

# Tier 4i Engine Transition



Presented by  
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Morbark Demo Days  
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# Tier 4i Transition - Agenda



1. About Us
2. Regulations behind “Tiered” Engine Levels
3. Tier 4 Interim vs. Tier 4 Final
4. Required Engine Changes for Tier 4 compliance
5. After-treatment Overview
6. Evolution of Engine Changes Tier 0 – Tier 4
7. Ultra Low Sulfur Diesel Fuel
8. Need to Know items and “Cause and Effect”
9. Financial Considerations
10. Service and Maintenance
11. EPA “Nonattainment Areas” , SIP’s & Local Regulations

# About Us



- ❖ Emissions Guru Inc. provides emission consulting and testing services related to combustion and spark-ignition engine emissions compliance in mobile and stationary applications.
- ❖ Corporation created to fill a “niche” in emissions compliance created by increasingly stringent emissions laws and regulations enforced by the United States Environmental Protection Agency and other Federal and State agencies.

Fleet Owners

Application

Alternative  
Fuels & ULSD

Original  
Equipment  
Manufacturers



Emerging  
Technology

Engine  
Manufacturers

After-treatment  
Devices

Reselling Dealer

*Regulators – EPA,  
CARB, LOCAL AIR  
AUTHORITY*

Created by Chris Rasmussen  
Emissions Guru Incorporated  
[www.emissionsguru.com](http://www.emissionsguru.com)



## Who is responsible for establishing these rules?



- Clean Air Act passed by congress defining EPA's responsibilities for protecting and improving U.S. air quality.
- EPA first established Off-Road compression – ignition engine standards starting with Tier 1 (1996). Range from Tier 0 – to Tier 4 Final.
- $\frac{3}{4}$  of a billion dollar combined value in human health and welfare benefits due to air quality improvements between 2007 and 2036 (according to the EPA).

# Why Tier Levels



Gradual reduction of Particulate Matter (PM) and NO<sub>x</sub> (Oxides of Nitrogen) from exhaust.

Cleaner engines to aid in State and Regional clean air compliance.

- Particulate Matter (PM) can be defined as incomplete combustion of diesel fuel (black smoke or soot emitted from exhaust pipe).
- Oxides of Nitrogen (NO<sub>x</sub>) atmospheric interaction causes ground level ozone or “smog”.
- Other exhaust emissions are regulated to a lesser extent.

# PM & NO<sub>x</sub> Examples



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# Off-Road Compression-Ignition (Diesel) Engine Standards (NMHC+NOx/CO/PM in g/kW-hr)

Maximum Power	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015+
< 8 kW	See Table 2 footnote (a)					10.5 / 8.0 / 1.0					7.5 / 8.0 / 0.80			7.5 / 8.0 / 0.40 <sup>a</sup>							
8≤kW<19						9.5 / 6.6 / 0.80					7.5 / 6.6 / 0.80			7.5 / 6.6 / 0.40							
19≤kW<37	—						9.5 / 5.5 / 0.80				7.5 / 5.5 / 0.60			7.5 / 5.5 / 0.30					4.7 / 5.5 / 0.03		
37≤kW<56							- / 9.2 / - / - <sup>b</sup>				7.5 / 5.0 / 0.40			4.7 / 5.0 / 0.30 <sup>c</sup>					4.7 / 5.0 / 0.03 <sup>c</sup>		
56≤kW<75														4.7 / 5.0 / 0.40					0.19/ 3.4 / 5.0 / 0.02 <sup>b,d</sup>		
75≤kW<130														6.6 / 5.0 / 0.30				4.0 / 5.0 / 0.30			
130≤kW<225							1.3 / 9.2 / 11.4 / 0.54 <sup>b</sup>				6.6 / 3.5 / 0.20			4.0 / 3.5 / 0.20 <sup>e</sup>					0.19/ 2.0 / 3.5 / 0.02 <sup>b,d</sup>		
225≤kW<450											6.4 / 3.5 / 0.20										
450≤kW≤560																					
Mobile Machines > 560kW	—					1.3 / 9.2 / 11.4 / 0.54 <sup>b</sup>					6.4 / 3.5 / 0.20					0.40 / 3.5 / 3.5 / 0.10 <sup>b</sup>		0.19			
560kW<GEN ≤900 kW																		3.5			
GEN>900 kW																		0.04 <sup>b</sup>			
																		0.19			
																		0.67			
																		3.5			
																		0.03 <sup>b</sup>			

a) The PM standard for hand-start, air cooled, direct injection engines below 8 kW may be delayed until 2010 and be set at 0.60 g/kW-hr.

b) Standards given are NMHC/NOx/CO/PM in g/kW-hr.

c) Engine families in this power category may alternately meet Tier 3 PM standards (0.40 g/kW-hr) from 2008-2011 in exchange for introducing final PM standards in 2012.

d) The implementation schedule shown is the three-year alternate NOx approach. Other schedules are available.

e) Certain manufacturers have agreed to comply with these standards by 2005.



Tier 1 Federal



Tier 1



Tier 2



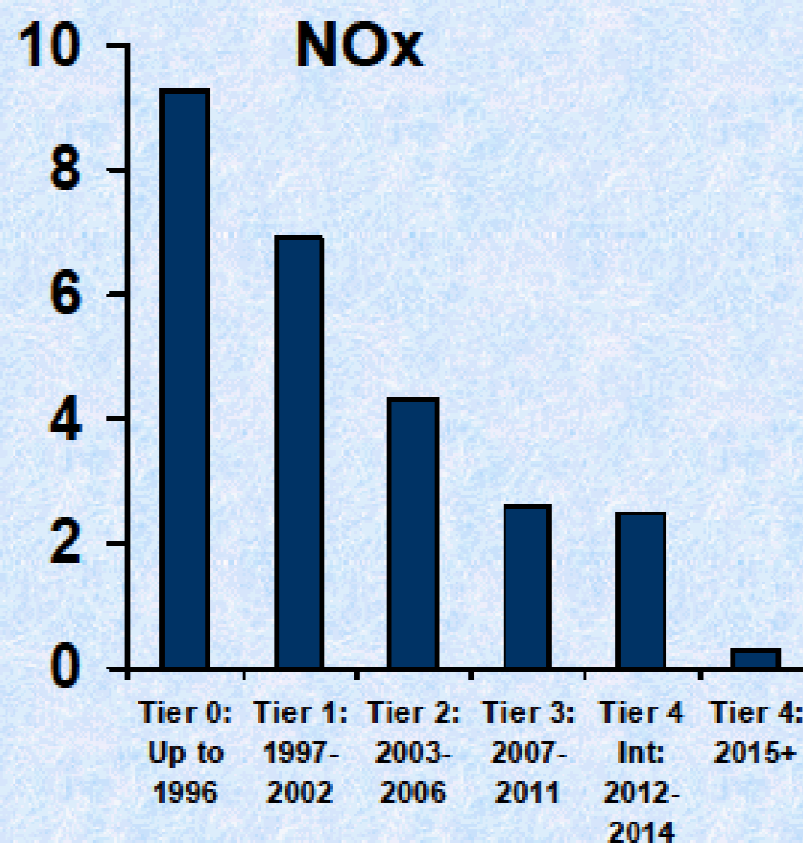
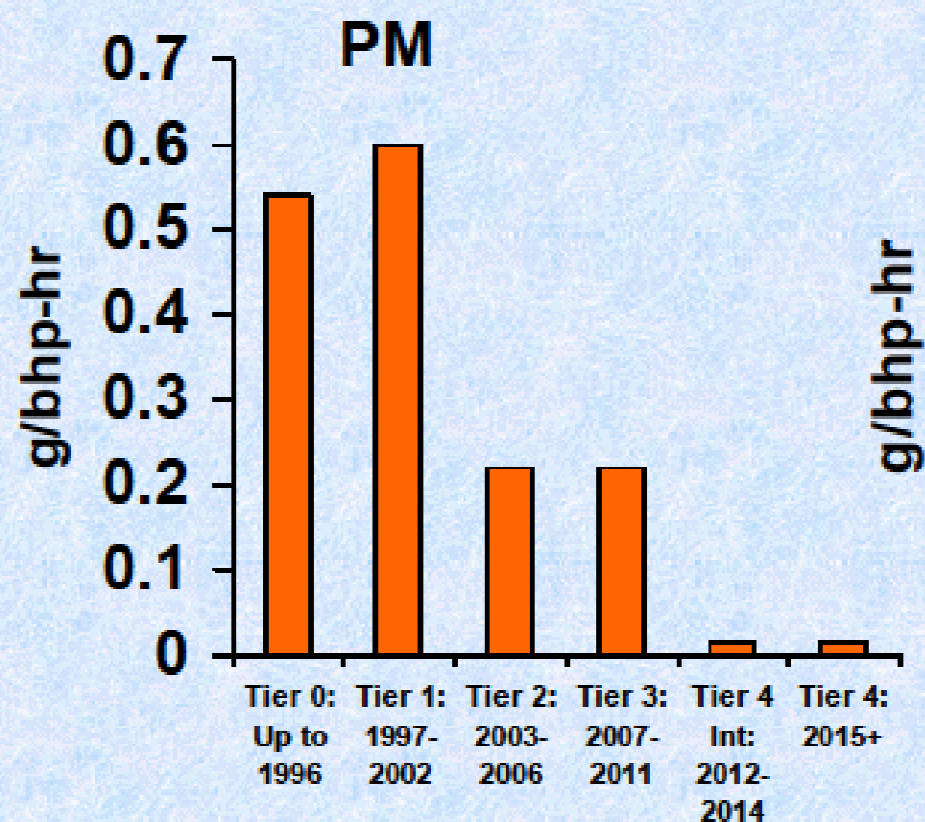
Tier 3



Tier 4 Interim / Final



# New Engine Standards Make New Engines Cleaner (100-174 hp)



# What is Tier 4 Interim and Tier 4 Final



- 45% reduction in NOx and a 90% reduction of PM emissions vs. Tier 3 counterpart.
- Tier 4 Interim is currently the standard for engine sizes 25HP – 75HP & 175 HP < (0-75 HP jumped to Tier 4 Final).
- Tier 4 Interim allows engine manufacturers more time to implement final emissions requirements.

# Tier 4 Final



- Tier 4 Final requires an additional 80% reduction in NOx emissions vs. Tier 4 Interim levels.
- PM figures remain unchanged.
- Final step in Tiered emissions requirements

# After-treatment options to reach Tier 4 Emissions Requirements



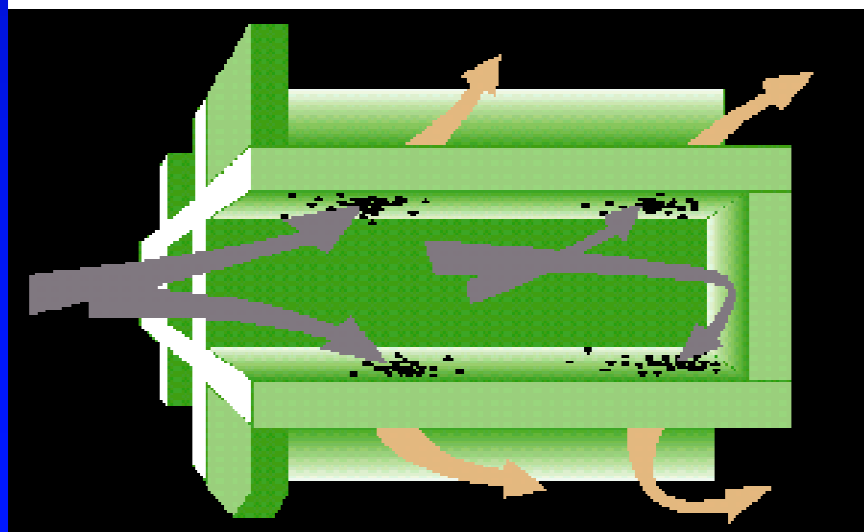
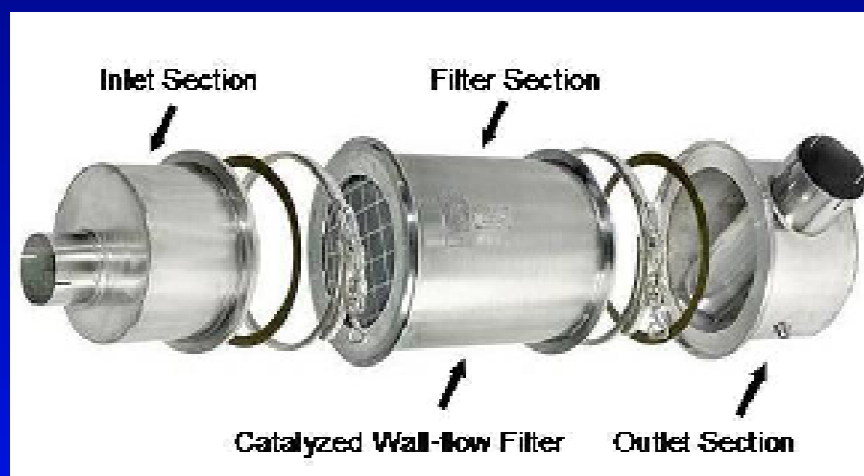
## Exhaust Gas Recirculation

- Essentially altering the combustion process by adding oxygen depleted exhaust gas back into combustion chamber.

## Selective Catalytic Reduction

- Post combustion process whereby diesel exhaust fluid (DEF) is injected to exhaust stream and mixed in a catalytic converter turning NOx into harmless Nitrogen & Oxygen.

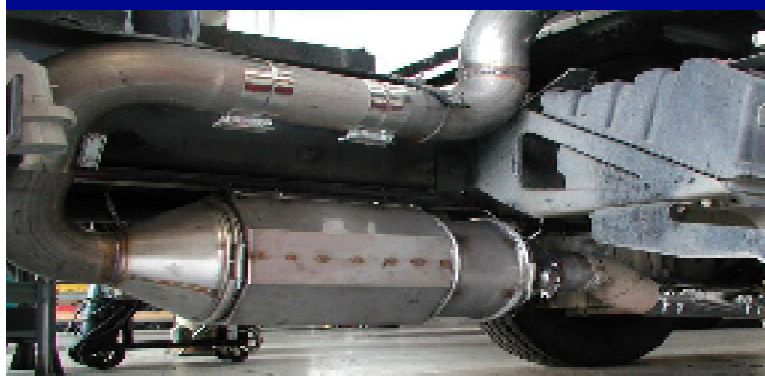
# Wall Flow Filters: Highest Filtration Efficiency (Passive)



- Level 3 PM reduction (>85%)
- Generally applicable to 1994 and newer engines
- Exhaust temperature dependent
- Similar filter technology to new 2007 diesel trucks

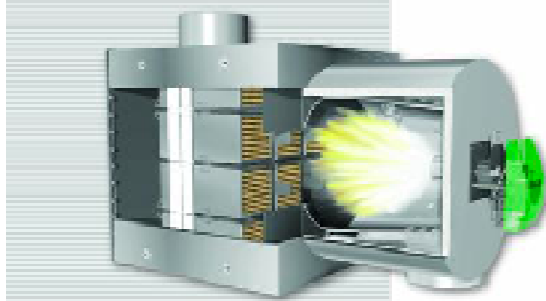


# Wall Flow Filters: Highest Filtration Efficiency (Active)



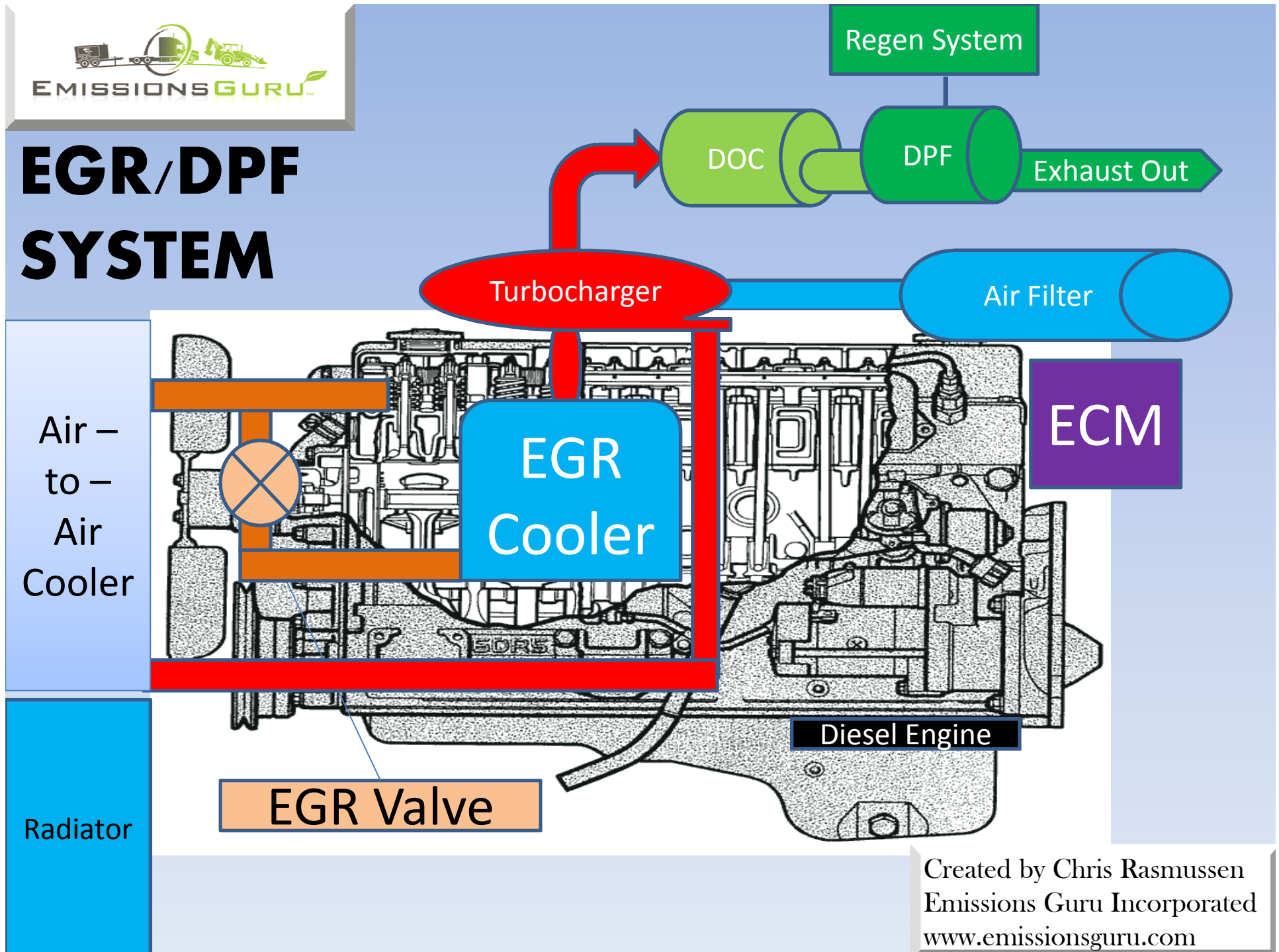
SOOT PARTICLE FILTER SYSTEMS

for mobile diesel engines.  
Regeneration without NO<sub>x</sub>!

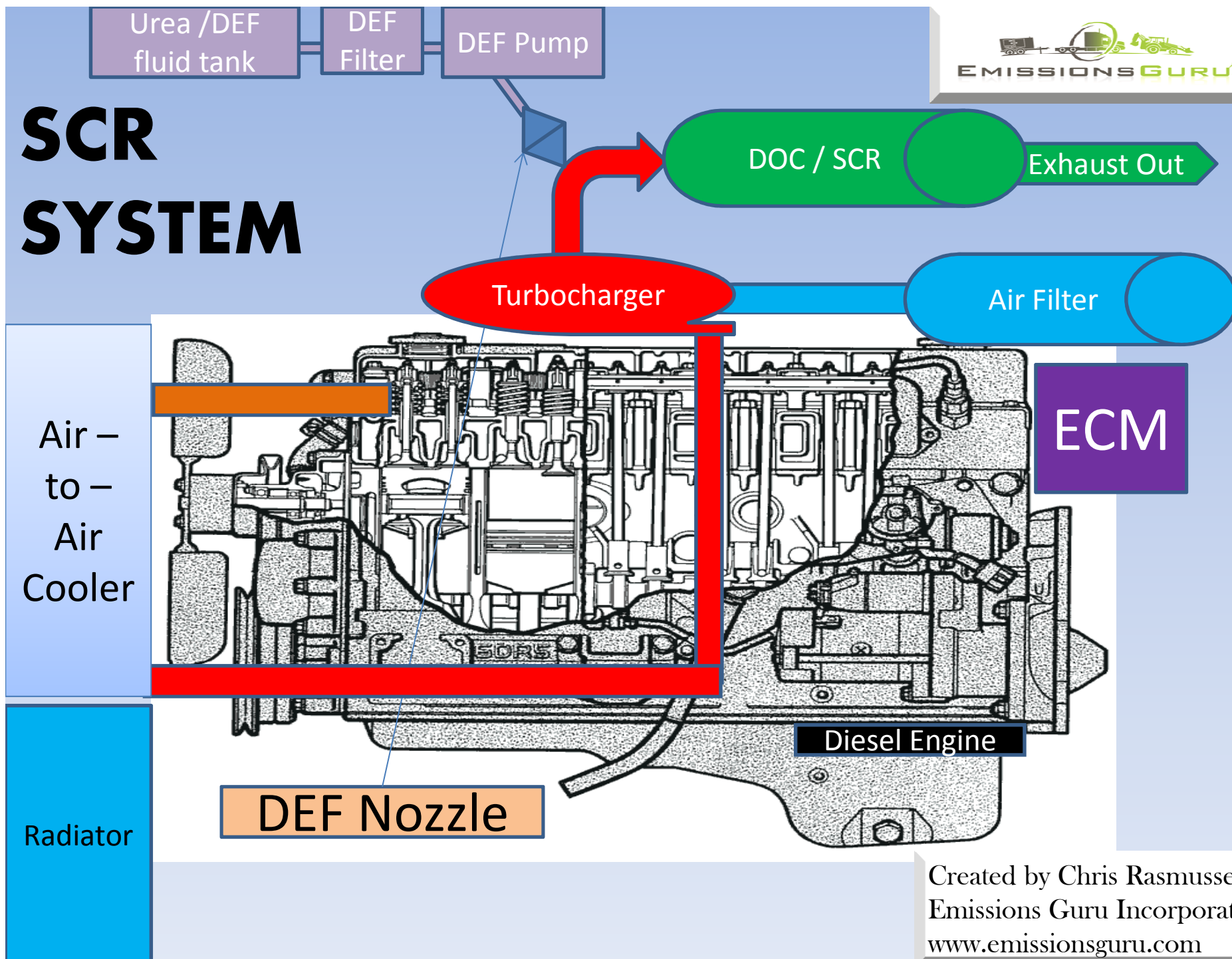


- Level 3 PM Reduction (>85%)
- Suited for applications with low exhaust temperatures
- Example: Uncatalyzed wall-flow filter with electrical regeneration
- Example: Uncatalyzed wall-flow filter with a fuel burner

# EGR/DPF SYSTEM



# SCR SYSTEM



# After-treatment options Tier 4i Emissions – Pro's



## Exhaust Gas Recirculation

- Extremely effective in reducing emissions
- No DEF required for EGR system.
- No catalyst and doser required.
- Less general maintenance requirements.

## Selective Catalytic Reduction

- Extremely effective in reducing emissions
- Enhances thermal efficiency and fuel economy.
- Reduces heat rejection and cooling system stresses (smaller radiator / fan possible).
- No DPF filter

# After-treatment options Tier 4i Emissions – Tradeoffs

## Exhaust Gas Recirculation

- Can be less efficient and burn more fuel due to lower combustion temperatures.
- Heat rejection increases could require larger radiator and fan assemblies.
- Additional manifolds and plumbing around engine.
- DPF filter required to meet standards. Power deration will take place if not regenerated properly.
- Engine expense

## Selective Catalytic Reduction

- Must add and maintain DEF (diesel emissions fluid).
- DEF fluid is not considered “readily available”.
- Power deration will take place if DEF fluid is not present.
- DEF fluid does not like cold weather.
- Engine expense



# ULSD – Ultra Low Sulfur Diesel



- EPA calculated a 4 to 5 cent increase in price for ULSD, however, it will vary depending on the refiners cost to produce.
- 500 ppm effective June 2007 for nonroad, locomotive and marine (NRLM) diesel fuels
- 15 ppm (ultra-low sulfur diesel) effective June 2010 for nonroad fuel, and June 2012 for locomotive and marine fuels
- Must be used with emissions control devices and Tier 4 engines.
- Bio-diesel use will be on a case-by-case basis

# ULSD – Ultra Low Sulfur Diesel Backwards compatibility - Stakeholders

- Tendency to deteriorate or oxidize more quickly than LSD.
- Refined using a process called severe hydro-treating. This process may cause the fuel to be harder to treat for cold flow improvement.
- More hygroscopic than LSD. Tendency to hold more dissolved water may have negative effects on cold weather operations and may increase corrosion.
- May affect fuel system elastomers (o-rings), which could cause fuel system leaks (depends on elastomer material and age, seal swell characteristics vs. previous fuel being used).
- May loosen deposits in fuel tanks of older machines which may cause fuel filter plugging.

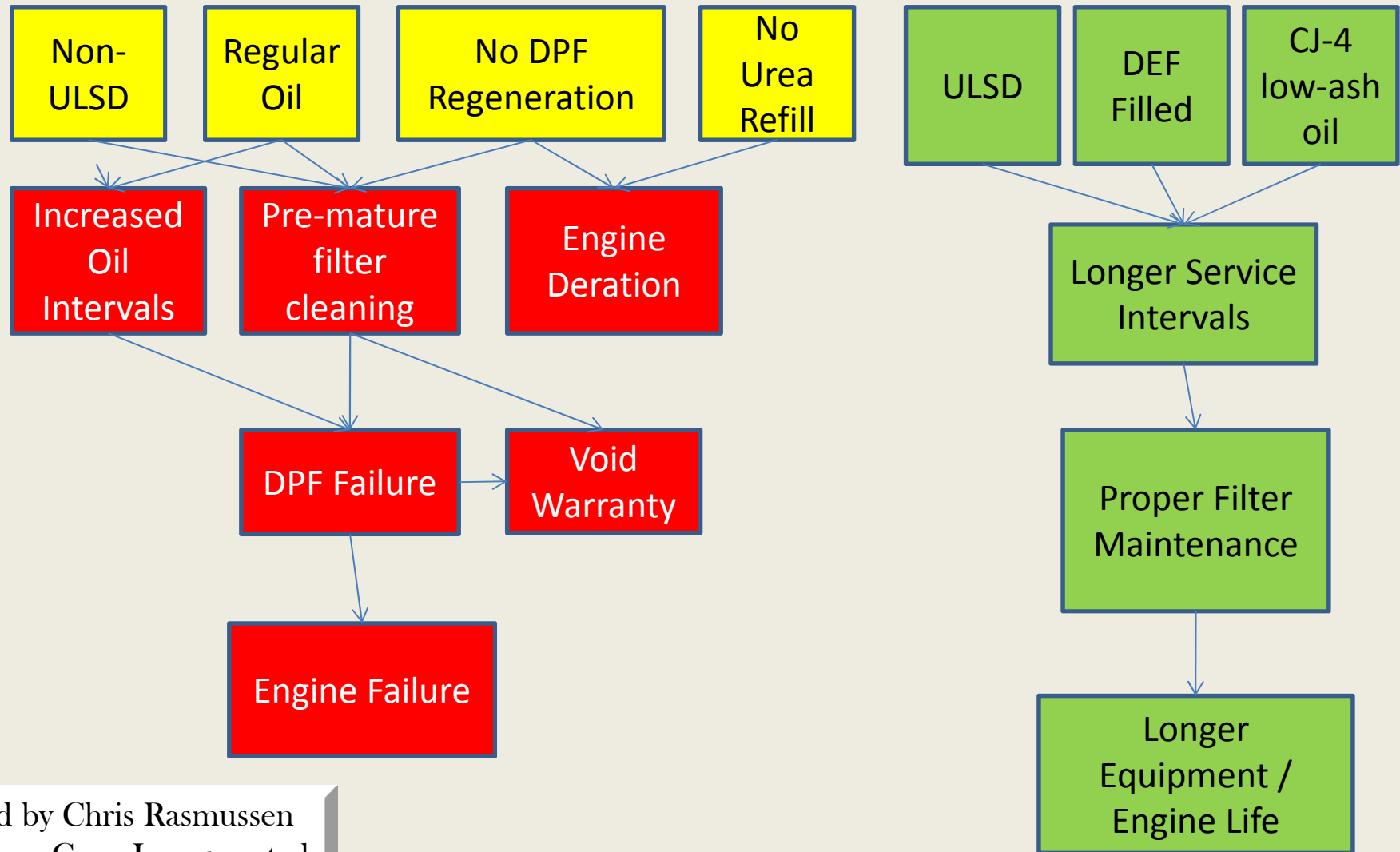
# Need to Know



- ☐ Special engine oil required (VDS-4, API CJ-4)
- ☐ ULSD fuel required
- ☐ Additional controls / warning lights included regarding after-treatment status
- ☐ Regen strategies will vary depending on engine and type of equipment.

# Tier 4 Cause and Effect

Tier 4 Engine



# Considerations



1. DEF comparably priced to diesel fuel and used at a rate of 3% to 5% of diesel fuel. Or 3 to 5 gallons of DEF per 100 gallons of diesel fuel.
2. ULSD 4 to 5 cents more.
3. CJ-4 low ash oil 15% increase.
4. Engine cost 25% to 45%.
5. OEM's integration cost associated with additional accessories – Varies
6. Filter cleaning - Varies
7. Misc. issues associated with “cause and effect” slide –TBD.

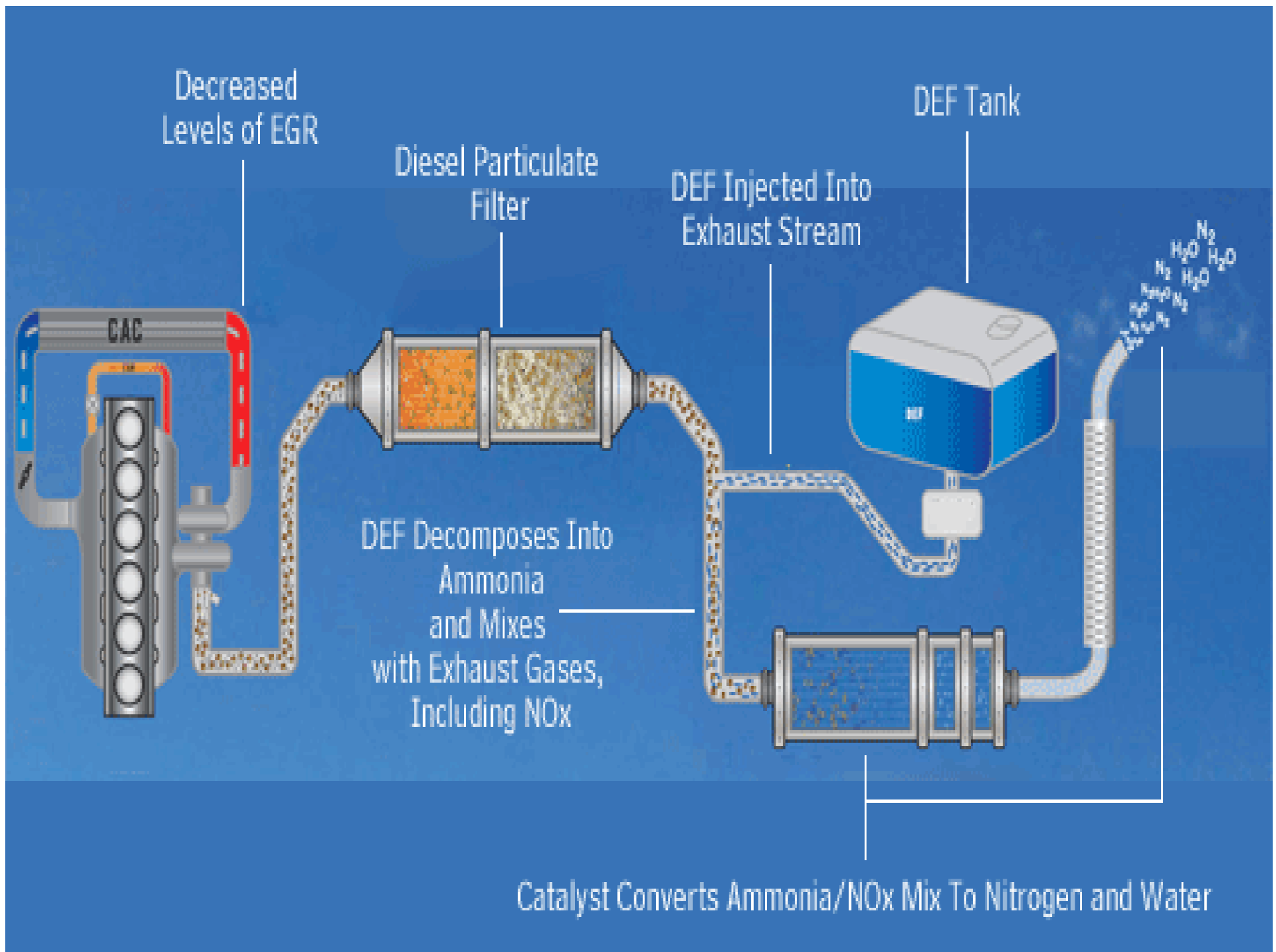
- ☐ TCO – Total Cost of Ownership or “life cycle” costs.
- ☐ ROI – Return on Investment
- ☐ Acquisition of used/older equipment must be weighted against possible tangible and intangible benefits of Tier 4.
- ☐ Increase in contract specs, job bids, project riders and contingencies that take emissions profile of equipment in the award process.



# Service & Maintenance



1. Special engine oil required (VDS-4, API CJ-4)
2. ULSD fuel required
3. Backwards capability needs attention
4. Additional controls / warning lights included regarding after-treatment status
5. Manual Regeneration
6. With proper use, DPF filter maintenance intervals should be 3,000 to 4,500 hours.
7. DEF filter – around 3,500 hrs. or two years.
8. DEF fluid about every other diesel fill up.
9. Crankcase filter
10. More hot surfaces – watch exposure to user, tech and sensitive surfaces.



## EPA Non-Attainment Areas

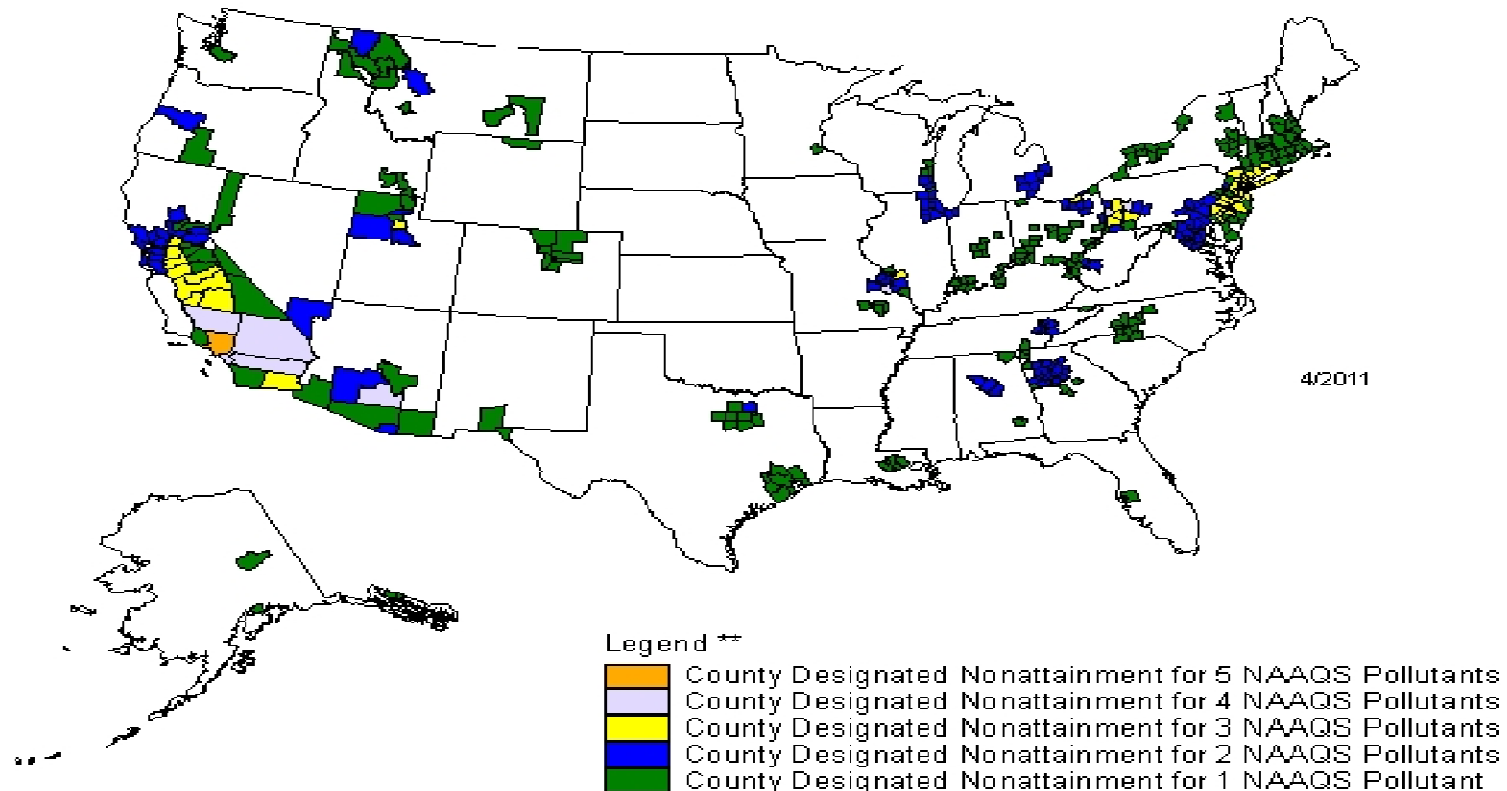
- Based on the Clean Air Act's National Ambient Air Quality Standards (NAAQS).
- 39 states have counties designated “non-attainment” areas within their boundaries.
- 45 states have counties designated as “non-attainment” or “maintenance”.

## EPA Non-Attainment Areas – SIP's

- Non-attainment and maintenance designations trigger enhanced State Implementation Plans (SIP).
- Non-attainment counties are ranked based on severity of non-compliance.
- States and counties are at risk of losing federal highway funds or federal intervention if SIP reduction plans are not met.

## Counties Designated "Nonattainment"

for Clean Air Act's National Ambient Air Quality Standards (NAAQS) \*



Guam - Piti and Tanguisson Counties are designated nonattainment for the SO<sub>2</sub> NAAQS

\* The National Ambient Air Quality Standards (NAAQS) are health standards for Carbon Monoxide, Lead, Nitrogen Dioxide, 8-hour Ozone, Particulate Matter (PM-10 and PM-2.5), and Sulfur Dioxide.

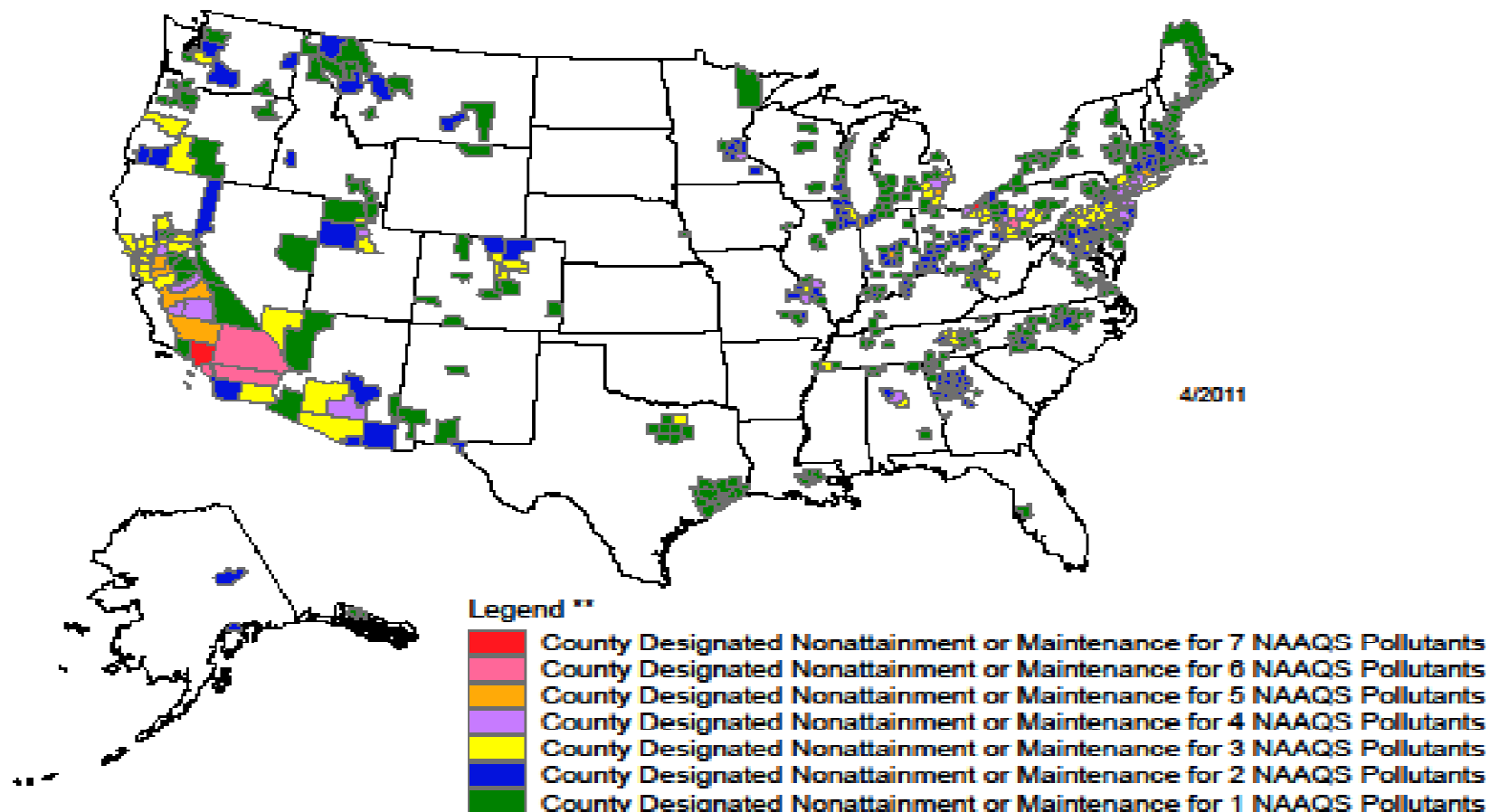
\*\* Included in the counts are counties designated for NAAQS and revised NAAQS pollutants. 1 hour Ozone is excluded. Partial counties, those with part of the county designated nonattainment and part attainment, are shown as full counties on the map.

The Indiana portion of the Chicago-Gary-Lake County, IL-IN 8-hr Ozone multi-state nonattainment area has been redesignated, but the area is not considered a maintenance area until both states in the area are redesignated. All of the counties for this area are displayed as being in nonattainment



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# QUESTIONS ?



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