Reducing NOx and PM Emissions in Today's Machines:

A Caterpillar Perspective

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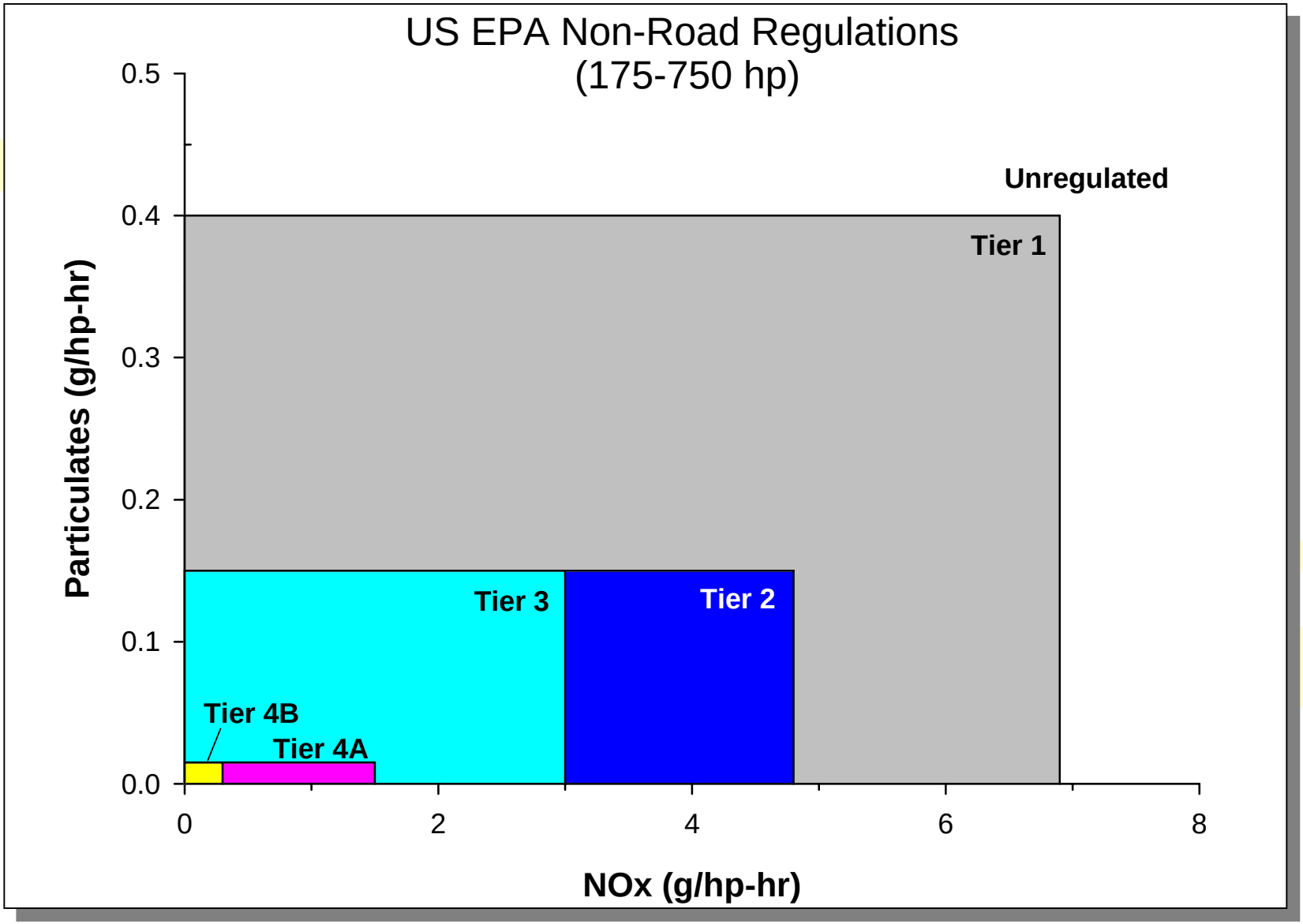
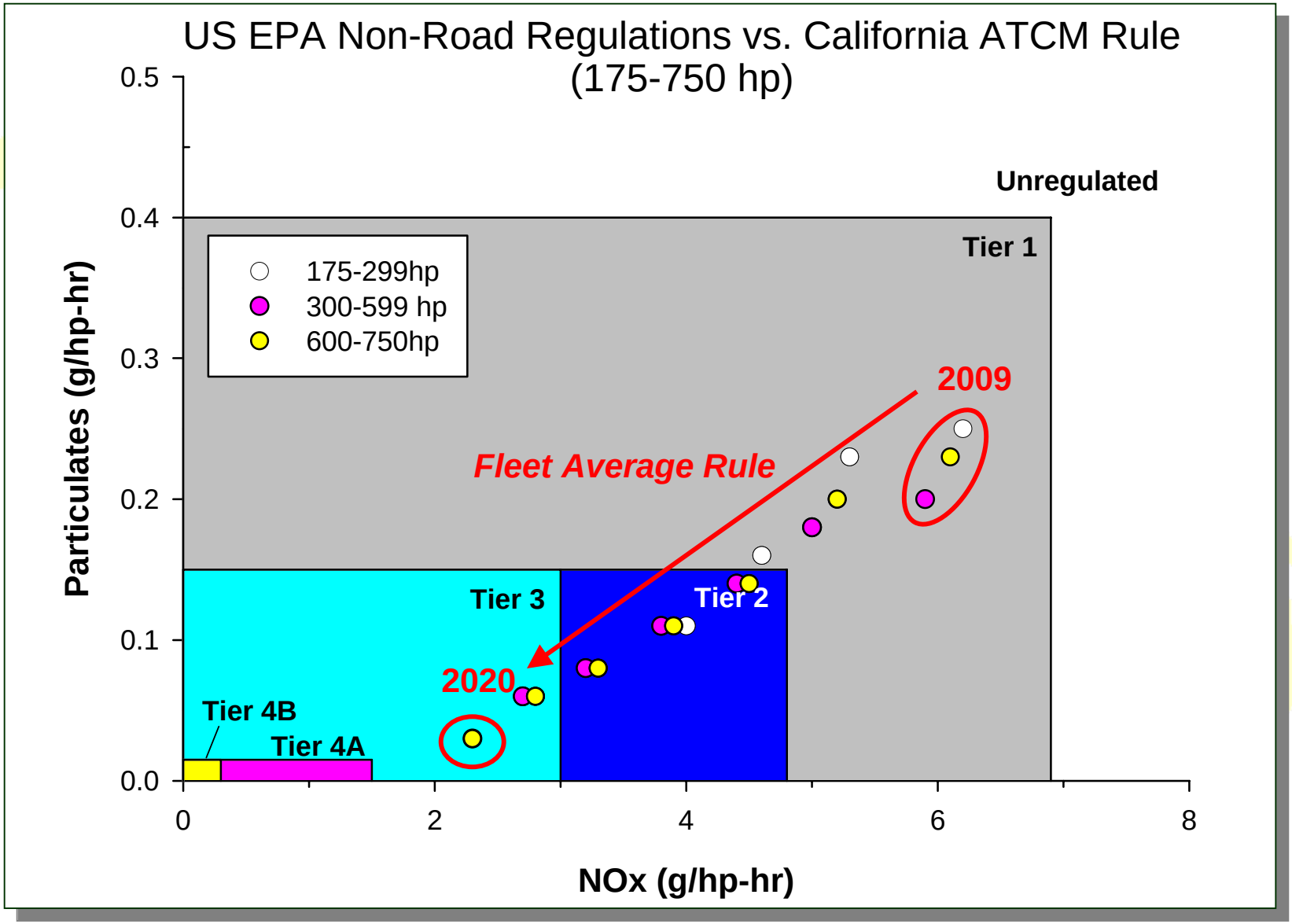
Outline

- The Emissions Landscape
- Caterpillar's Path to Emissions Reduction
  - ✓ The RePower Opportunity
  - ✓ Upgrading Older Engines
  - ✓ Aftertreatment – the final frontier…
- Summary

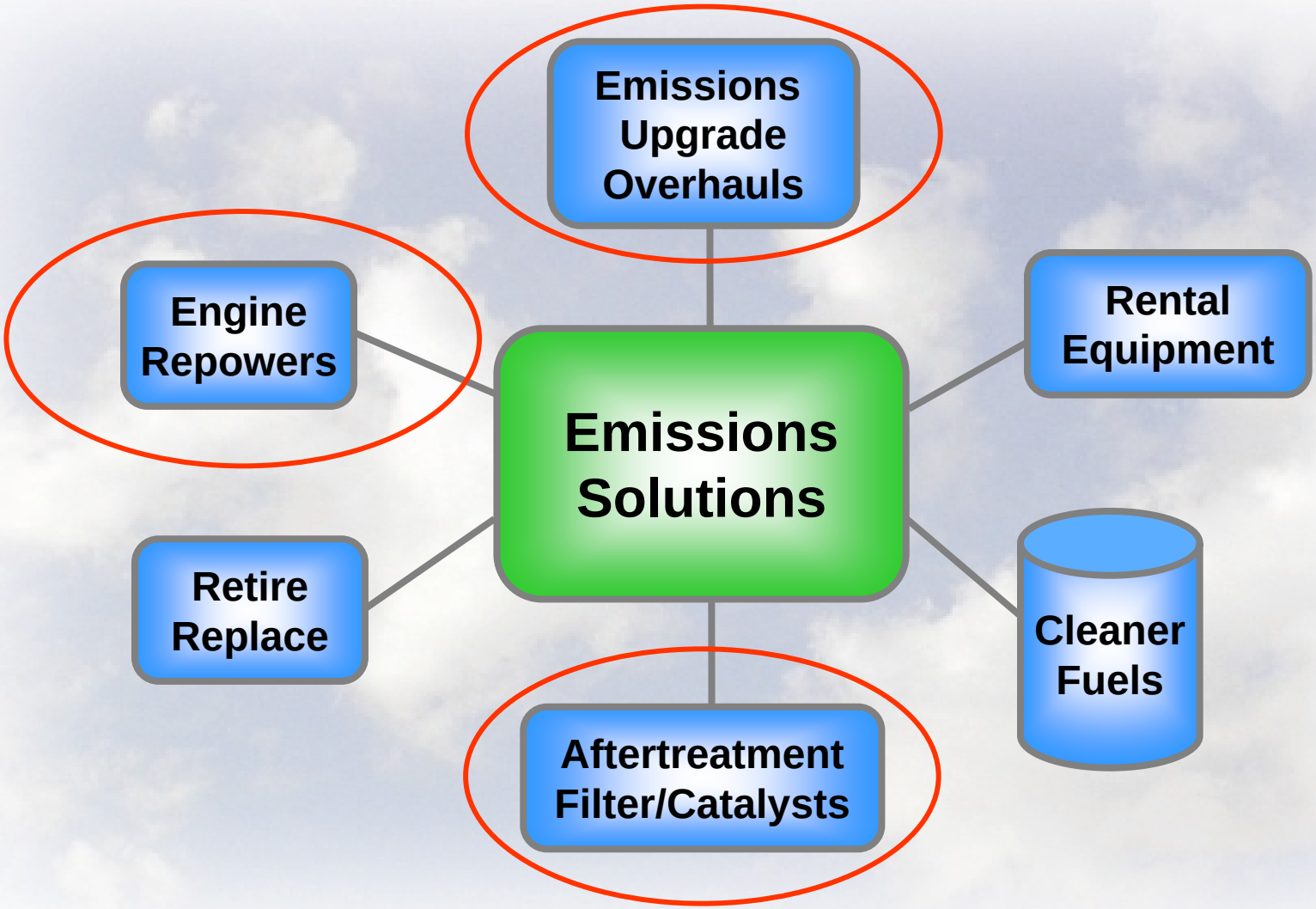
The Emissions Landscape: US EPA Regulations



The Emissions Landscape: Upcoming CA ATCM Rules



Caterpillar's Path to Emissions Reduction



CAT's Engine RePower Program

- **Tier 1, Tier 2, and Tier 3**
- **Primary NOx solution for Cat Retrofit**
- **100+ machine models; 2000+ repowers**

Replace the pre-Tier 1 engines with a lower emissions engine for the most cost-effective NOx reduction

Emissions Retrofit Engine Upgrade Groups

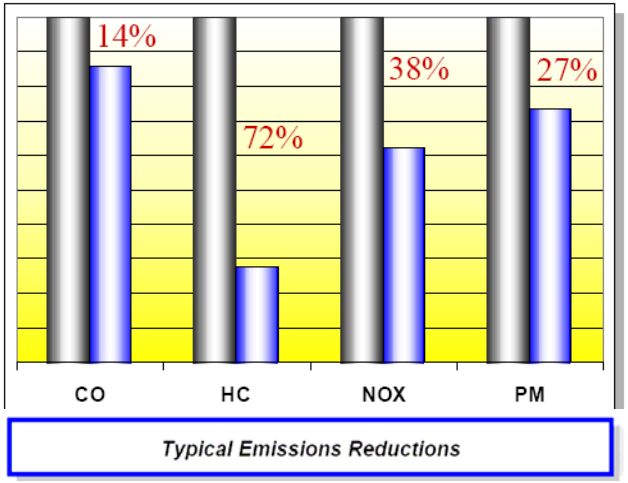
Upgrade to Tier 1 emissions levels during an engine overhaul

Turbochargers

Fuel pumps / Governors

Cylinder packs

- **Cost effective solutions**
- **Same Caterpillar reliability and serviceability**
- **Available for select 3306 off-road applications**
- **Available for 3406 off-road in 2007**

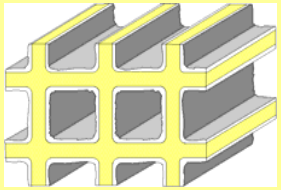


Diesel Emission Reduction: Aftertreatment Solutions

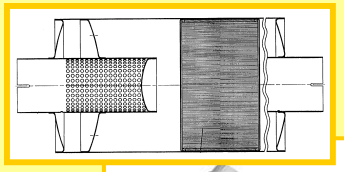
Exhaust Aftertreatment

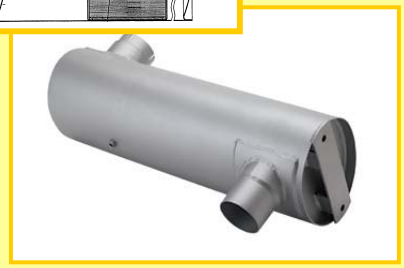
HC + CO Reduction

- Oxidation Catalysts (80-95%)



"Flow-thru" catalyst system

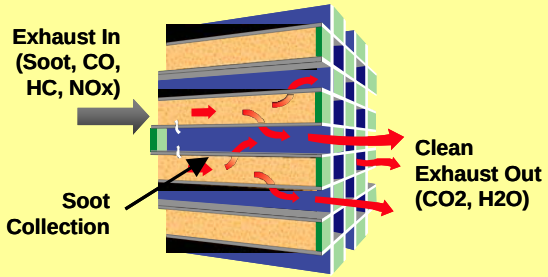




Generally a muffler replacement

PM Reduction

- Oxidation Catalysts (up to 20-25%)
- Particulate Filters (> 85%)



"Wall-flow" catalyst system

Ideally a muffler replacement, but often much larger

NOx Reduction

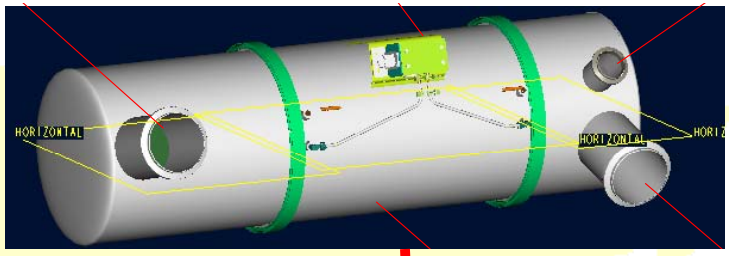
- Urea-SCR
- HC-SCR
- Lean NOx Traps
- Hybrid Catalysts

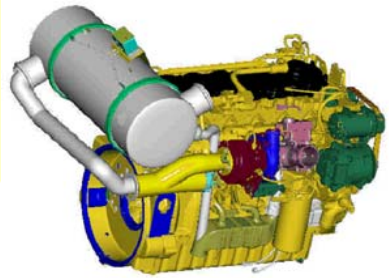
Reducing Particulate Emissions in CAT Machines

➢ ***The Diesel Particulate Filter***

High filtration efficiency, but…

- ✓ **Space claim & Weight**
- ✓ **Backpressure (fuel economy)**
- ✓ **Cost ($$$)**





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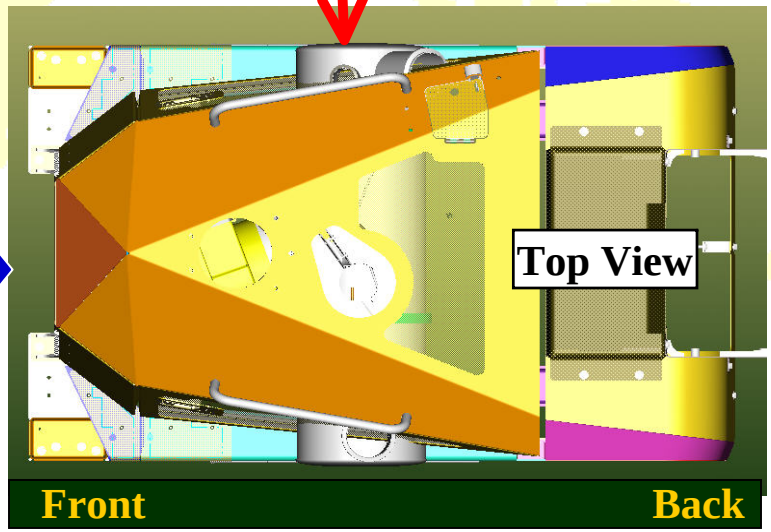
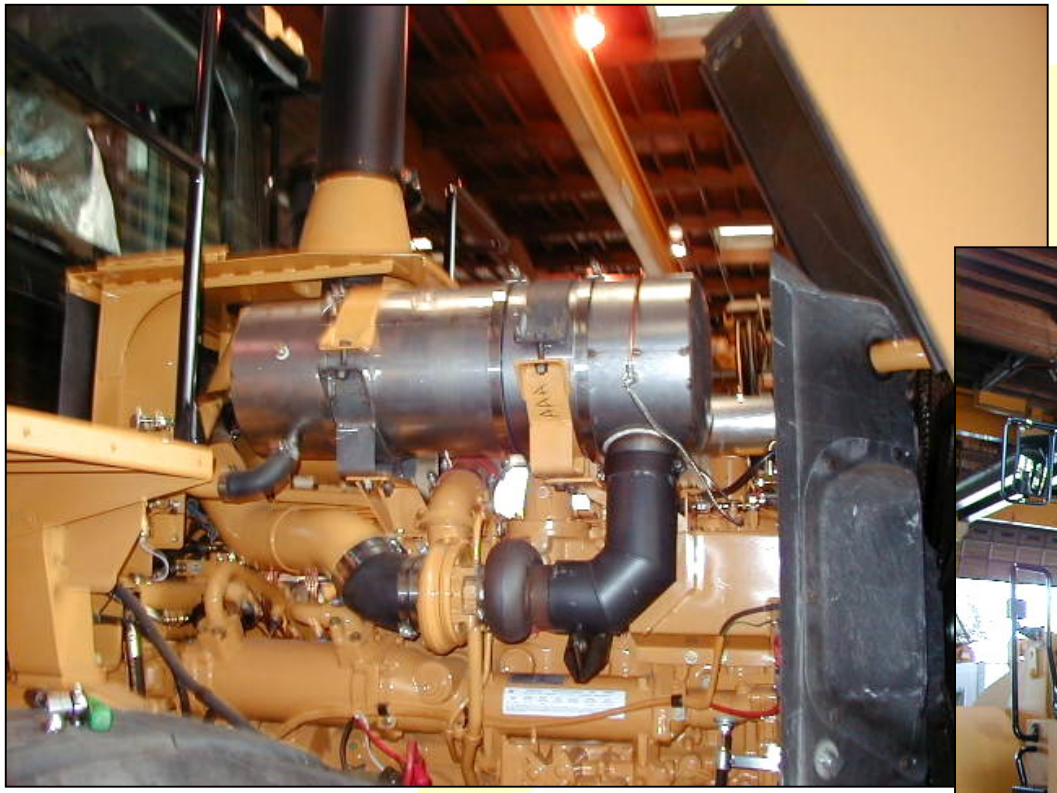


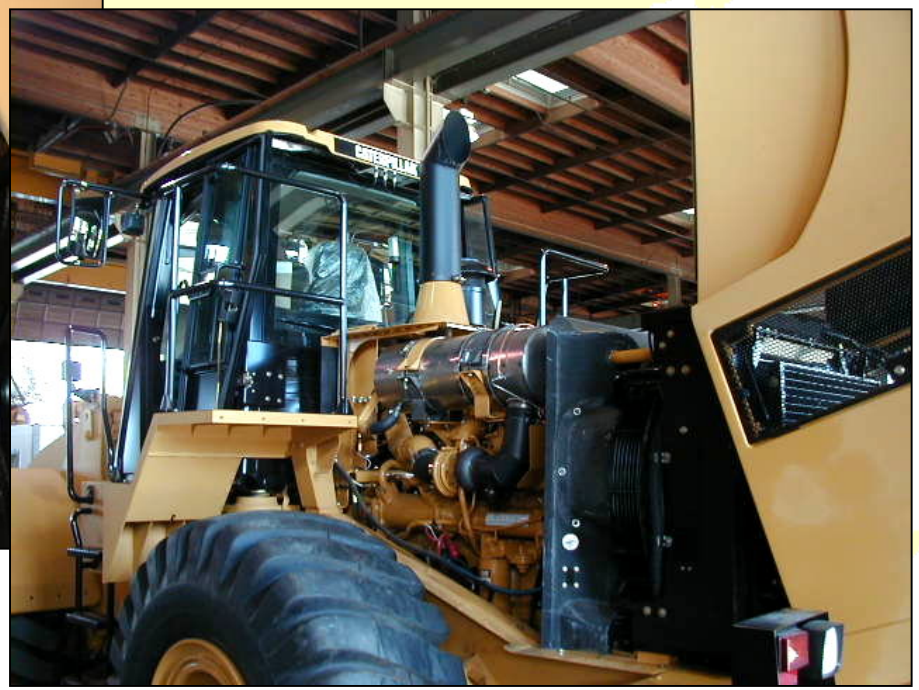
Considerable engineering required to ensure an optimum retrofit design.

Successful DPF Installations

966G-II Wheel Loader



CAT Engineered & CAT Dealer Installed



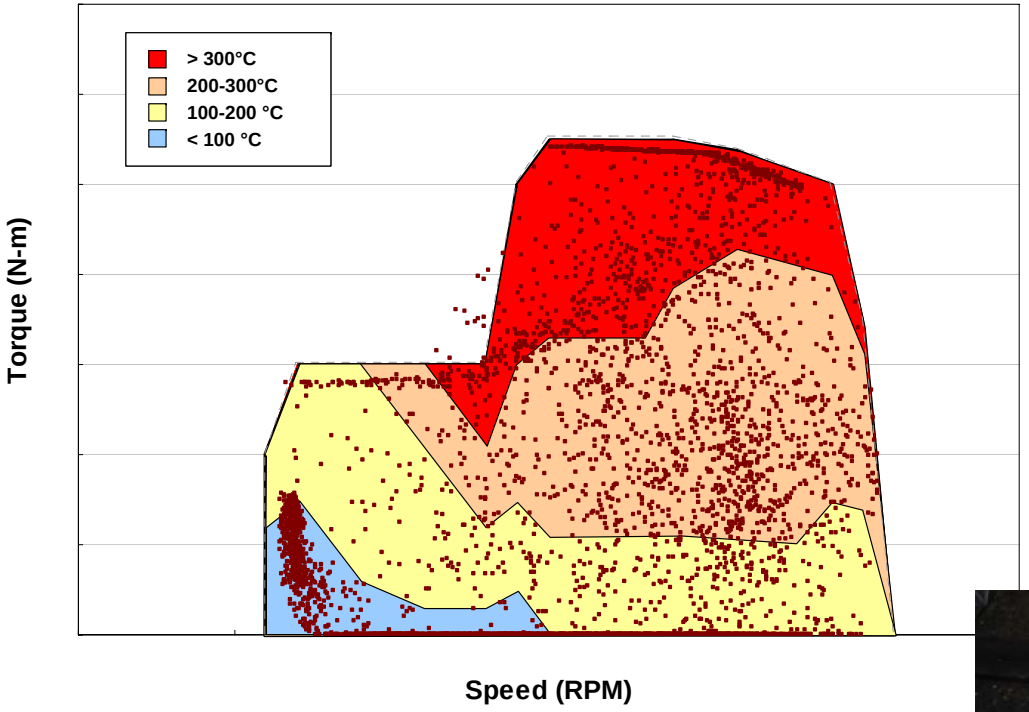
CAT DPFs have survived over 6,000hr in the field.

Successful DPF Installations

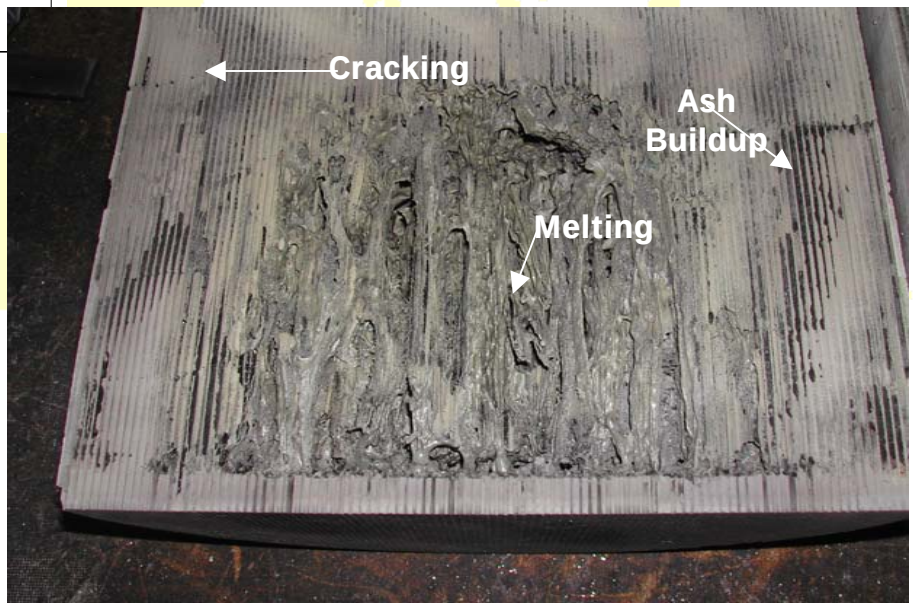
HEX Dual DPF Retrofit Installation in Switzerland

Sometimes machine modification is required.

Passive Systems: The Dilemma of Cold Duty Cycles



Operating Region Below Threshold for Passive Regen



- **Excessive soot loading can lead to an unexpected thermal event.**
- **Temps can exceed 1000C, resulting in localized melting**
- **Severe thermal up-shock induces structural failure.**

Active Regeneration Strategies

Direct Oxidation:

We are currently evaluating several active designs to provide the best customer solution.

Active Regeneration (550-650°C)

- **Auxiliary Combustion Systems**
- **In-Exhaust Injection (DOC+CSF)**
- **Electrically-Heated Systems**

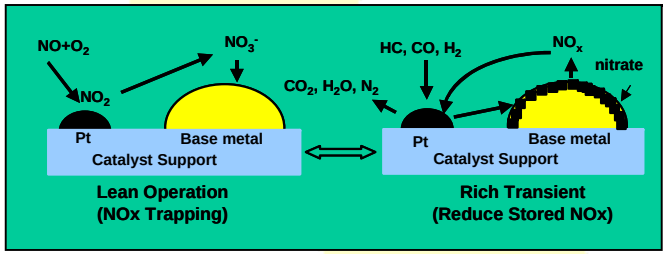
Goal:

- ✓***No NO_2 generation as in many passive systems***
- ✓***Regen on demand (operator transparent)***
- ✓***Eliminate "unexpected thermal events"***
- ✓***Flexible to various application requirements***

NOx Aftertreatment Technologies

NOx Reduction

NOx Adsorber



- **Sulfur-tolerance?**
- **Cost?**

Urea SCR

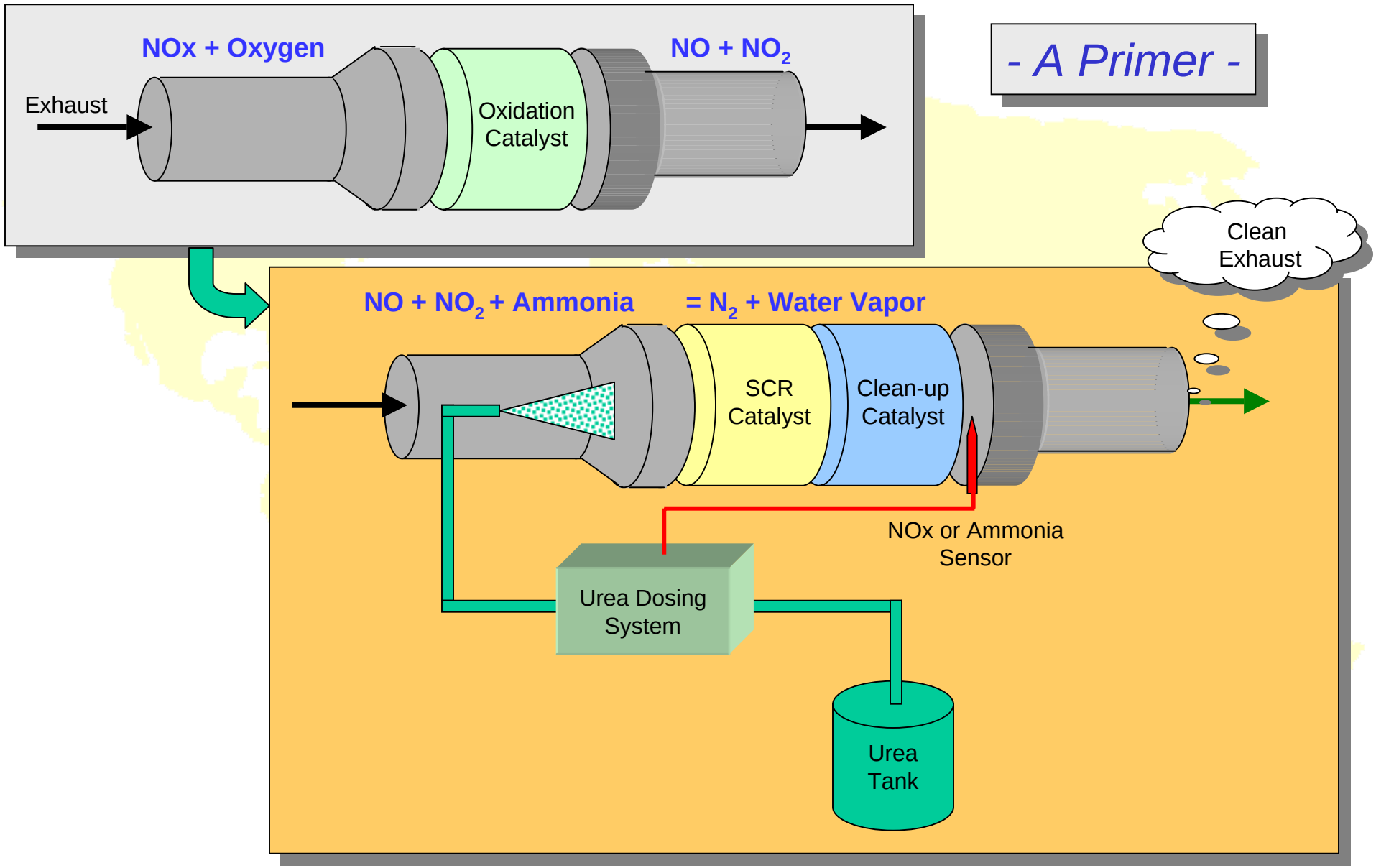
- **Urea Infrastructure?**
- **Regulator Acceptance?**
- **Operator Acceptance?**

DeNOx Catalyst

- **Efficiency?**
- **Sulfur-tolerance?**

Retrofittable NOx A/T strategy will depend on technical, commercial and regulatory issues.

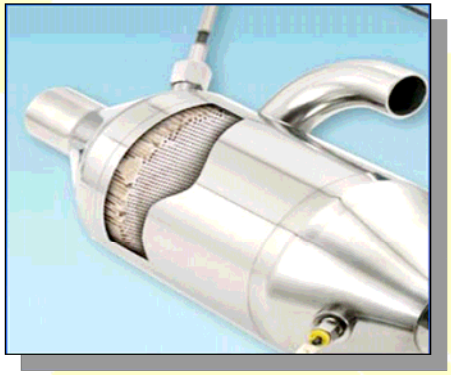
Urea-Selective Catalytic Reduction ("SCR")



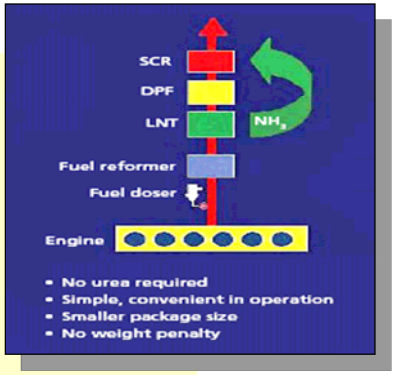
“Urea-Free” Technology – Ready for Prime-Time?

“Honda Develops Next-Generation Clean Diesel…”

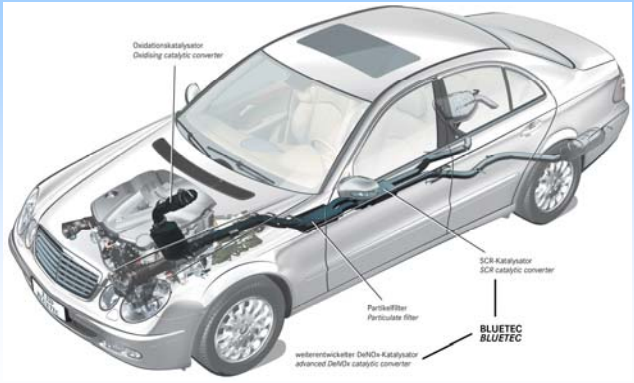
Delphi Develops Diesel Fuel Reformer System

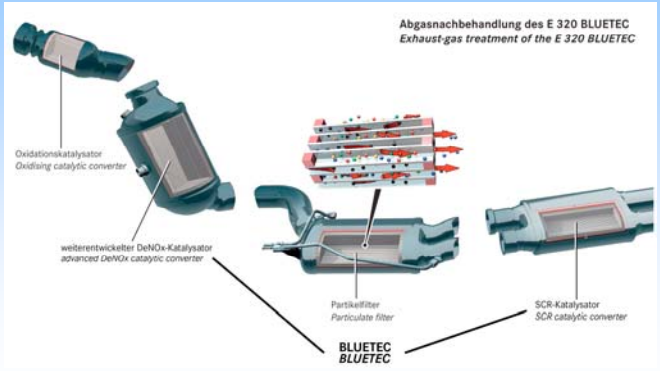


“Eaton Develops Urea-Free System for Trucks”



DaimlerChrysler’s BlueTec System





While questions remain, too early to rule out significant advances in technology...

Summary and Retrofit Issues

- **Incentives and legislation driving down emissions in todays fleets.**
- **CAT is actively engaged in providing products, but only when they can meet our standards of excellence**
- **Engine Repowers and Emission Upgrade kits are an excellent path to reduce NOx emissions and increase machine value**
- **While successful, most Passive DPF Systems require considerable engineering effort - and expertise of the DPF technology, engine and machine application**
- **Active Systems permit use of DPFs in broader machine applications, but must do so without introducing new, unintended consequences**
- **Availability of ULSD expands aftertreatment toolbox for HC, PM and NOx**
- **NOx aftertreatment will likely come as on-highway technology evolves**

CAT continues to assess latest technological advances to cost-effectively reduce emissions in existing machines.

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Thank you for your attention.