Northeast Diesel Collaborative

Steering Committee Meeting

Locomotive and Marine Emission Reduction Technology Progress

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MJ Bradley & Associates
October 11, 2006

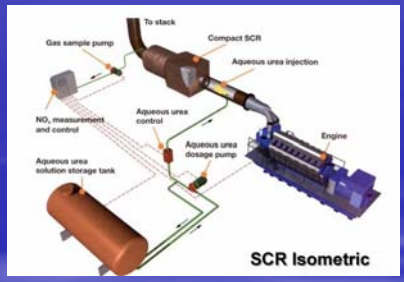
Control Technologies

Hardware PM Emission Effectiveness

20%

APU

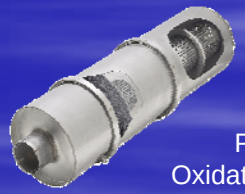
Off-board Emission Control System
(SCR, Scrubber, Cartridge Collector)



Selective Catalytic Reduction (NOx)

xidation
Catalyst

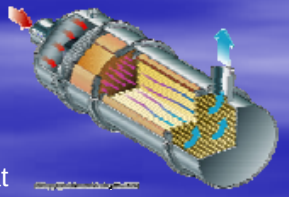
Closed
Crank Case
Filter



Performance
Oxidation Catalyst

TSE

Engine Rebuild



Diesel
rticulat
Filter

Hybrid Electric

Engine Repower

90+%

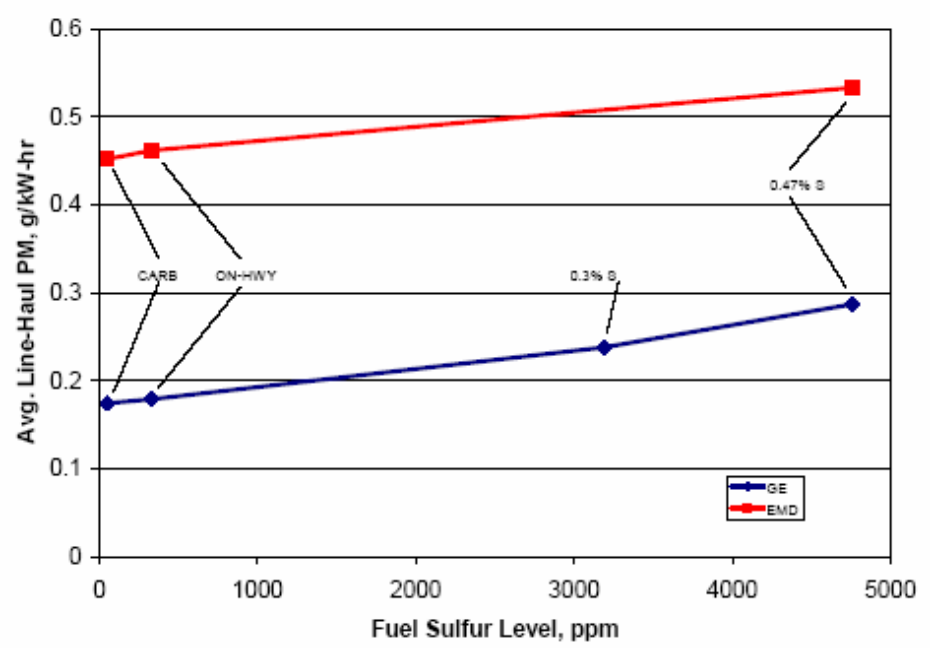
Technology Progress

- Research & Development (R&D)
  - Systematic study of technology in a lab environment
- Proof of Concept (PoC)
  - Proven technology in a new or different application
  - Demonstration in principle, Prototype
- Demonstration (PoC extension, pre-verification)
  - Performance and in-use durability testing, optimization
- Deployment
  - Verified/Certified product, warranty, part #, etc.

LSD vs. ULSD Fuel

	Current	June 2006	June 2007	June 2010	June 2012
On-Road	500	15	15	15	15
Off-Road	~3,000	~3,000	500	15	15
Marine/Rail	~3,000	~3,000	500	500	15

- Most Marine and Rail emission control technologies are actually LSD tolerant



ICEF2005-1228, S. Fritz et al, SWRI, ASME

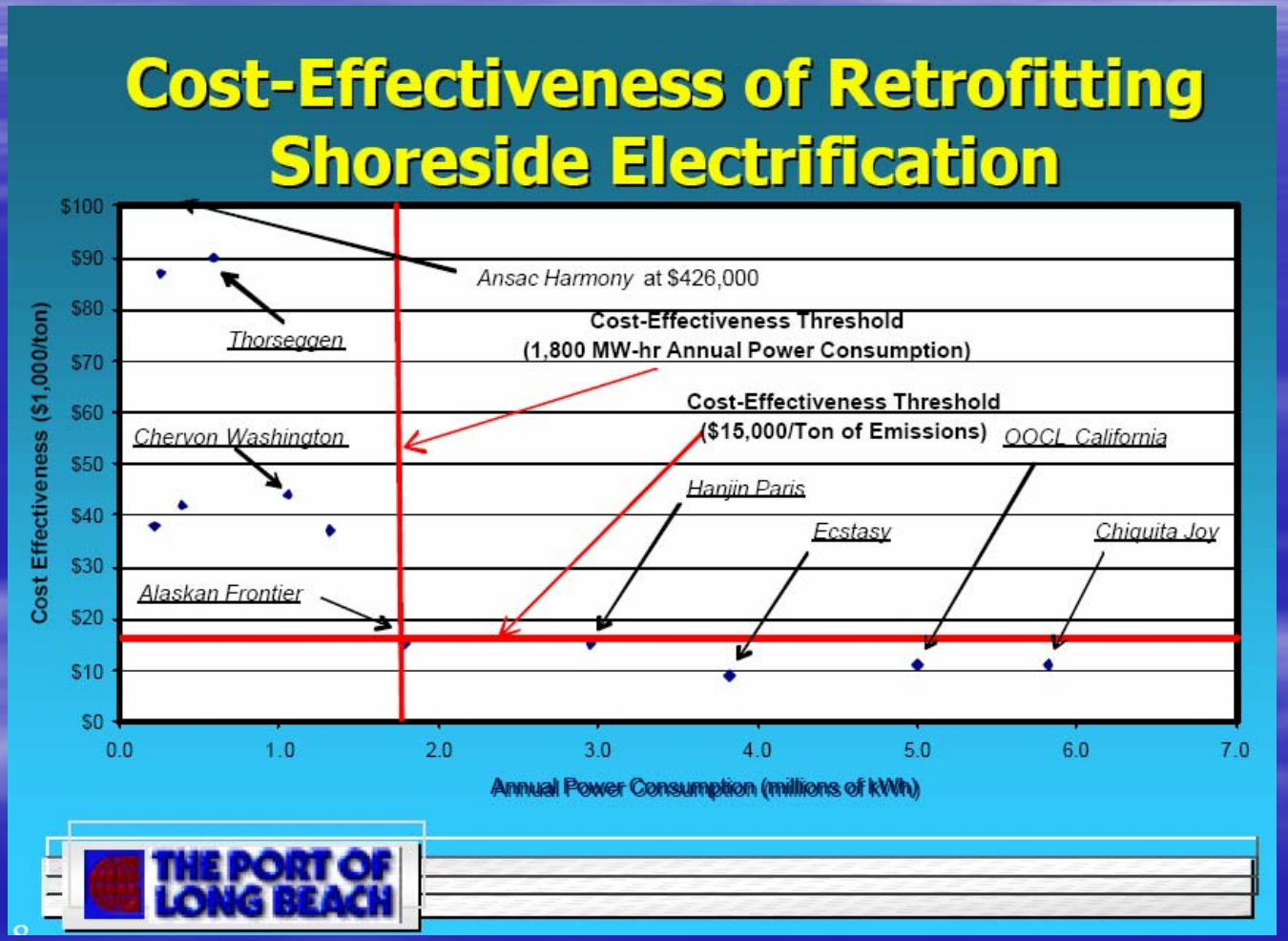
Marine Overview

- APU – Standard Equipment
- Dock Electrification – Cold Ironing (Yes)
- DOC – (Demo Yes), HPDOC (No, PoC)
- Rebuild to newer standard – (Yes)
- Repower to Tier 2 – (Yes)
- SCR/DOC – (SIF demo Yes, 500-ppm fuel)
- DPF – (Europe only, low sulfur fuel is the only stumbling block, active DPF systems are 500-ppm tolerant)
- Sea Water Scrubbing (PoC outside US)
- Off-Board Emission Control System (Planned demo, CA)

Marine Cold Ironing

•Port Juneau, AK

Marine Cold Ironing



Port of Long Beach, CA (all pollutants summed)

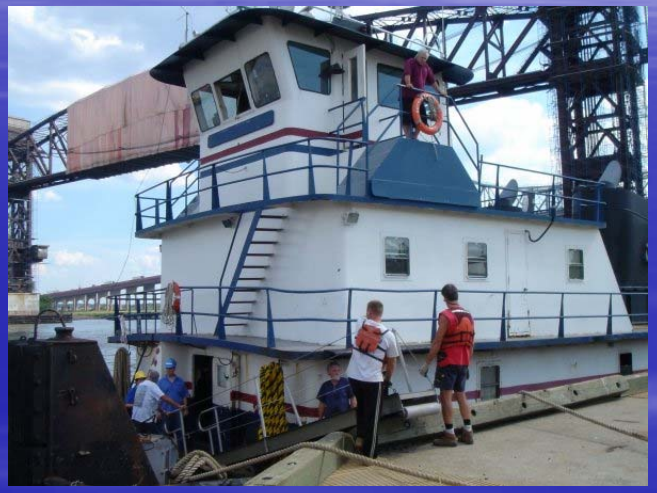
Marine Diesel Oxidation Catalyst

NYSERDA, Private Ferry Retrofit

- Main Engine DOC Retrofits
  - •DOC + Fuel Borne Catalyst
  - •DOC
  - •LSD and ULSD fuels
  - •SCR (proposed, not implemented)

Marine Engine Repowers (Tier 2)

- PANYNJ, Commercial Marine Vessel Repowers (>20 vessels)
  - Repower main engines with New Tier-2 and IMO-40%
    - Tug/Tow Boats
    - Excursion Vessels
    - Ferry (BPJ proposed)
  - Existing Engine Scrapped
  - NOx/PM reductions
- SIF Barberi Class Rebuilds (2 vessels)
  - MV Newhouse, Tier 1 Rebuild for EMD 2-stroke engines (4 of 8 complete)
  - Tier 2 Rebuilds for Molinari Class



Marine SCR/DOC

PANYNJ – Staten Island Ferry

- Selective Catalytic Reduction (SCR)
  - >70% NOx reduction
- Diesel Oxidation Catalyst (LSD, 500-ppm fuel)
  - ~75% CO reduction
  - ~75% HC reduction
  - ~40% PM reduction

Marine DPF

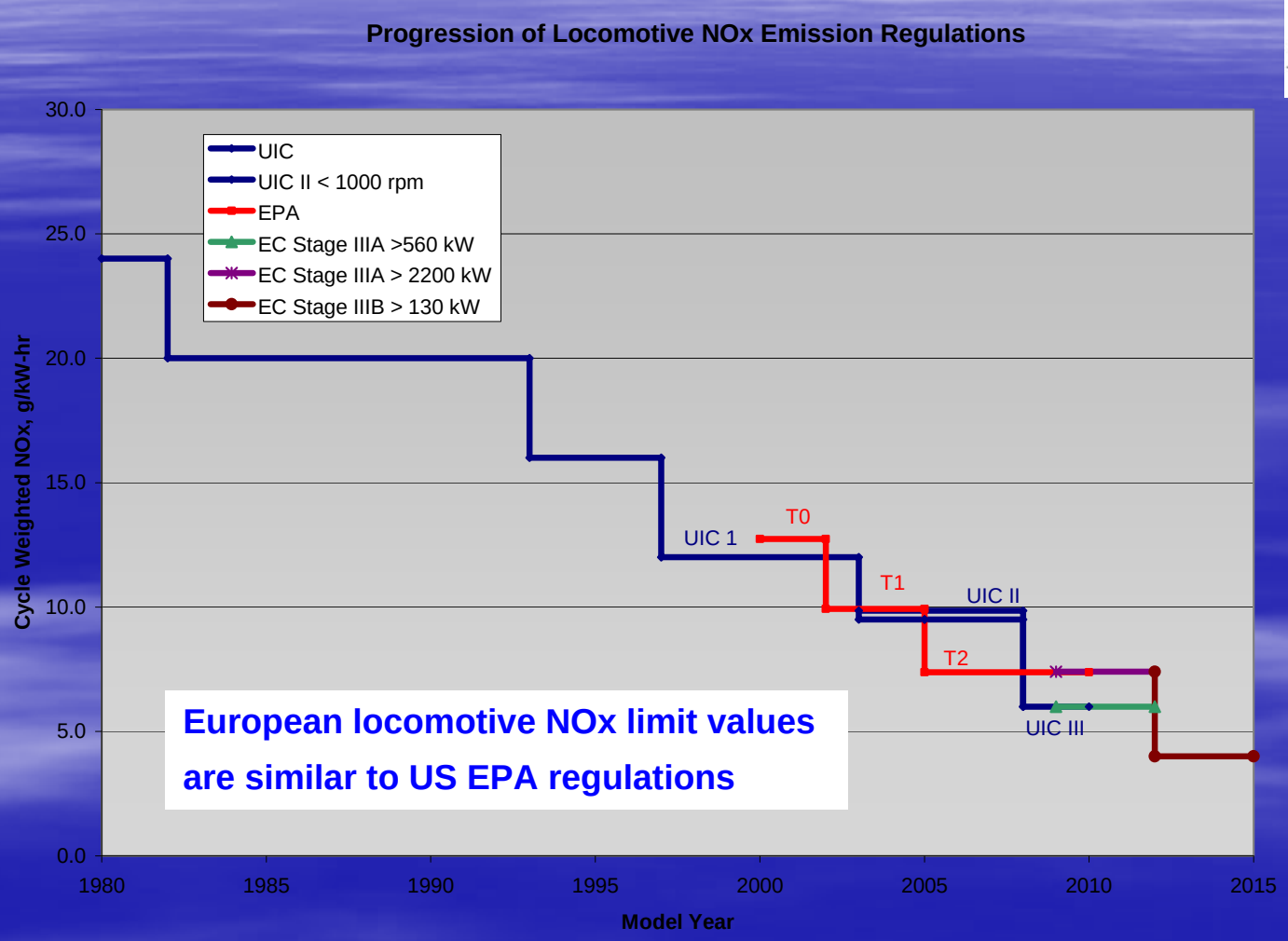
Certainly Possible, Fewer Space Concerns

- Non-US Marine DPFs are mostly active regen
- ULSD fuel not required until 2012, LSD in 2007 (Active DPFs are lightly catalyzed)
- Passive DPFs considered for SIF Austen Class Auxiliary Engines but no ULSD at that time
- Active SCR/DPF considered for SIF Barberi Class but Tier 1 rebuilds implemented first

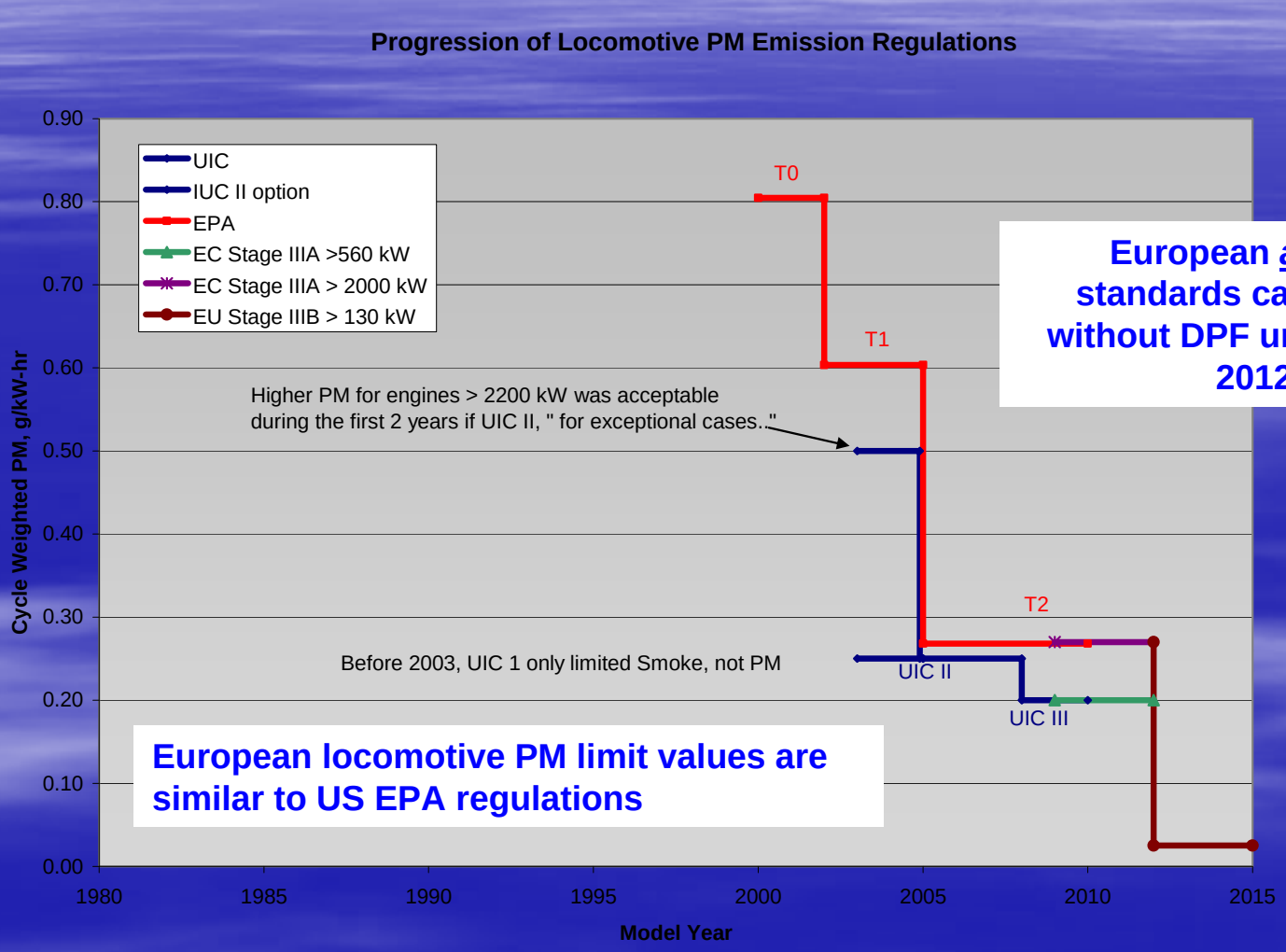
Locomotive Overview

- AESS – Automatic Start/Stop idle management (Yes)
- APU – Small IC unit separate from HEP units (Yes)
- Wayside Electrification – i.e. Electric Coolant/Oil heaters, battery charge (Yes)
- DOC/HPDOC – (Proof, Demo in progress, MA, CA, BC)
- Rebuild to newer standard – (Yes for Tier 0, demo for Tier 1)
- Repower to Tier 2 (No), Tier 3 off-road (Yes, Genset locomotives)
- Hybrid Electric (Yes, Green Goat)
- LNG Switchers (4-1200 hp located in CA, 11-year experience)
- DOC – (UP/BNSF Demo planned in CA)
- SCR/DPF – (Planned Metrolink HEP and 12-710 demo in CA)
- Off-Board Emission Control System (Roseville PoC complete in CA)

Locomotive NOx Standards



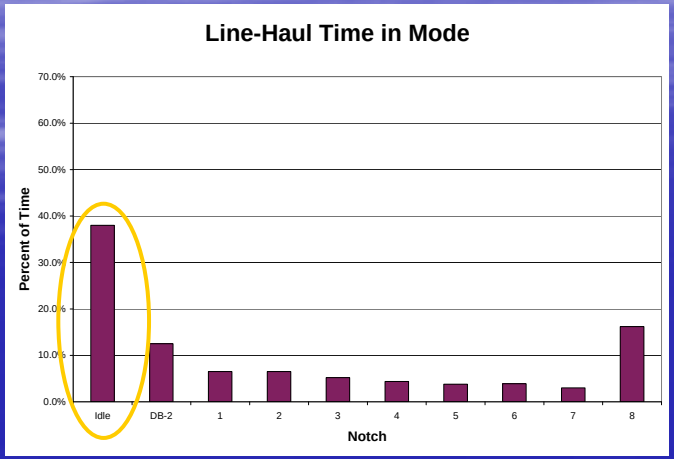
Locomotive PM Standards

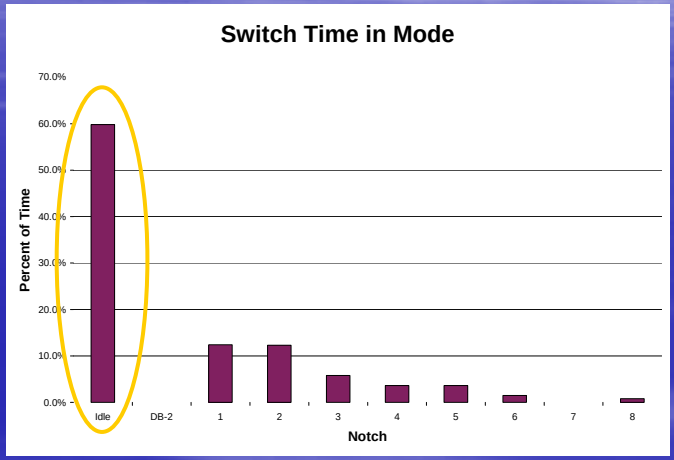


European *and* US standards can be met without DPF until at least 2012

European locomotive PM limit values are similar to US EPA regulations

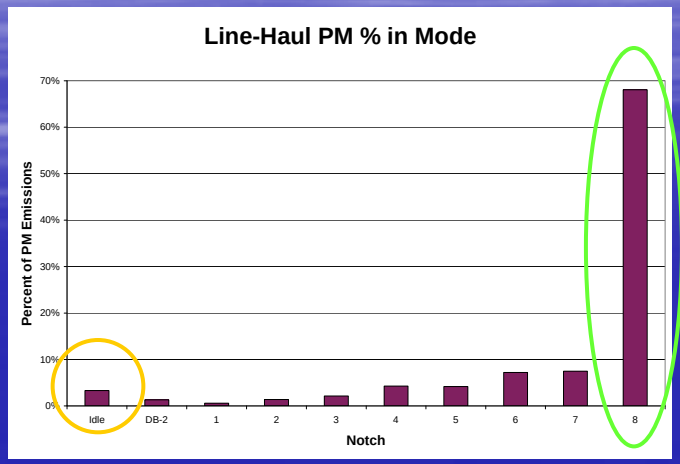
Locomotive Time in Mode

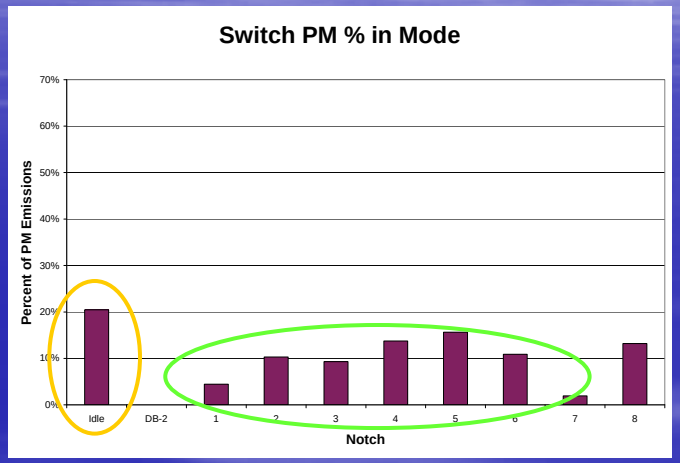




- Annual Locomotive Idle time is significant portion of operation
- Idle reduction technologies and measures can save upwards of 7,500 to 12,000 gallons annually per locomotive
- Idle technologies reduce emissions, fuel and have a favorable return on investment

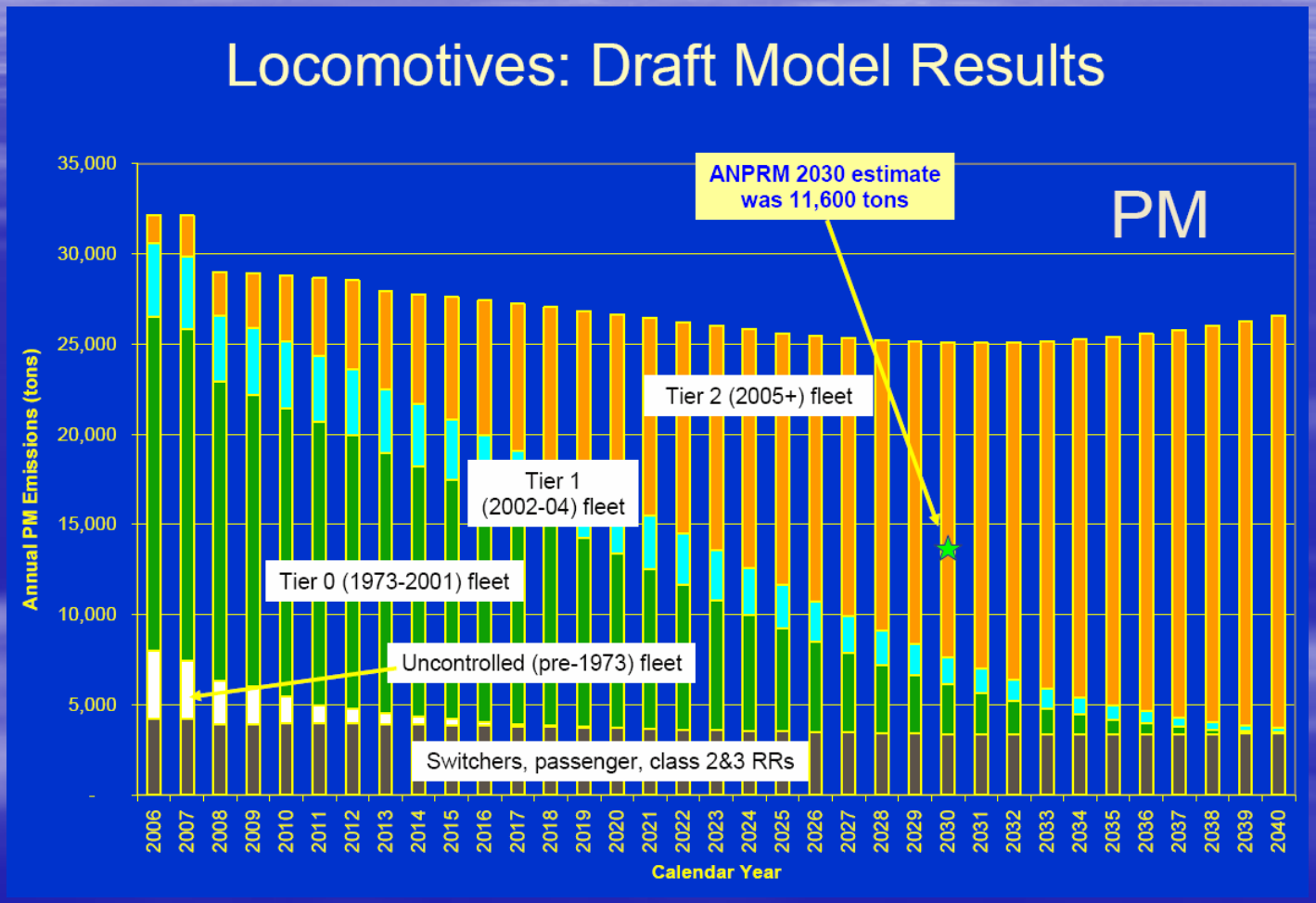
Locomotive Emission in Mode





- Idle PM emissions annually are about
  - 3% of total PM for Line-Haul, >20% for Switch
- Other technologies (i.e. DOC/DPF/SCR) are needed to achieve greater NOx and PM reductions in higher fuel consumption notches

Locomotive Inventory

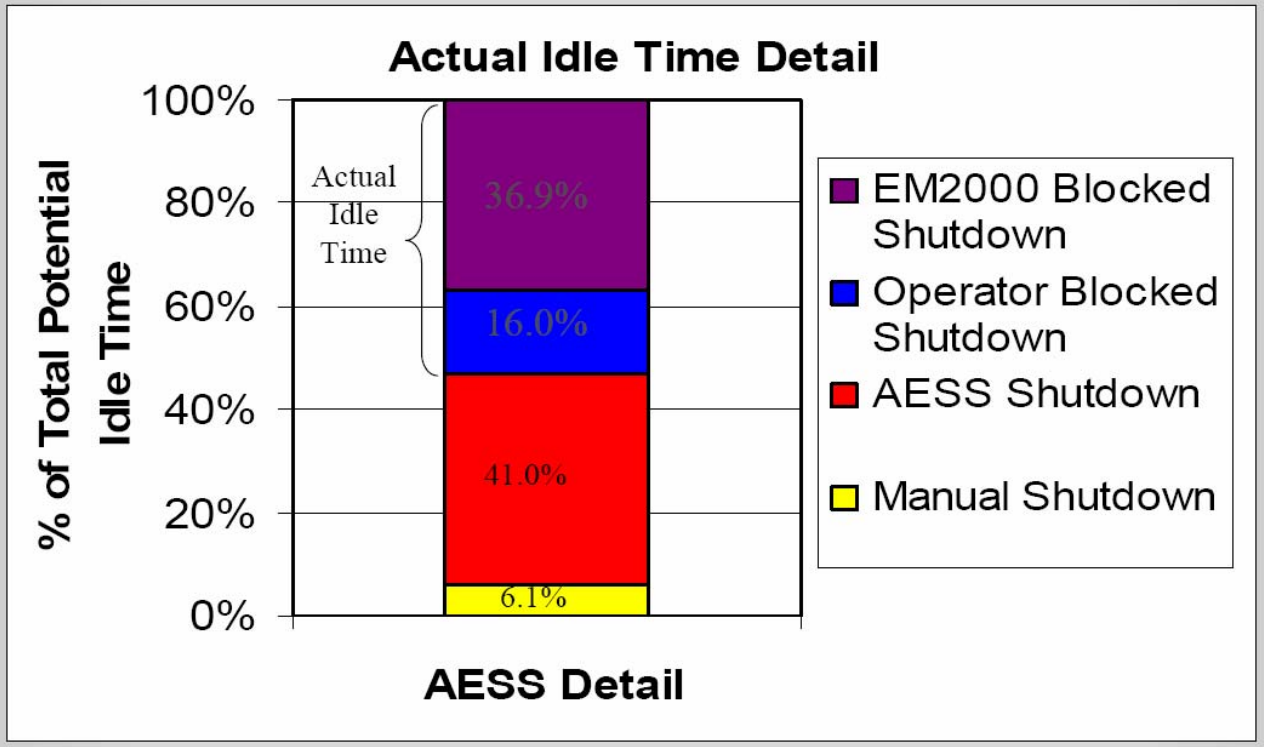


Locomotive Idle Minimization

- Idle Technologies
  - AESS
  - APU
  - Electrification
- Parameters Monitored
  - Coolant Temperature
  - Air Pressure (brakes)
  - Battery Voltage (for restart)
  - Ambient Temperature
- Benefits Include
  - Fuel Savings
  - Emission Savings
  - Reduced Noise

Locomotive Idle Emissions

AESS Impact on Emissions



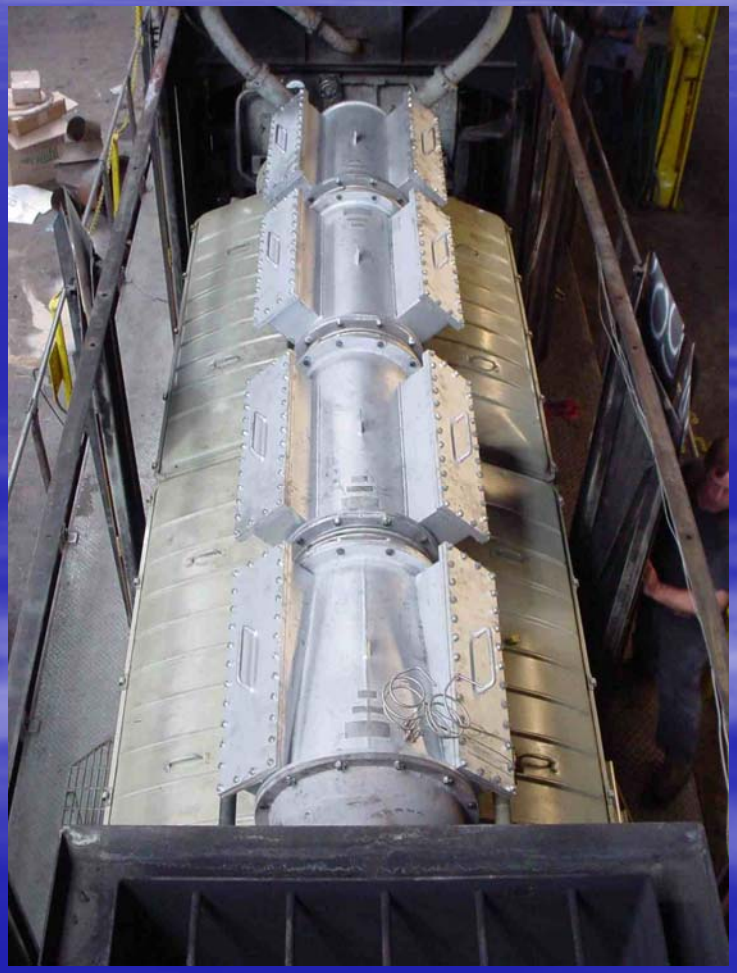
ELECTRO-MOTIVE

Locomotive DOC (1)

- DOC – PoC
  - DOCs located in exhaust manifold to conserve heat, reduced risk of face plugging
  - On turbo engines, DOC is pre- turbocharger
  - MBTA, Boston
  - SwRI Evaluation

Locomotive DOC (2)

- DOC – Demo
  - UP, BNSF, California
  - SwRI Pre-evaluation

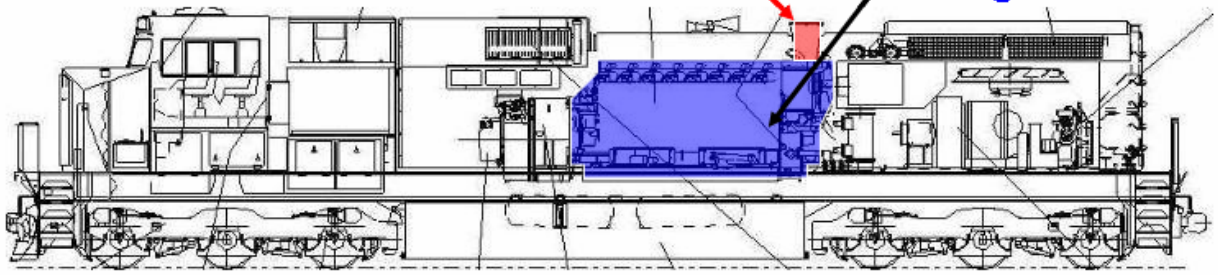


Locomotive (US vs. Euro)

GE *4400 HP* diesel-electric AC locomotive

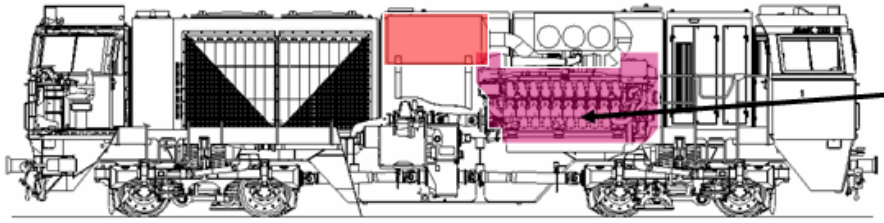
GE Evolution-series medium-speed 4400 HP diesel engine (EMD 710 engine identical size)

Exhaust muffler



420,000 pound weight
76' long

Hug diesel particulate filter (DPF) inside muffler



MTU high-speed 3600 HP diesel engine

200,000 pound weight
57' long

Vossloh MaK 2000BB *3600 HP* diesel-hydraulic locomotive

UP/BNSF DPF Switchers (4), CA

Hybrid/Genset Switchers

- Railpower
  - Green Goat ™ (UP has 10 in TX, 11 in CA)
  - Genset Switcher (UP has 98 ordered for TX)
- National Railway Equipment (NRE)
  - Genset Switcher (UP has 60 ordered for CA)
  - Was Tier 2, now Tier 3 no after treatment yet

2005-built EPA Tier 2

BNSF, LNG Switchers, CA

SwRI, WA 1-2 w/ EPA

- Preliminary work assignment to determine feasibility SCR for Tier 3, Tier 4 standards
  - Stakeholder prelim meetings in 2006
- Proof of Concept designs for:
  - SCR/DOC and SCR/DPF
  - Marine and Rail Applications
- Potential for an additional EPA sponsored marine SCR demonstration

Locomotive Information

Southwest Research Institute

- Original SwRI and other Rail presentations as presented to California ARB are available on CARB locomotive web page
  - http://www.arb.ca.gov/msprog/offroad/loco/loco.htm