2013

MECA Diesel Retrofit Sales Survey Results (Total U.S. – On-Road and Off-Road)



Total of 26,863	Total of 31,283	Total of 29,180	Total of 24,640	Total of 20,177	Total of 16,262

MECA Diesel Retrofit Sales Survey Results

- Recent decline in retrofit sales (outside CA) related to:
  - Decrease in DERA funding
  - Recent trend of funding being spent more on repowers and replacements
  - Decrease in DOC and CCV sales
- DPF sales in CA increasing slightly, but 2011-2012 sales did not see expected bump from ARB truck and bus regulation compliance deadlines
  - Effective enforcement policy needed for truck and bus regulation
- Amendments to ARB off-road diesel vehicle regulation depressing retrofit market opportunity

Retrofits Have Excellent Performance Record

- Of ~25,000 DPFs deployed in California since 2002, ARB found less than 15 cases where devices failed to point of unsafe vehicle operation ("Bill Analysis" report on SB 1230: www.leginfo.ca.gov/pub/11-12/bill/sen/sb_1201-1250/sb_1230_cfa_20120409_115325_sen_comm.html)
  - Failures attributed to either poor engine or device maintenance, misapplication of device, or ignoring of warning alarms
- 2003 survey of 3,848 construction retrofit installations from 2001 to 2003 in Europe found failure rate of only 1-2% (SAE Paper 2004-01-0076)
- Need for effective public outreach and education
  - Dispel myths about retrofits

Retrofit Devices Work But Require Care and Maintenance

Solutions for Broadening Retrofit

- More funding needed
  - CMAQ funding ($4.44 billion for FY 2013-14); ~$325 million set aside for PM2.5 projects in FY 2013 and again in FY 2014
    - New York truck voucher incentive program
  - Funding/incentives need to be expanded or re-invented to capture more of the health and climate change benefits of clean diesel technologies
    - New Jersey diesel risk reduction law (uses non-federal funds) and clean construction program
- Timely implementation and effective enforcement of regulations
  - ARB diesel fleet rules
- Streamline technology verification
  - Verification continues to be expensive, slow process that could benefit from more resources at both EPA and ARB
- Clean construction initiatives
  - Contract specifications to promote use of emission controls
- EPA's five-year in-use clean diesel strategy
  - Target areas with high PM exposure areas (e.g., ports)

Other Future Retrofit Considerations

- WHO/IARC classified diesel exhaust as carcinogenic to humans in June 2012
  - Old diesel vs. new diesel
- New off-road engines meeting Tier 4 limits without filters
  - As clean as new on-road heavy-duty diesels with filters?
  - Particle number emission standards may need consideration to ensure reduction of ultrafine particulates and use of best available controls
    - July 2013 MECA report on health impacts of ultrafine particulates
- Diesel replacement parts
  - Potential market opportunity for emission control replacement parts for diesel vehicles certified with emission control devices

Next Steps

- Over 13 years of progress, but still millions of legacy diesel engines operating across the U.S.
- Manufacturers continue to invest and expand the retrofit technology options available for reducing PM and NOx emissions from existing diesel engines
- Need effective policies/strategies to increase interest in retrofit projects
- Defined window of opportunity for retrofit

www.dieselretrofit.org