Emissions Control Approaches and Options for On-Road Heavy-Duty Container Trucks

Container Movement Technology Forum and Roundtable
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Michael Jackson
Jon Leonard
Patrick Couch
TIAX LLC
jackson.michael@tiaxllc.com
Leonard.jon@tiaxllc.com

1. Overview of Strategies, Challenges & Programs
2. A Closer Look at Retrofit Options
3. Summary and Conclusions

1 Overview of Strategies, Challenges & Programs

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3 Summary and Conclusions

California's Key Strategies to Reduce Emissions from Container Trucks

- Promulgation of 2007 and 2010 emissions standards for new truck engines
- Cleaner fuels for new and/or in-use vehicles (e.g., ULSD, LNG)
- Accelerate turnover of oldest frequent-visitor container trucks ("fleet modernization")
- Retrofit container trucks that are poor candidates for replacement
- Improve logistics and efficiency of trucking operations at ports
  - Modify terminal operations to reduce engine-on time (truck idling, waiting)
  - Require "green" or proactive leasing and contracting
  - Restrict or shift hours of operation (e.g., PierPass OffPeak)
- Modal shift: decrease truck container moves by substituting rail and/or emerging technologies
- Regulatory and enforcement activities, e.g.:
  - ARB's stepped-up truck inspections near ports
  - ARB's 2-track fleet rule (private HDV fleets including port trucks, expected 11/07)
  - Local air district rules, e.g., potential AQMD fleet rules

On-road container trucks involve special circumstances and challenges

- Most container trucks are owned and operated by individuals rather than fleets
- These "owner-operator" truckers often don't speak English as their first language
- This "drayage" vocation is probably the harshest within the HD trucking business
  - Payment by trips rather than hourly wages --- with little or no fringe benefits
  - Daily trips are limited (frequent waiting to receive / discharge / deliver containers)
  - Vocational expenses (fuel, insurance, etc.) reduce trucker's **net** income to low levels
- Result: a preponderance of older, higher-polluting trucks hauling containers at Ports
  - Many in-use port trucks pre-date electronic engines and emissions controls
  - Emissions problem exacerbated by infrequent or poor maintenance
- These realities have constrained ARB's options for <u>regulatory</u> solutions
- <u>Incentive programs</u> to replace and/or retrofit port trucks are essential and can work well . . . . with caveats (as described further)

Examples of Strategies as Applied to Container Trucks

- **Refuel:** Alternative and cleaner diesel fuels, e.g.:
  - LNG, Electric Drive
  - ULSD, Synthetic Diesel

  Status: SPBP pursuing LNG, battery-electric trucks in niches
- **Replace:**
  - Fleet mod w/ electronic / EGR engines & other upgrades

  Status: a leading CA strategy (Gateway, Moyer, CAAP)
- **Retrofit:** Aftertreatment devices, e.g
  - Level 2 Flow-Through Filter (FTF)
  - Level 3 Diesel Particulate Filter (DPF)
  - Level 3 DPF with Lean-NOx Catalyst (LNC)

  Status: now being implemented for San Pedro Bay Ports, with good potential for success but significant challenges
- **Repair / Rebuild** to restore/maintain low emissions, e.g.:
  - Low-NOx Reflash

  Status: feasible and effective, but a "capture" mechanism is needed for port trucks (e.g. Gateway or CAAP)
- **Reduce Idling:**
  - Legislation
  - Technology (e.g., EPA' SmartWay Transport Partnership)

  Status: some successes, but excessive idling still occurs

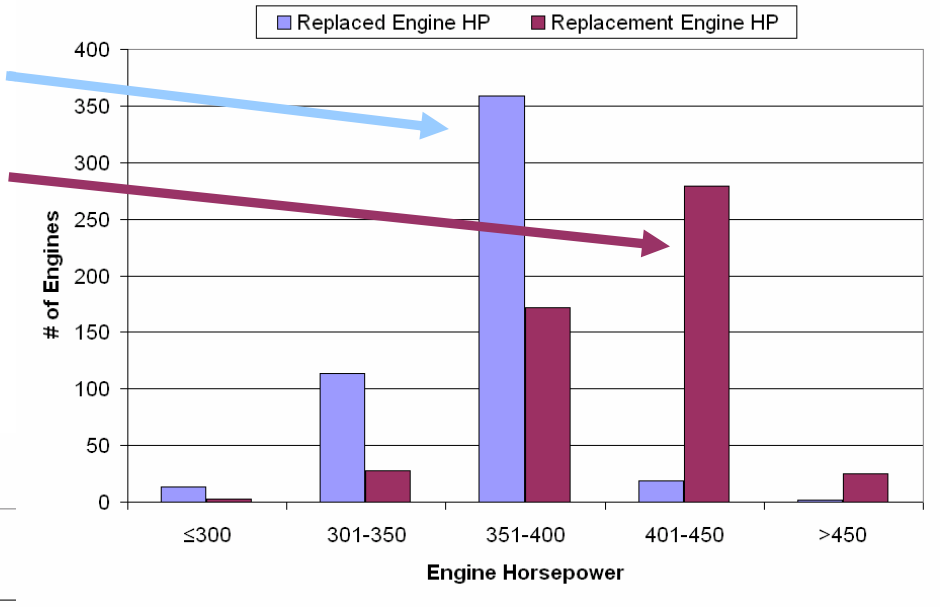
Westport HPDI LNG Tractor

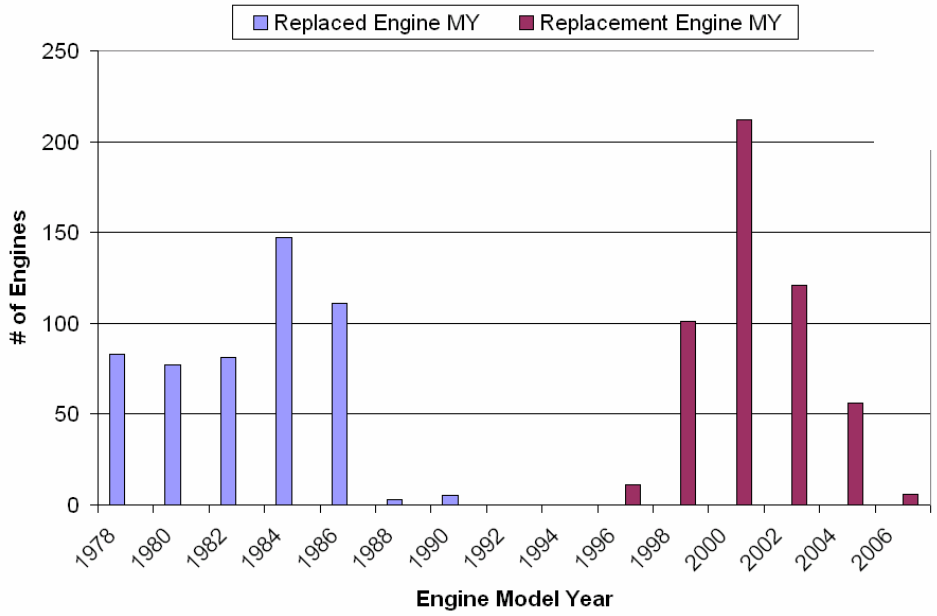
MY 20001 Gateway Replacement Truck

MY 2003 Gateway Truck retrofitted with DOC and Crankcase Ventilation System

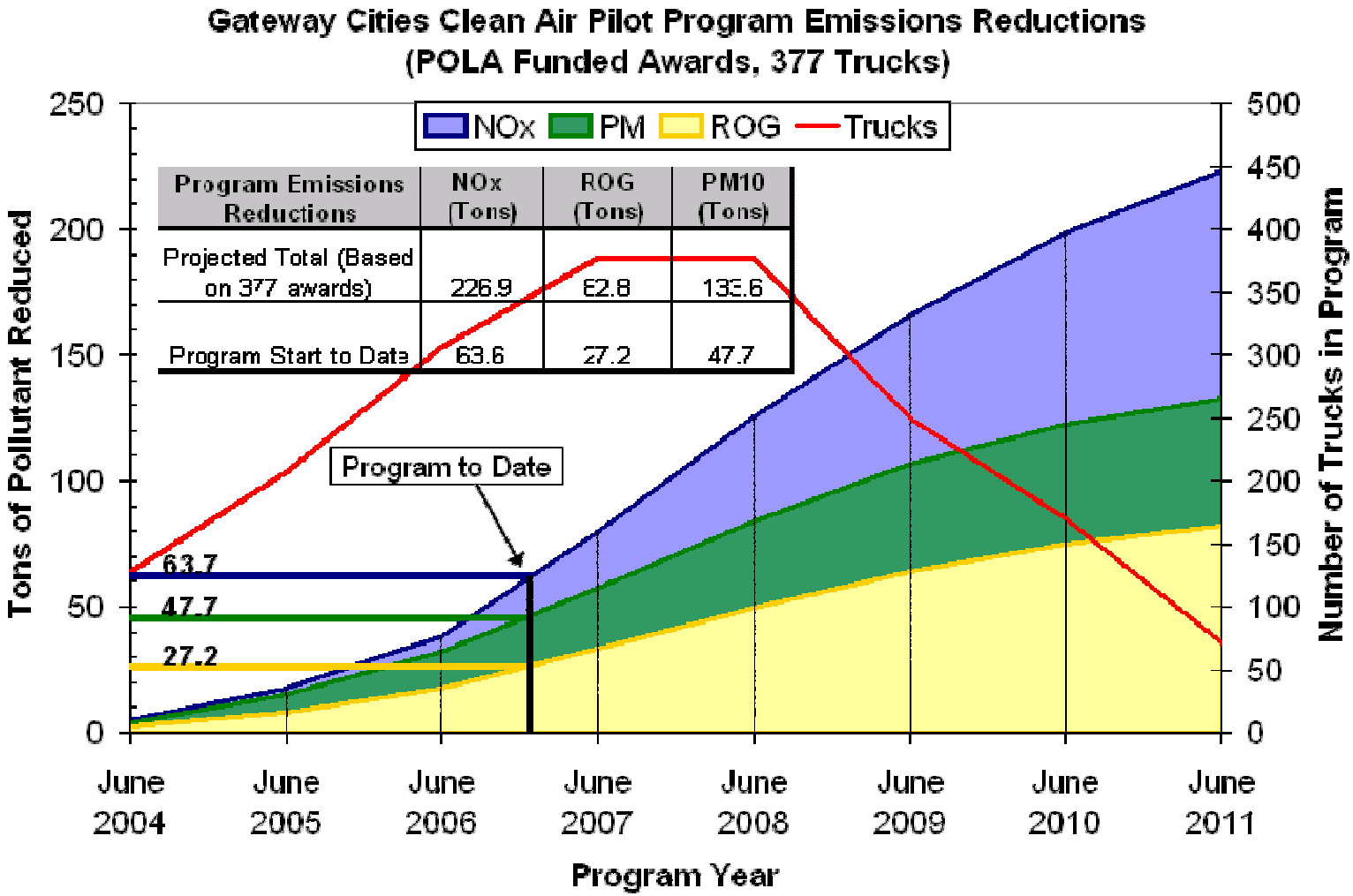
Fleet Mod Under Gateway Cities Program (>525 Older Trucks Destroyed & Replaced)

- Replaced trucks (pre-1987) are dominated by Cummins Big Cam engines at 350 to 400 HP
- Replacement trucks (1994 and newer) mostly have 400 to 450 HP engines (e.g., DDC S60)
- "De-rating" replacement truck's HP is frequently necessary to maintain HP rating within 20% of original truck





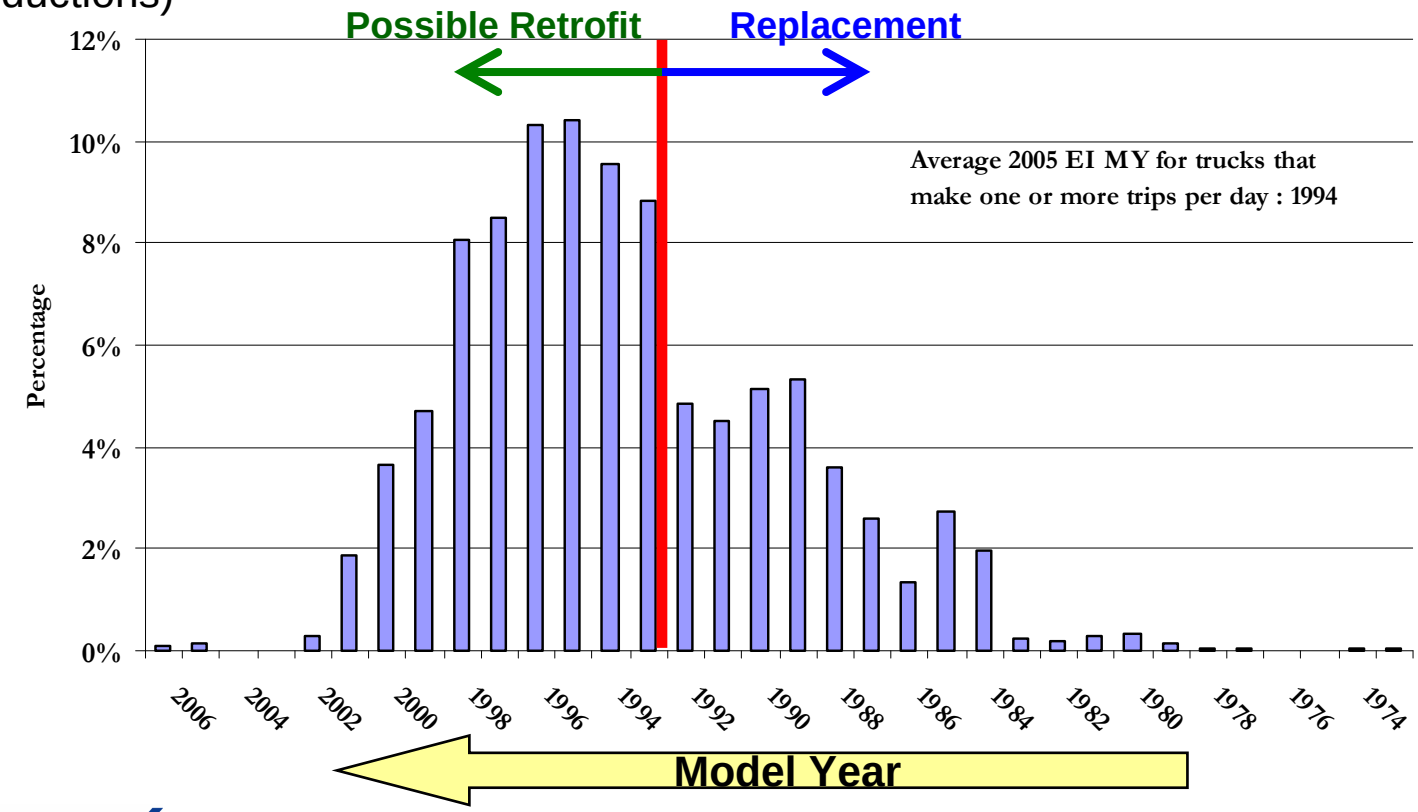
- Most common engines for replacement trucks are MY 2000-2001 (due to lower truck cost)
- 2004+ MY engines becoming more popular as truck prices drop; these engines also benefit from improved cost effectiveness due to EGR
- Some Level 1 retrofits have been implemented on replacement trucks (mixed results)



- Based on 377 awarded trucks funded by POLA (most are container trucks)
- Estimated using EMFAC 2007, assuming 30,000 annual miles per truck

San Pedro Bay Ports CAAP: Replace or Retrofit ***Thousands of Port Trucks***

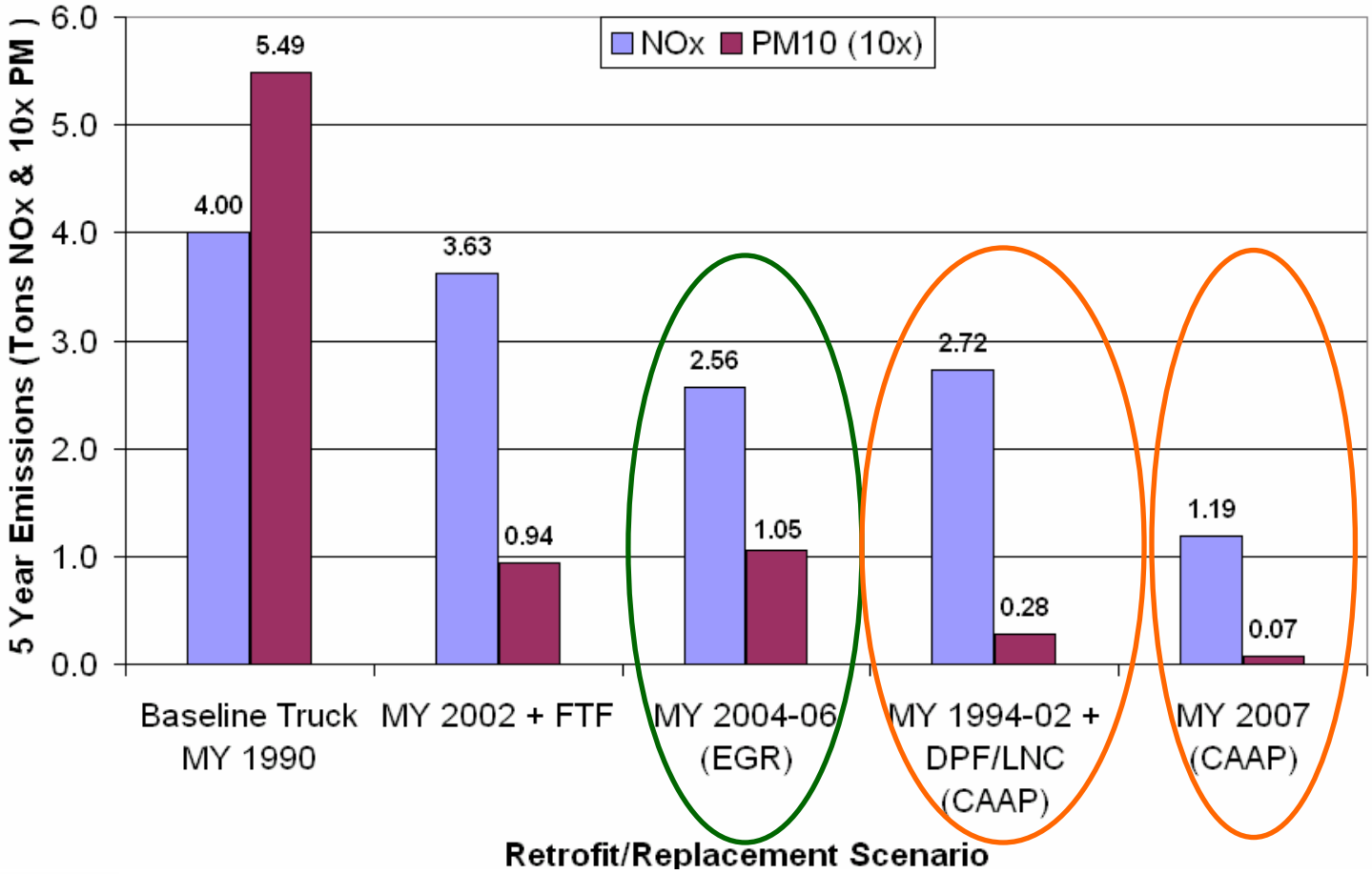
- MY 1992 and older trucks to be replaced with new port trucks meeting 2007 emissions standards (both diesel and LNG technologies)
- Approximately 50% of MY 1993 to 2006 trucks will be retrofitted with verified Diesel Emissions Control Strategies (including current "BACT" device with 85% PM / 25% NOx reductions)



Source: Final 2006 San Pedro Bay Ports Clean Air Action Plan Technical Report

- **The CAAP seeks replacement / retrofit scenarios that maximize PM10 and NOx reductions**
- **For "bridge funding" that transitions current POLA-funded Gateway program into longer-term CAAP, it may make sense to "modernize" with EGR engines that currently can't be retrofitted, depending on the relative weighting of NOx and PM benefits**

Five-Year Per Truck Emissions for Port Trucks Under Various Scenarios



Beginning with fleet applications (carrier-owned trucks), LNG-fueled container trucks are expected to be rolled out in 2008 under the San Pedro Bay Ports CAAP

Westport HPDI LNG Trucks at Norcal Waste

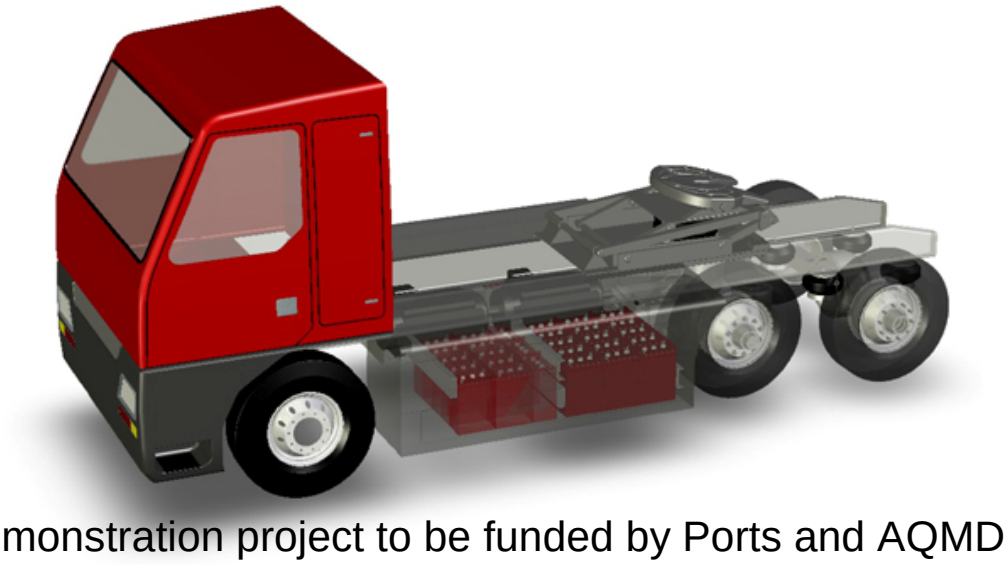
Clean Energy LNG Fueling Station

	Anticipated LNG Port Trucks
Engine and Provider	Cummins ISX with HPDI technology from Westport Innovations
Possible Chassis and Providers	Kenworth T800 / Freightliner, others
Availability	Baseline trucks available and awaiting go-ahead from Ports for LNG conversion
Certification Status	Expected mid 2007 certification of Westport HPDI Cummins ISXG
Infrastructure Needs	1 or more dedicated fueling facilities Maintenance facility
Cost	Estimated at $150k / truck (~$30 to $50k incremental cost over diesel) ~$2M to $4M per LNG facility ~$1M per maintenance facility
Benefits	Small PM emissions benefit* (if baseline diesel engine certed to '07 standards)

*Example: 2007 ISX HPDI engine certified to 1.2 g/bhp-hr NOx + HC / 0.008 PM compared to 2007 diesel engine certified to 1.2 g/bhp-hr NOx + HC / 0.01 PM

For the longer term, zero-emissions container trucks are needed and under development

- Initially, likely to be limited to niche uses (inside or near the terminals)
- Potentially viable for much broader use over the longer term
  - Battery electric (San Pedro Ports-SCAQMD demonstration program)
  - Hybrid electric (including alternative fuels)
  - Hydrogen fuel cell



Electric tow tractor demonstration project to be funded by Ports and AQMD

Image from: http://www.portoflosangeles.org/images/etruck_large.jpg

Reducing Emissions from Container Trucks *Agenda*

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General Suitability Tests for Retrofitting On-Road HDVs

- Considerations and selection criteria include:
  - Is there a CARB-verified device for the engine make/model year?
  - Does engine have EGR, for which no passive DPF is currently verified?
  - Is specific end user group conducive to using / maintaining device properly?
  - Does intended duty cycle / application generate sufficient exhaust temperatures for a passive DPF? If not, can an active DPF work? Would a Level 2 flow-through filter be better for the applications?
  - Are there horsepower restrictions? Does truck have dual exhaust?
- Additional considerations for retrofits:
  - Operation and maintenance costs
  - Infrastructure requirements
  - Failure mode of the device
  - Variability of driver workload and duty cycle

Specific challenges for retrofitting container port trucks include:

- Average daily mileage varies among drivers (from 50 to 300 miles per day)
- Drivers carry different cargo (20,000 – 80,000 lbs GCVW)
  - 20’ and 40’ containers
  - Empty containers
- Workloads can change seasonally
- Drivers may change carriers, drive for multiple carriers, drive to the port part time, and/or temporarily leave for another trucking vocation
- Engine may not be properly maintained
- **These factors affect the average exhaust temperature and/or PM generation rates, which dictate viability of a given retrofit device**
- **Port truckers can least afford higher operational costs that may result from retrofitting an existing truck**

Fuel costs to the Trucker: replace & retrofit project, versus retrofit existing truck only

Scenario 1: replace MY pre-1987 truck with MY 2003, and retrofit it with DPF / LNC system

- Trucker gets newer, safer, more-reliable truck while **lowering annual fuel costs** by $1,400 to $5,200

Range of % FE Increase From Replacing Older Mechanical Truck with Newer Electronic Truck (Retrofitted with DPF / NOx Device)	Percent Reduced Annual Fuel Cost	Annual Fuel Cost Saving Over Baseline ($)
(Baseline of Old Truck @ 5.0 mpg)		
6.8%	-6.4%	$ (1,425)
12.0%	-10.7%	$ (2,400)
18.0%	-15.3%	$ (3,417)
24.0%	-19.4%	$ (4,335)
30.0%	-23.1%	$ (5,169)

Assumptions for both scenarios:

Electronic eng. FE is up to 37% greater than baseline mechanical

40,000 miles per year

Diesel at $2.80 / gallon

3% to 5% FE penalty for DPF/LNC

Scenario 2: retrofit existing MY 2003 truck with DPF / LNC system

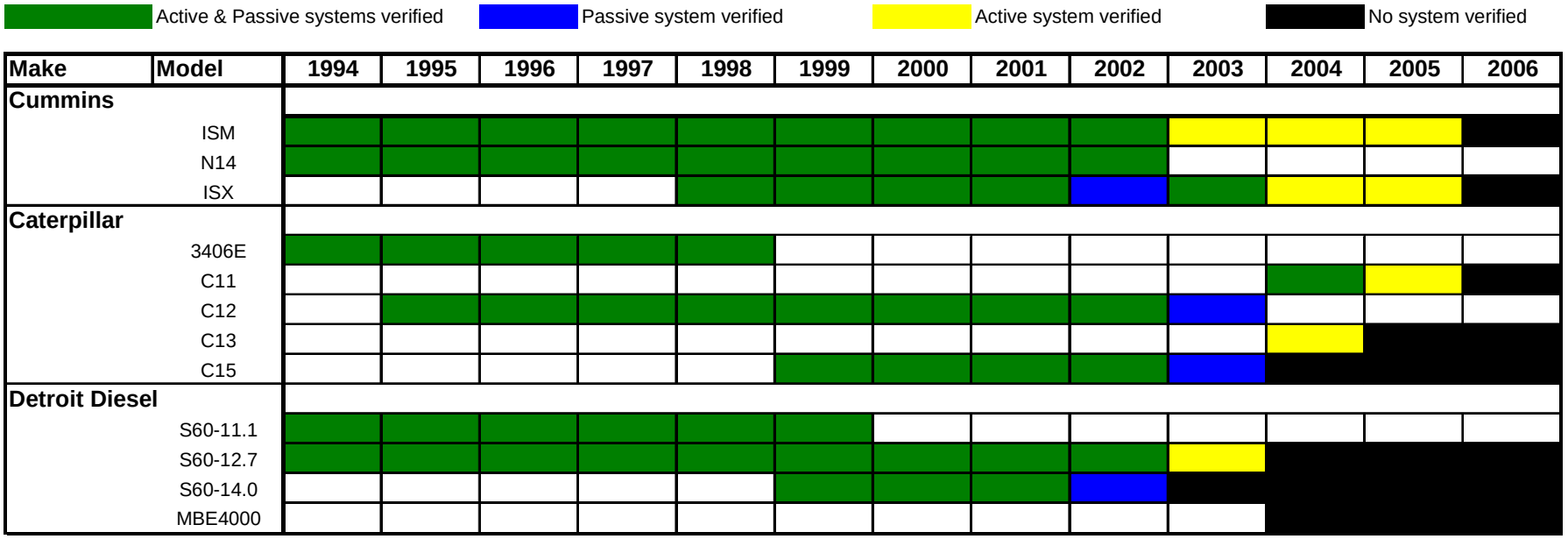
- Trucker sees no obvious personal benefit, while **increasing annual fuel costs** by $500 to $850

Range of % FE Penalty When Simply Retrofitting Newer Electronic Truck with DPF / NOx Device	Percent Increased Annual Fuel Cost	Annual Fuel Cost Penalty Over Baseline ($)
(Baseline of Newer Truck @ 6.8 mpg)		
-3.0%	3.1%	$ 508
-4.0%	4.2%	$ 689
-4.9%	5.2%	$ 847

NOTE: both scenarios entail new annual costs to the trucker for DPF maintenance (filter changes and de-ashing)

Lesson: Costs make or break port trucker viability. Retrofit-only program requires special planning, subsidies and outreach to port truckers!

Verified device coverage of engines and model years typically serving the Ports

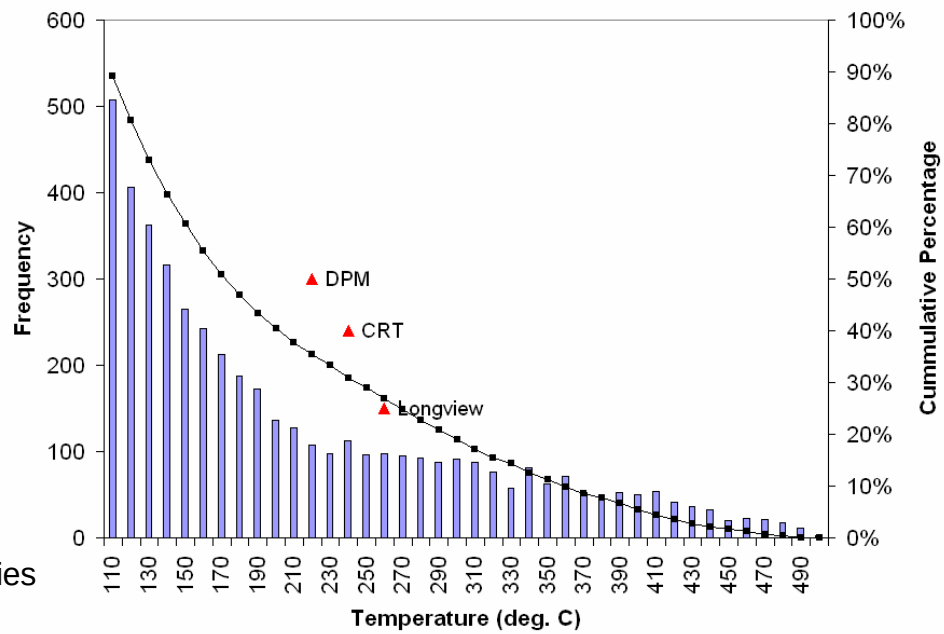


Make	Model	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Cummins														
	ISM													
	N14													
	ISX													
Caterpillar														
	3406E													
	C11													
	C12													
	C13													
	C15													
Detroit Diesel														
	S60-11.1													
	S60-12.7													
	S60-14.0													
	MBE4000													

- Many ’94 – ‘02 engines can <u>theoretically</u> utilize currently verified passive or active systems
- In reality:
  - Applicability of passive DPFs depends on exhaust temperatures, condition of engine, etc.
  - Active systems that regenerate onboard with electrical power (e.g., Cleaire Horizon) may only work for company-owned container trucks (requires access to power outlets)
  - Active DPF retrofit system that uses fuel burner (Huss) has size restrictions; for typical engines used in container trucks, this currently costs >2X over a passive DPF

TIAX's exhaust temperature testing effort of port trucks for POLA / POLB

- Objective: determine if container trucks generate enough exhaust heat to meet verification requirements of **passive DPF systems** (especially Longview DPF / LNC)
- Test Plan: data log 30 trucks (MY '93 to '06, various engine makes, models, etc.)
- Test Parameters: mileage, exhaust temperature, driver workload (survey), engine on/off time (estimated)
- Results to Date: approximately 23 port trucks have been successfully datalogged
- Preliminary conclusion: Longview passive DPF system can work for a large percentage of port trucks, with careful screening



Example exhaust temperature histogram showing viability of verified DPF technologies

TIAX measured temp. losses along the exhaust pipe of one Class 8 Tractor

Turbo Outlet	1995 Freightliner w/DDC S60 Engine	Muffler Inlet
		
Temperature Range: 11 – 482 °C	Approx. 12 ft. of non-insulated exhaust piping.	Temperature Range: 10 – 430 °C

Exhaust Flow

- Container trucks typically have sleeper cabs, resulting in extra-long exhaust piping
- On average, there was a 36 ℃ loss along the non-in sulated exhaust pipe
- 26% of time >260 ℃ at muffler → 31% of time >260 ℃ at turbo
- **Conclusions:** heat loss is significant, and exhaust pipe insulation would be beneficial in some cases; but this is probably not a practicable solution for port trucks

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Various technologies, control strategies, and incentive programs can be effective in reducing emissions from container trucks, including:

- Engineering approaches, e.g.:
  - cleaner fuels
  - aftertreatment devices
  - anti-idling technologies
- Logistics and efficiency approaches
  - "Smart" terminals
  - Off-peak access programs
- Modal shift to rail and emerging technologies
- Regulatory and enforcement approaches
  - Anti-idling laws
  - Stepped-up truck inspections at the ports
- Incentive programs such as fleet modernization
  - Gateway Cities program (grants for newer port trucks are currently funded by both POLA and MSRC)
  - SCAQMD Carl Moyer program
  - Upcoming San Pedro Bay Ports Clean Air Action Plan

Various technologies, control strategies, and incentive programs can be effective in reducing emissions from container trucks, including:

- Retrofitting of 1993 to 2003 container trucks with BACT DECS
  - Container trucks operate under unique parameters that determine DECS viability and choices
  - Certain passive DPFs appear to be viable for large-scale retrofit efforts, with application of the following:
    - Screening tools to ID trucks that have most-conducive duty cycle and meet other requirements (e.g., good engine condition)
    - Outreach programs for the affected population of port truckers, with possible compensation for higher operating costs
  - Active DPF systems (similar to those used on new trucks to meet 2007 PM standards) are not yet readily available and feasible for retrofitting onto container trucks
  - The technology landscape for all retrofit devices is rapidly changing, and new / better choices are likely to emerge soon (i.e., **the CAAP will be an evolving program**)
- All potential control measures need to be evaluated for cost effectiveness (multiple pollutants), size of reduction for application, appropriateness of measure for affected end user population, availability of incentives, etc.

Thank You For Your Attention!

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Contacts:

Michael D. Jackson
jackson.michael@tiaxllc.com

Jon Leonard
leonard.jon@tiaxllc.com

Patrick Couch
couch.patrick@tiaxllc.com