Low Emissions Drilling
Power for Onshore Rigs

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Notice

• The information in this presentation is not an announcement of Caterpillar’s plans for future products, this material is a general discussion of engine/aftertreatment technology.
• The following material represents an overview of anticipated regulatory requirements related to engine emissions for nonroad engine and equipment manufacturers.
• The material is intended for general informational purposes only.
• The information is NOT COMPREHENSIVE and DOES NOT address specific manufacturers’ circumstances.
• There is no substitute for reading and understanding the rules; companies are strongly encouraged to investigate and apply the regulations accordingly.
• Regulations may change, and these materials may not be updated to reflect the latest regulatory revisions.
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• The information IS NOT intended to be and should not be construed as legal advice or as a substitute for competent legal advice.
• Please consult your legal advisor if you have questions or need assistance.
Key Points Summary

- Emissions are most stringent in US and the European Union, and will be more challenging globally within the next 10 years.
- Tier 4 regulations provide necessary “flexibility” options for transitioning to newer technology engines.
- Tier 4 emission limits are very stringent and will require a combination of in-cylinder and or aftertreatment systems.
- Tier 4 emissions will increase content and cost of the engines, require specific maintenance, and require rig operator training.
- Local “non-attainment” areas are likely to expand due to more strict regulatory drivers: NOx, PM, NO₂ and Ozone.
- There are alternative fuel options that can help reduce emissions and lower owning and operating costs.
Agenda

- Emissions – Regulations Summary
  - Emissions Evolution, Tier 4 Interim & Tier 4 Final
  - Non-Gensets
  - Gensets >1200 bhp
  - EPA Flexibility Program
  - Localized N. America Air Standards
  - World Emissions Trends

- Tier 4 Tech. Summary - High Level Costs and Challenges

- Alternative Fuels
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Nonroad Mobile Non-Generator Drive > 750bhp

Tier 2 to Tier 4 Final:
- 48% Reduction in NOx
- 80% Reduction in PM
Nonroad Mobile Gensets > 1200 bhp

Emissions Tier

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Tier 2 to Tier 4 Final:
90% Reduction in NOx
85% Reduction in PM
**Existing Fleet Impact**

- Nonroad regulation (previous slides) apply to newly manufactured engines. Existing fleets contain engines that are certified by EPA to prior tier emission standards and thus need to meet those emission limits during their useful lives.

- California DOES require fleet owners of self powered mobile equipment to meet preset emissions averages. This rule has not yet received a waiver from EPA and therefore is not enforceable yet.

- Most drilling equipment not self powered and fall under California PERP (Portable Equipment Registration Program) requirements, **which does not yet require fleet updating**.
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USA Tier 4 Flexibility- Easing the Transition

§ US EPA Allows OEM’s to use up to 700 engines of the previous Tier from 2011-2017 (>175 hp using Small Volume Allowance) for each EPA defined power category.
  – 700 total engines, 200 per yr maximum

§ Power Categories
  – 175-750 hp Category
    – 700 engines, 200/yr
  – > 750 hp Category
    – 700 engines, 200/yr

§ Regulatory Requirements in Canada are Changing
  – Will likely not completely align with US EPA Tier 4 Regulations
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Nonroad Emission Regulations (>750hp) 2011

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Localized Regulations

- EPA Regs are minimum requirement for nonroad mobile equipment
- Counties can limit area emissions which could have an indirect impact on nonroad mobile equipment
  - May limit hours of operation based on NOx and PM, NO$_2$ and Ozone
  - May require aftertreatment
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8-hr Non Attainment Zones - Ozone

Source: Environmental Protection Agency
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Drilling Activity & Non-Attainment

Likely areas for non-attainment issue management:

• California
• Colorado - Niobrara
• Texas - Barnett
• Pennsylvania-Utica/Marcellus
• Ohio – Utica/Marcellus
• W. Virginia – Utica/Marcellus

Drilling Activity Data Courtesy of Baker Hughes
Non-Attainment and Localized Emissions Issues

Non-Attainment Issue Management

– Usually doesn’t impact nonroad mobile sources, a Local government cannot preempt a federal nonroad emissions limit

– When a local area is in non-attainment, there are several ways that a state could regulate areas that might have an indirect impact on nonroad mobile equipment:
  • Well Permits
  • Operating time Limits
  • BACT (Best Available Control Technology)
  • LAER (Lowest Achievable Emissions Reduction)
  • Offsetting Emissions
Incentives for Updating Emissions

_DERERA (Diesel Emissions Reduction Act)_
- Federal program to offer incentives for re-powering older higher emissions engines
- Likely can be applied to non-road mobile drilling power

_Texas and California offer Grant programs for non-road diesel engine emissions updates_
- TX - TERP – (ERIG) – Currently closed
- CA – Moyer Program Chapter 9 Off Road Equipment Replacement – Funded Through 2013
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Agenda

§ Tier 4 Tech. Summary - High Level Costs and Challenges
  – Tier 4 Tech Possibilities
  – Costs and Challenges
  – Inducement
  – Worldwide Sulfur Variation

§ Emissions – Regulations Summary

§ Alternative Fuels
**Different Tier 4 Approaches – SCR**

**SCR – Selective Catalytic Reduction**

- NOx Reduction occurs in aftertreatment
- NOx reduction is a chemical reaction requiring aqueous ammonia – DEF (Diesel Exhaust Fluid)
- Does not require engine to ingest exhaust gases
- Simpler to maintain engine performance
- Requires second fluid on site
EGR (exhaust gas recirculation)

• Dilutes combustion mixture with inert exhaust gas, lowering the excess oxygen and reducing peak combustion temperature

• NOx forms much faster at high temperatures, EGR serves to limit the formation of NOx

• Slower combustion allows more advance timing and better fuel efficiency

• Cooling exhaust gas will impact heat rejection
**EGR - SCR**

No easy answer when evaluating engine technology decision:

- EGR requires more on engine content, can be air system and combustion chamber design limited, drives increase in heat rejection
- SCR allows simpler path to maintain today's performance, while requiring more substantial emissions reduction in aftertreatment

<table>
<thead>
<tr>
<th>Ease of Meeting Design Target</th>
<th>EGR</th>
<th>SCR</th>
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<tbody>
<tr>
<td>Simple Operation</td>
<td>✔</td>
<td></td>
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<tr>
<td>Initial Cost</td>
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<tr>
<td>Heat Rejection</td>
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<tr>
<td>Simple Packaging</td>
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<td>Transient Performance</td>
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<tr>
<td>Weight</td>
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High Level Costs and Challenges

- Extra Drilling Tier 4 Iron Costs
  - Higher engine costs
  - Higher Capacity Cooling Systems
  - Aftertreatment

- Extra Operational Costs
  - Extra Crankcase and other misc engine filters
  - Possible second fluid (DEF) on site
  - Training maintenance/operators
  - Fleet Management

- Challenges
  - DEF Cold Weather and Storage
  - Fuel Sulfur Variation By Region
**Probable Engine Manufacturer approach to managing Life Cycle Cost - SCR**

**Increased Life Cycle Costs:**
- Higher Purchase Price
- Extra filters
- Aftertreatment maintenance
- DEF Costs

**Decreased Lifecycle Costs**
- Improved Fuel Consumption
- Serviceability improvements, improved service intervals

**Lifecycle Owning and Operation Cost Strategy**

**Tier 2 Compared to Tier 4**

- Tier 2
- Maintenance
- DEF
- Fuel Savings
- Serviceability Impr.
- Tier 4

Overall approach will likely target reduced operating costs even with additional DEF costs and extra maintenance items.

**Low Emissions Drilling Power for Onshore Rigs**
Probable Engine Manufacturer approach to managing Life Cycle Cost - EGR

Overall approach will likely target reduced operating costs even with additional engine costs and extra maintenance items.
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International Fuel Sulfur Variation
(Most recent sample available between 2008-2010)

Latest Emissions Technology require ULSD or <15ppm
Sulfur Misfueling will damage engine/aftertreatment and could limit international rig moves.
SCR Cold Weather and Storage Challenges

What is DEF? – Diesel Exhaust Fluid
– AKA: AUS32, Urea or Aqueous Urea
– Safe, organic, easy to store
– It is a colorless liquid made up of 67.5% de-mineralized water and 32.5% urea.

DEF has a shelf life
– Designed for 1yr max with temps at or below 30C
– Warmer storage temps will accelerate decomposition into ammonia, UV exposure can cause algae growth

DEF freezes at -11 °C, DEF lines critical to operation should be heated if cold weather operation needed
– If engine/aftertreatment not equipped with heated DEF lines No operation or engine shutdown at - 11C and below

DEF should not come into contact with Non-Ferrous Metals and alloys
– Aluminum, Copper, Zinc and Lead will corrode
– Recommend quality corrosion resistant steel alloys, or stainless steel and most plastics
Agenda

- Emissions – Regulations Summary
- Tier 4 Tech. Summary - High Level Costs and Challenges
- Alternative Fuels
  - Gas/Diesel Diesel Drilling Power
  - Gas Drilling Power

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Alternative Fuels - Gas Drilling, Dual Fuel

Dual Fuel Engines – Aftermarket Systems Available
- Emissions
  - Reduced NOx and PM
  - Higher Carbon Monoxide (CO) levels will likely drive a catalyst in N. America
- Performance
  - Maintains Diesel Performance
- Operating Costs
  - Very Attractive diesel fuel savings

Gas Drilling Engines
- Emissions
  - Reduced NOx and PM
  - SI engines classified and permitted differently than CI engines
- Performance
  - Minimum loads required
  - Different Transient Response Characteristics
- Operating Costs
  - Very Attractive diesel fuel savings
Theoretical Fuel $ Savings
Gas/Diesel System

Potential Fuel Savings - Gas/Diesel System

Real World Limitations of Gas/Diesel System:
- Exhaust Valve Temp
- Fuel Injector Tip Cooling

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Theoretical Raw Fuel Savings
Main Rig Power

<table>
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<tr>
<th>Fuel Strategy</th>
<th>Diesel (Gallons/yr)</th>
<th>Potential $ Fuel Savings per yr</th>
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<tbody>
<tr>
<td>100% Diesel</td>
<td>223,000</td>
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<tr>
<td>50% Gas/50% Diesel</td>
<td>111,500</td>
<td>$424k</td>
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<tr>
<td>70% Gas/30% Diesel</td>
<td>66,900</td>
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<td>SI Gensets</td>
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SI Genset Analysis Assumes:

- 4x 1.3Mw Gas Gensets with load management at 50%
- $4.35/MMBTU Gas Price
- Diesel fuel at $4.20 per gallon

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Questions?