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In-Use Emissions Measurements of Off-Road Diesel Engines




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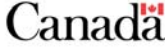
Outline:

- Emissions Measurements
 1. Historical Emissions Data from off-road diesel engines
 - Overview/Measurements
 - Emission Rates
 - Emission Factors
 - Emissions: OEM vs Control Technologies
 2. Current approaches for emissions measurements in off-road engines
 - Overview/Measurements
 - Real World In-use operation
 - Emissions comparison to older tractors
- Summary
- Acknowledgements



Page 2 – September-13-18

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1. Historical Tier 1 and Tier 2 Engine Emissions

- ECCC has been involved with a number of individual studies measuring diesel exhaust emissions from a variety of non-road vehicles and equipment operating under normal in-service operations
- In the 1990's the non-road sector received increased attention as their contribution to urban air quality was increased, in part due to the stricter regulation of emissions from the on-road sector
- In these projects, performed by ECCC, the impact of off-road equipment to local air quality was investigated - with specific a emphasis on PM
- 34 Units were tested and the types of machinery included:
 - Dumptrucks, Loaders, Bulldozers, Excavators, and Miscellaneous Equipment
- The units varied in model year from 1973 to 2005 with engine displacements and power from 85 HP (63kW) to 700 HP (522kW)
- Emissions data is presented for the units in OEM configuration and with select units equipped with retrofit emission control technologies such as:
 - DOC, DPF, SCR, and diesel/water emulsion fuel strategies and EGR and LNC

Page 3 – September-13-18



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Historical DOES2 Set-Up

Analyzer
Test
Bench



Exhaust Probe and Heated Line Vacuum Pump Box



Page 4 – September-13-18



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Test Measurements

- ECCC developed a patented portable exhaust emissions sampling system (DOES²) in the mid-1990s prior to the introduction of the Portable Emissions Measurement Systems (PEMS) that are commercially available today
- This system was designed to enable PM collection gravimetrically to mimic conventional regulatory testing and batch sampling of gaseous emissions
- The analysis of emissions was made at a temporary site with standard lab grade gaseous emissions analyzers; sample media for the measurement of target compounds were transferred back to the laboratory for analysis
- The non-road vehicles and equipment were operated under normal in-service operations over their representative duty cycle running on commercially available diesel fuels purchased locally
- The equipment was tested in their as received condition and maintenance intervals were not a subject of these studies
- Emissions were measured in g/min and converted to g/kWhr
- For comparative purposes emissions factors were calculated based on EPA technical report EPA-420-R-10-018 *Exhaust and Crankcase Emission Factors for Nonroad Engine Modeling – Compression-Ignition, NR-009d* Page 5 – September-13-18

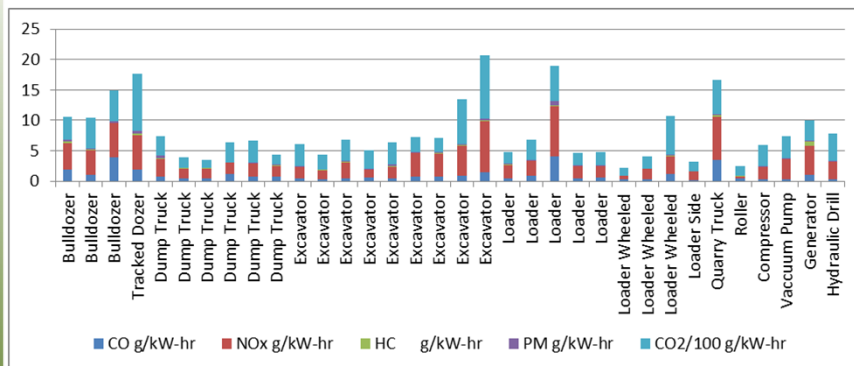


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Composite graph of measured emission rates (g/kW-hr) from non-road equipment



Page 6 – September-13-18

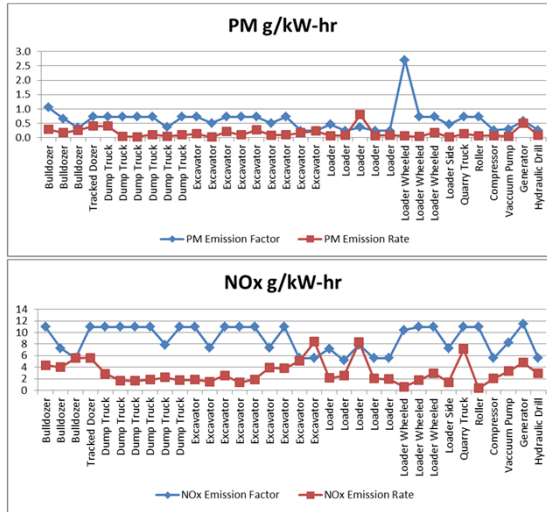


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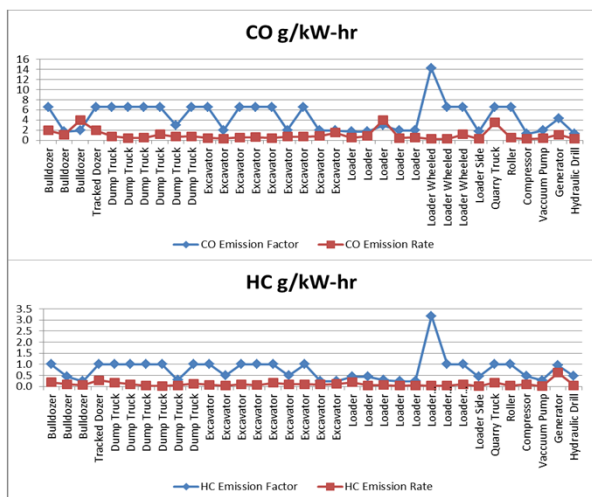
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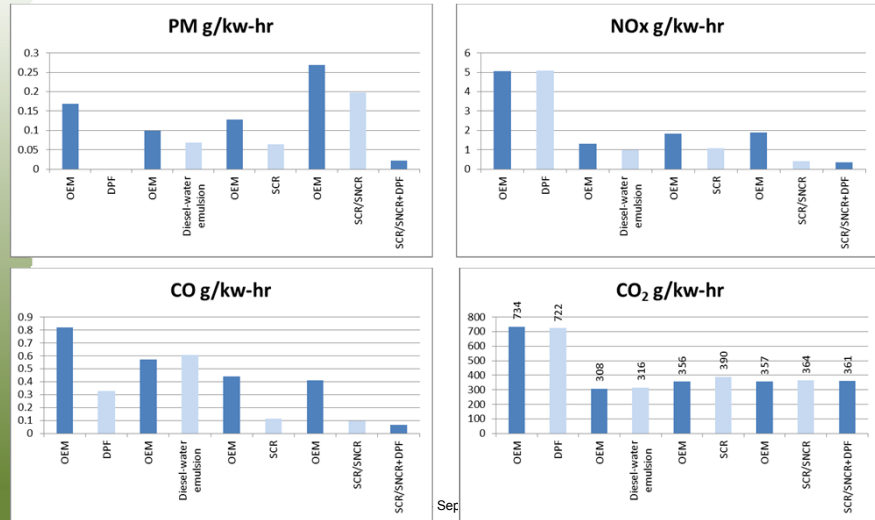
PM and NOx emissions rates and calculated NOx emission factors (g/kW-hr)



CO and HC emissions rates and calculated emission factors (g/kW-hr)



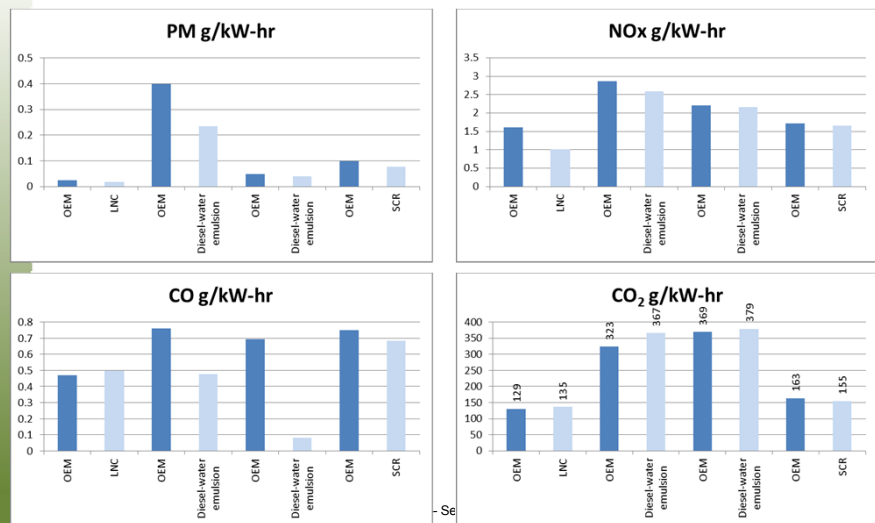
Excavator emission rates (g/kW-hr) in OEM configuration and with emission controls



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Dumptruck emission rates (g/kW-hr) in OEM configuration and with emission controls



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2. Current Approach:

- Current PEMS systems were developed to provide real time gaseous emissions measurements with an emphasis on NO_x to ensure compliance of on-road HDVs
- PEMS systems were used to quantify gaseous emissions of new Tier 3 and 4 engines in the agriculture and power generation sector
- ECCC, in collaboration with AAFC, tested two farm tractors and one windrower during real- world use with commercial PEMS
- Real-world in-use tests were conducted during tillage operation at the Central Experimental Farm, Ottawa, ON
- Emissions were compared with a previous study conducted by ECCC investigating emissions from 4 on-farm tractors
- ECCC also tested two heavy-duty generators that were attached electric load banks

Page 11 – September-13-18

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PEMS Setup – Agriculture Tractors

Exhaust Flow Meter Tube



Sample Line

Generator
Mounting Plate Assembly

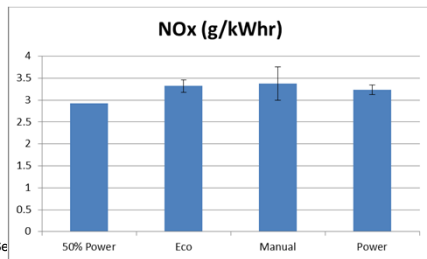
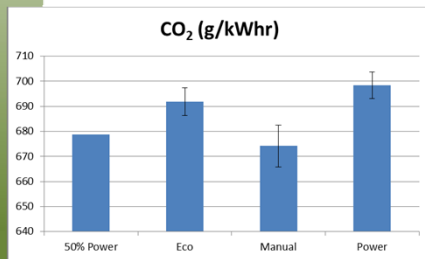
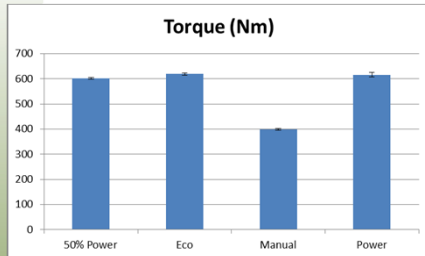
Commercial PEMS

Page 12 – September-13-18

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CO₂ & NO_x emissions during real-world in-use testing



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Emissions Comparison to Older Tractors

Manufacturer	Landini	Massey Ferguson	John Deere	John Deere	McCormick	MacDon	CASE Farmall 75C
Engine Type	85 Blizzard	375 Perkins	7410	5325	X7.450	Cummins QSB4.5	CASE IH FPT
Model Year	1996	1993	2001	2005	2014	2015	2017
Rated Speed (RPM)	2200	1893	2100	2400	2200	2200	2300
Rated Engine Output (HP)	80	72	120	67	150	160	74
Displacement (L)	4.1	3.9	6.8	3	4.5	4.5	3.4
Cylinder #	4	4	6	5	4	4	4
Combustion Cycle	4 Stroke	4 Stroke	4-Stroke Turbocharged	4-Stroke Turbocharged	4-Stroke Turbocharged	4-Stroke Turbocharged	4-Stroke Turbocharged
Exhaust Aftertreatment	None	None	None	None	SCR	SCR	EGR, DOC, PTOX



ERMD Report #06-37 Exhaust Emissions from Agricultural Tractors Operating Biodiesel Blends Page 14 – September-13-18

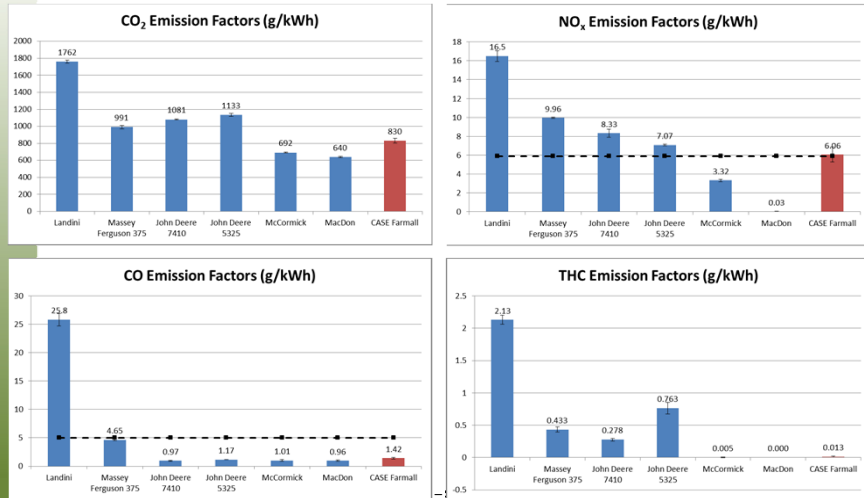


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Emissions Comparison of Tractors (g/kWhr)



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PEMS Setup – HD Generators



Max Advertised Power:
127.4 kW @ 1800 RPM

Page 16 – September-13-18

Max Advertised Power:
99.2 kW @ 1800 RPM

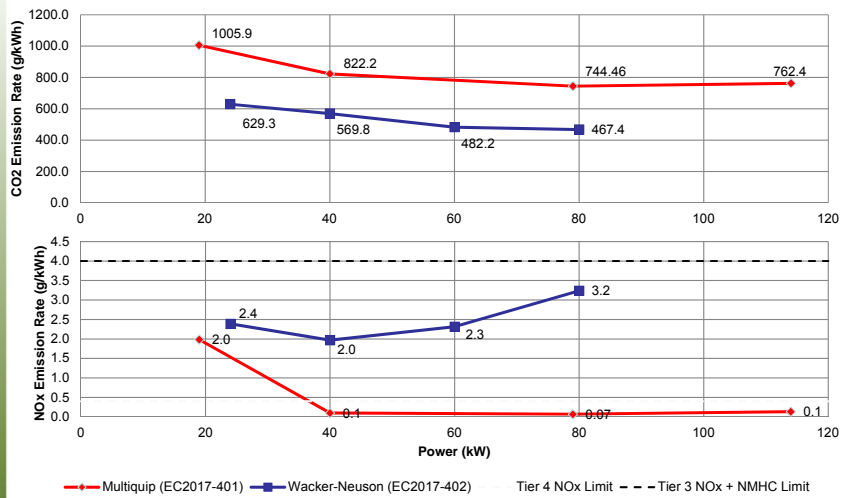


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Emissions Comparison of HD Generators



Page 17 – September-13-18



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Summary

- It is evident based on the comparison to older-generation tractors that there have been significant improvements in off-road heavy-duty engines and emission controls in response to tighter emission standards
- In-use testing offers a timely and cost-effective option to ensure we are achieving air quality benefits as attended by the regulations
- Black carbon, N₂O and ammonia from different on-road and off-road sources are being investigated

Page 18 – September-13-18



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- Environment and Climate Change Canada
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 - VETEV - Vehicles and Engines Testing for Emissions Verification
 - Jason Hickey

Page 19 – September-13-18



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Additional Information

- *Advanced Motor Fuels Technology Collaboration Program/International Energy Agency*
- *Annex 50: Fuel and Technology Alternatives in Non-Road Engines*
- http://iea-amf.org/content/projects/map_projects/50

Page 20 – September-13-18



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