



# Diesel Generators – Tier 4

MADRI – THE ROLE OF DISTRIBUTED GENERATION  
IN DEMAND RESPONSE PROGRAMS

SEPTEMBER 6, 2012

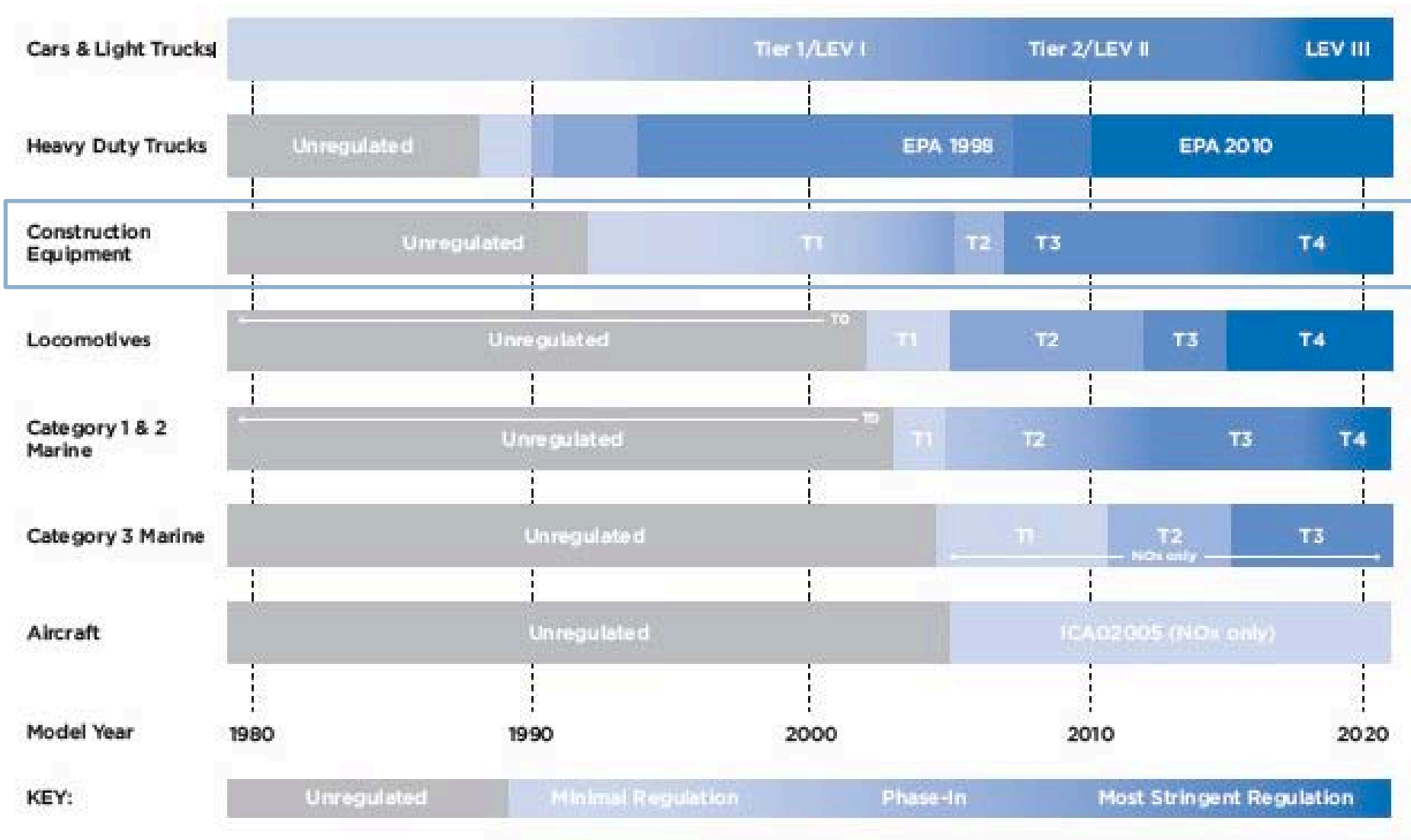
Dana Lowell  
(603) 647 -5746 x 103  
dlowell@mjbradley.com

MJB & A

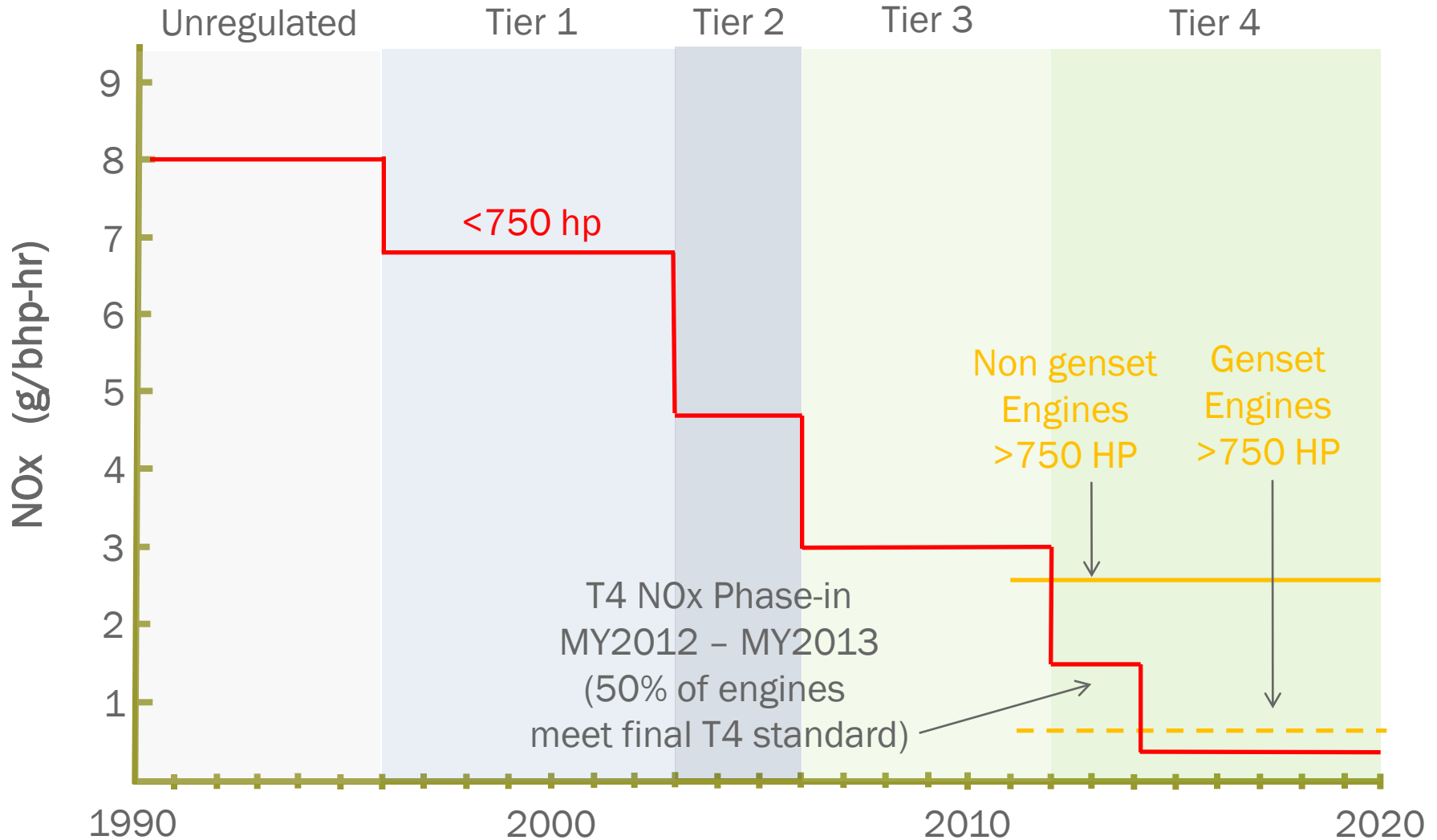
MJB & A

**M.J. Bradley & Associates LLC**  
(978) 369 5533 / [www.mjbradley.com](http://www.mjbradley.com)

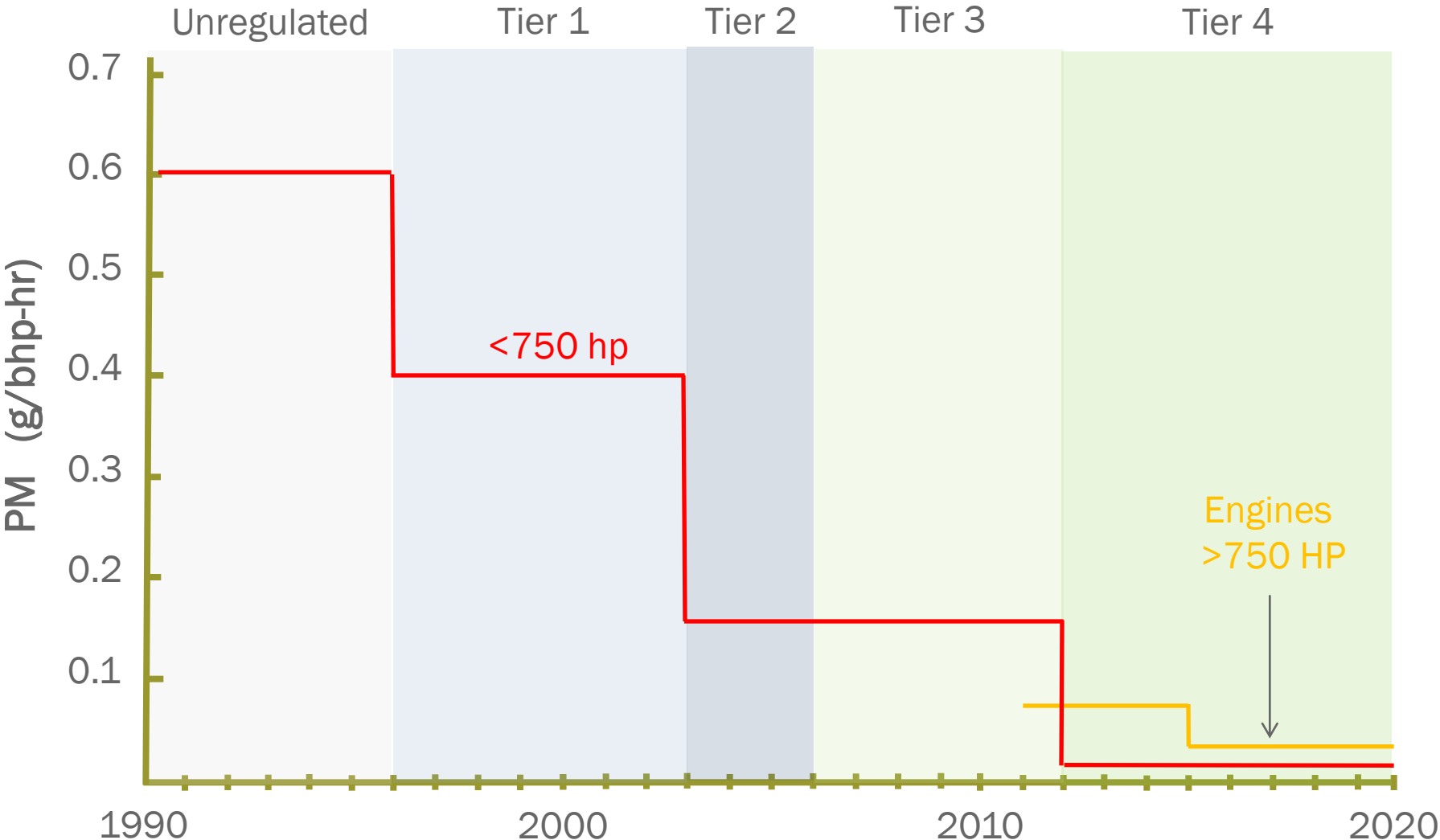
# CHANGING EMISSION STANDARDS



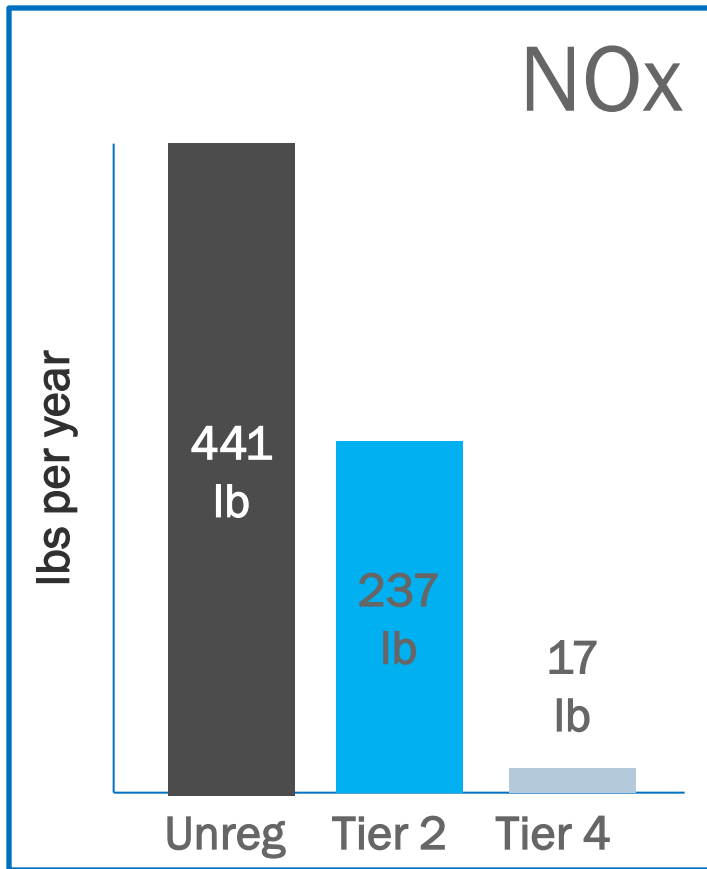
# PHASE-IN OF NONROAD ENGINE NO<sub>x</sub> STANDARDS



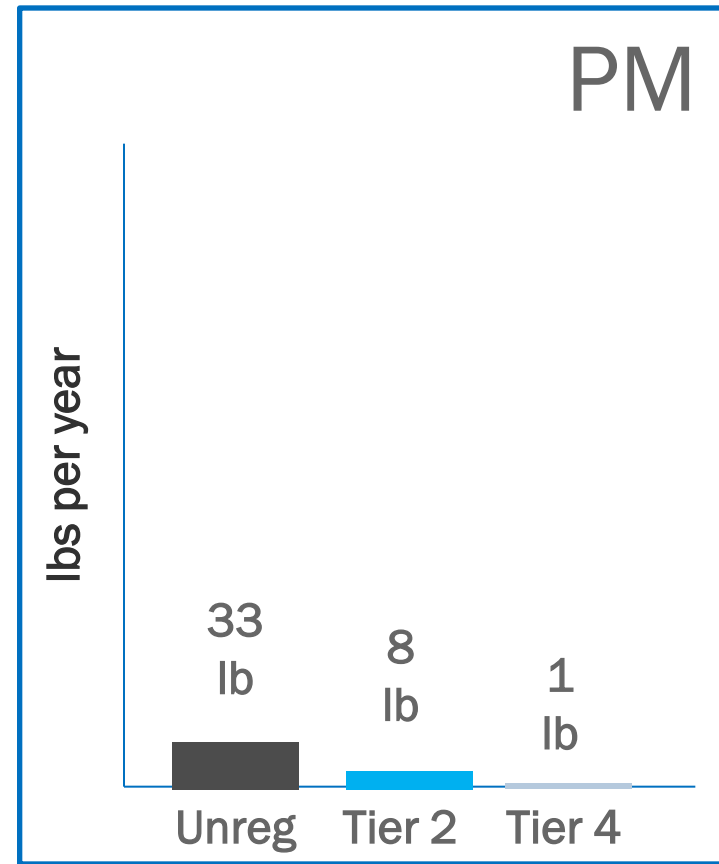
# PHASE-IN OF NONROAD ENGINE PM STANDARDS



# POTENTIAL EMISSION REDUCTIONS



Unregulated → Tier 2 -46%  
Unregulated → Tier 4 -96%



Unregulated → Tier 2 -75%  
Unregulated → Tier 4 -98%

*Assumes 500 HP engine, 50% load factor, and 100 hours per year*

# TECHNOLOGIES TO ACHIEVE LOWER EMISSIONS

CLEANER

- 4-stroke cycle from 2-stroke cycle
- Better lube oil control
- Piston bowl shape
- **Electronic control of fuel injection**
- Higher pressure fuel injection
- Variable Geometry Turbo-charger
- Charge air cooling
- Exhaust Gas Recirculation
- After-treatment
  - Diesel Oxidation catalyst
  - Diesel Particulate Filter
  - Non-selective Catalytic Reduction
  - Selective Catalytic Reduction

2007 ONROAD

2010 ONROAD

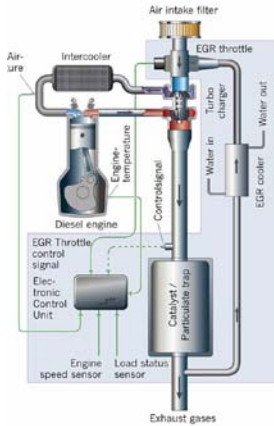
TIER 2 NONROAD

TIER 3 & 4 NONRAD

# RETROFITS - NO<sub>x</sub>

## EGR

- Exhaust gas recirculated to air intake to reduce combustion temp
- May reduce engine efficiency



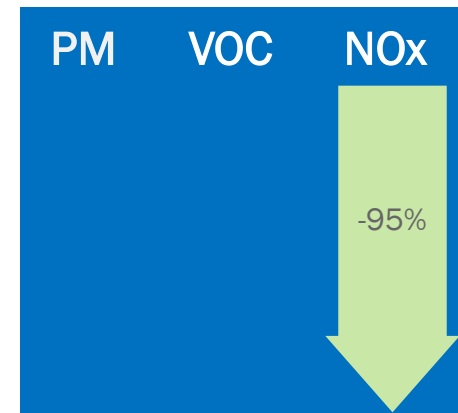
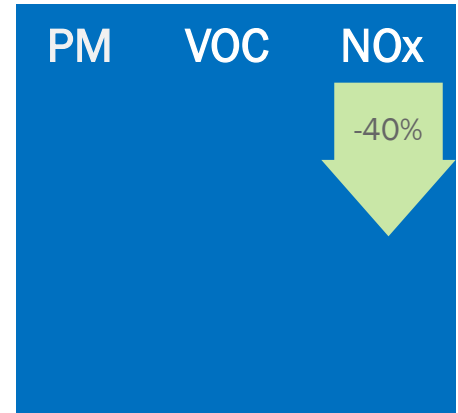
## NSCR

- Requires catalyst and diesel fuel reductant
- 2-4% increase in fuel use

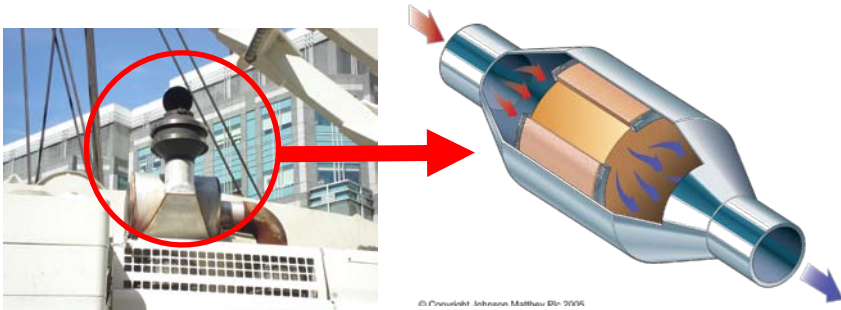


## SCR

- Requires catalyst and urea reductant
- Urea use is 3-5% of fuel use

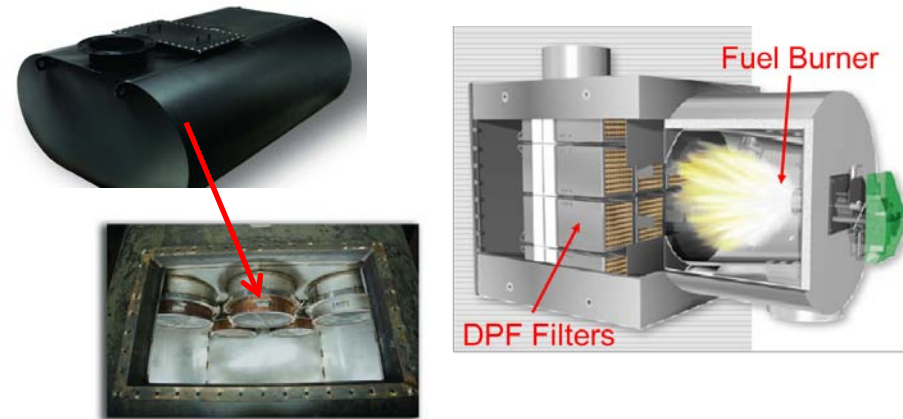
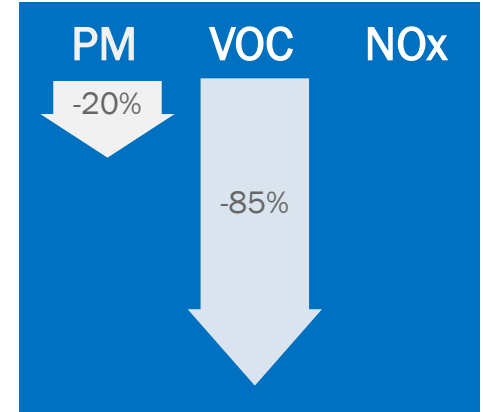


# RETROFITS – PM/VOC/HAPS



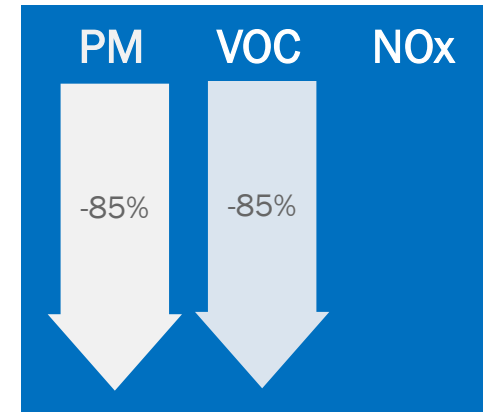
## DOC

- Totally passive
- Easy to install



## DPF

- Passive devices require minimum exhaust temperature
- Active devices require fuel or electricity for filter regeneration



PASSIVE

ACTIVE



# REPOWER/REPLACEMENT

- Fully-compliant Tier 4 engines available in all size ranges in 2015
- Compared to unregulated engines will reduce NOx and PM by 95+%
- For <750 HP engines, will likely require in-engine changes plus DPF + SCR after-treatment
- For >750 HP engines, other technology paths may be possible
  - ✓ In-engine PM reductions + SCR + DOC
  - ✓ In-engine NOx reductions + DPF
- Cost of Tier 4 compliance relative to current Tier 2 engines will depend on technology path
  - ✓ Likely 10 – 30% increase
  - ✓ May be capital/operating cost trade-offs
- Compared to retrofit options repowering is often cost-effective and may reduce fuel use in some applications

# COST OF LOWER EMISSIONS

		DOC RETROFIT	DPF RETROFIT	EGR RETROFIT	SCR RETROFIT	REPOWER REPLACE **
Capital Cost		\$15 /hp	\$80/hp	\$80/hp	\$150/hp	\$300/hp
Operational Issues		None	1-2% fuel penalty	1% fuel penalty	Urea use 4-6% of fuel	Urea use 2-4% or fuel
500 HP Engine	Capital	\$7,500	\$40,000	\$40,000	\$75,000	\$150,000
	Incr Annual Operating *	\$3.00	\$60.00	\$50.00	\$175.00	\$100.00
Cost Effectiveness *		\$227,000 per ton PM	\$290,000 per ton PM	\$45,000 per ton NOx	\$37,000 per ton NOx	\$240,000 per ton PM  \$25,000 per ton NOx

\* Assumes 50% load factor, 100 hours per year, and 10-year retrofit life, 20-year new engine life

\*\* Assumes T4 engine w/SCR, costing 20% more than current T2/T3 engines. Cost effectiveness based on 50% of cost attributed to NOx reduction, 50% to PM reduction