TAMPERE UNIVERSITY OF TECHNOLOGY

PEMS measurements of particle number and mass emissions from loaders using conventional and renewable diesel fuels

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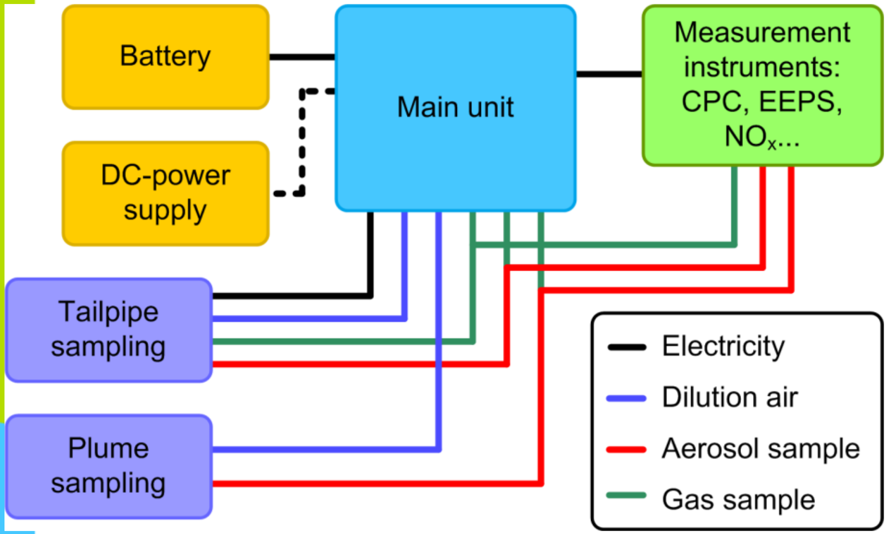
Motivation

- Stara's working machines are used to construct and maintain the streets as well as various tasks in the parks of Helsinki
- Here focus was to study, what are the air quality related emissions if regular diesel fuel is replaced by renewable diesel fuel
- We conducted real operation mimicing PEMS measurements of exhaust particle emissions from two loaders of Stara

TUT-PEMS



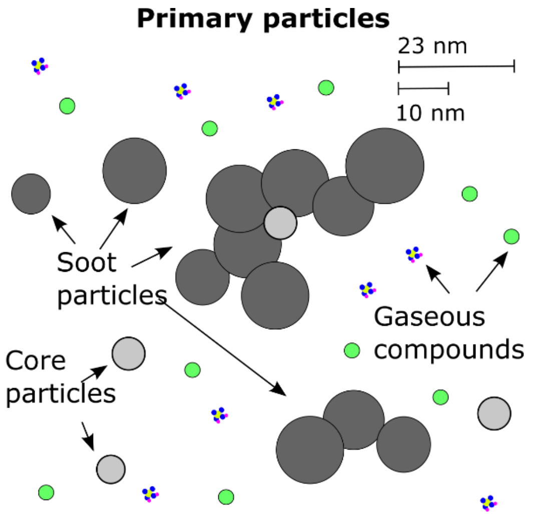
Platform for different exhaust emission measurements

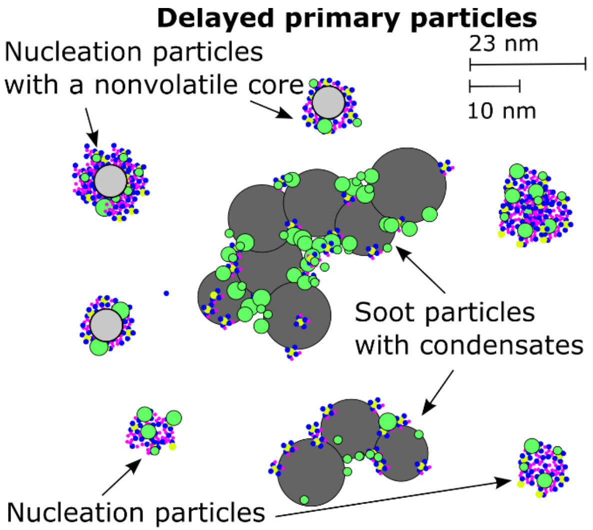
(Järvinen et al. ETH conference, 2015)

Dilution options in TUT-PEMS

Heated dilution
(porous tube / ejector)

Cold sampling (porous tube) /
Plume sampling





Loaders in tests

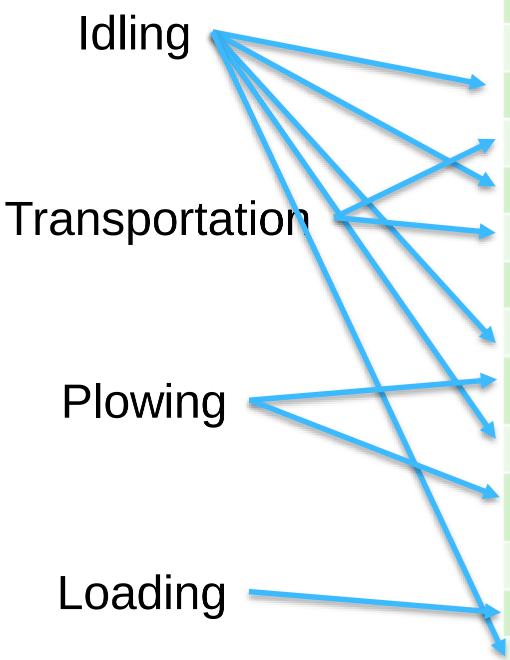
Wille 355B

Production year	2009
Power [kW]	36
Emission standard of the engine	Stage 3A
Fuel supply	Distributor pump
Air induction	Naturally aspirated engine
Mass [kg]	2630

Wille 855C

Production year	2014
Power [kW]	97
Emission standard of the engine	Stage 3A
Fuel supply	Common rail
Air induction	Turbo with intercooler
Mass [kg]	6510

Measurement procedure designed based on discussions with the operators



Test sequence	Duration	Description
Preparation	-	Calibration and starting of emission measurement equipment
Start of the test		Starting the engine
Idling	2 min	
Transportation		Driving one lap around the 300m x 300m test track
Idling	2 min	
Transportation		Driving one lap around the 300m x 300m test track
Preparation for plowing	2 min	Connecting of blasting mat to trailer
Idling	2 min	
Plowing		Driving one lap around the test track with blasting mat attached to the trailer
Idling	2 min	
Plowing		Driving one lap around the test track with blasting mat attached to the trailer
Preparation for loading	2 min	Detach blasting mat, fasten loading bucket, idle for 2min
Loading		Raise, hold in upright position and lower the front loader 5 times
Idling	2 min	The test ends after 2 min idling
Preparation for the next test		Detach loading bucket, return to starting position, turn of the engine for 10 min hot soak before repeating the cycle with the same fuel.

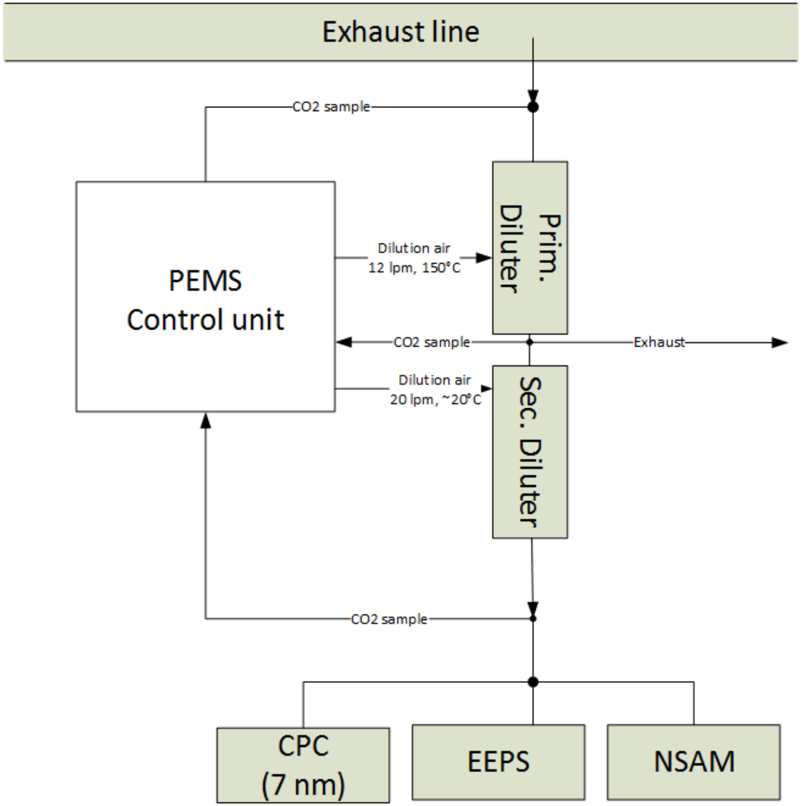
Properties of the two fuels used in the tests

Test fuels were conventional current EN590 standard fulfilling automotive diesel fuel containing 7 % fatty acid methyl ester (FAME) and hydrotreated diesel fuel Neste Renewable Diesel produced from renewable raw materials, mainly from waste and residues.

	EN590 B7	Neste MY Renewable Diesel
density at 15 °C, kg/m^3	841	780
viscosity at 40 °C, mm^2/s	3.6	2.8
aromatic hydrocarbons, wt-%	16.1	0.3
net heating value, MJ/kg	42.7	43.9
net heating value, MJ/l	35.9	34.2
cetane number IQT	57	79
final boiling point, °C	356.5	303.5
sulphur content, mg/kg	6.6	<1
ash content, w-%	<0.001	<0.001
FAME content, vol-%	7.3	-

Particle measurement

- Dilution with double ejector system
  - Primary dilution air heated to 150 °C
  - Secondary dilution air at ~ 15 °C
  - Dilution ratio based on CO_2-concentrations
- From PEMS control unit:
  - Filtered dilution air flow
  - Dilution air heating
  - CO_2-concentration measurements from different sampling locations
- Particle instrumentation used here
  - Airmodus A20 CPC, > 7 nm particle number
  - TSI EEPS, 5.6-560 nm particle size distribution
  - TSI NSAM particle surface area monitor

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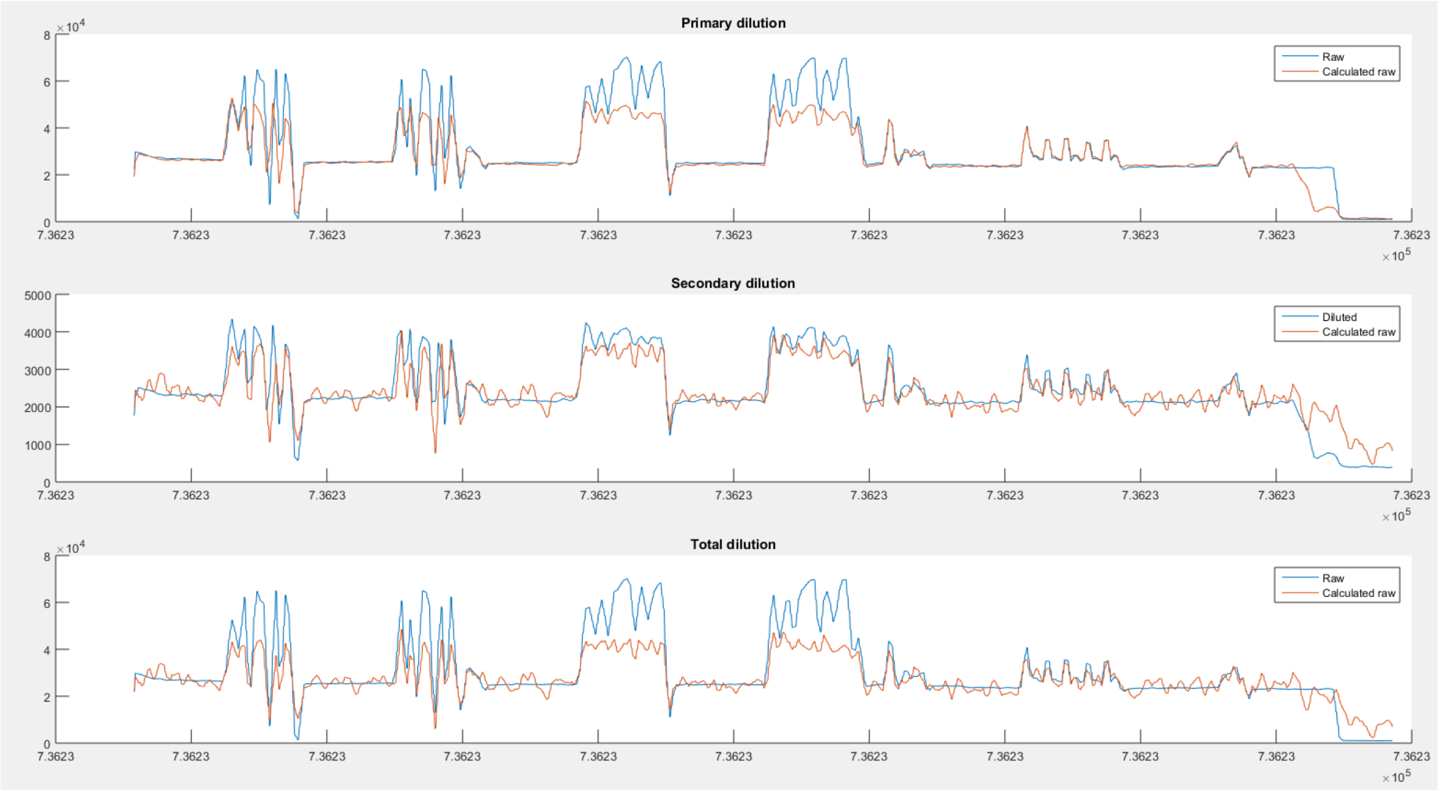
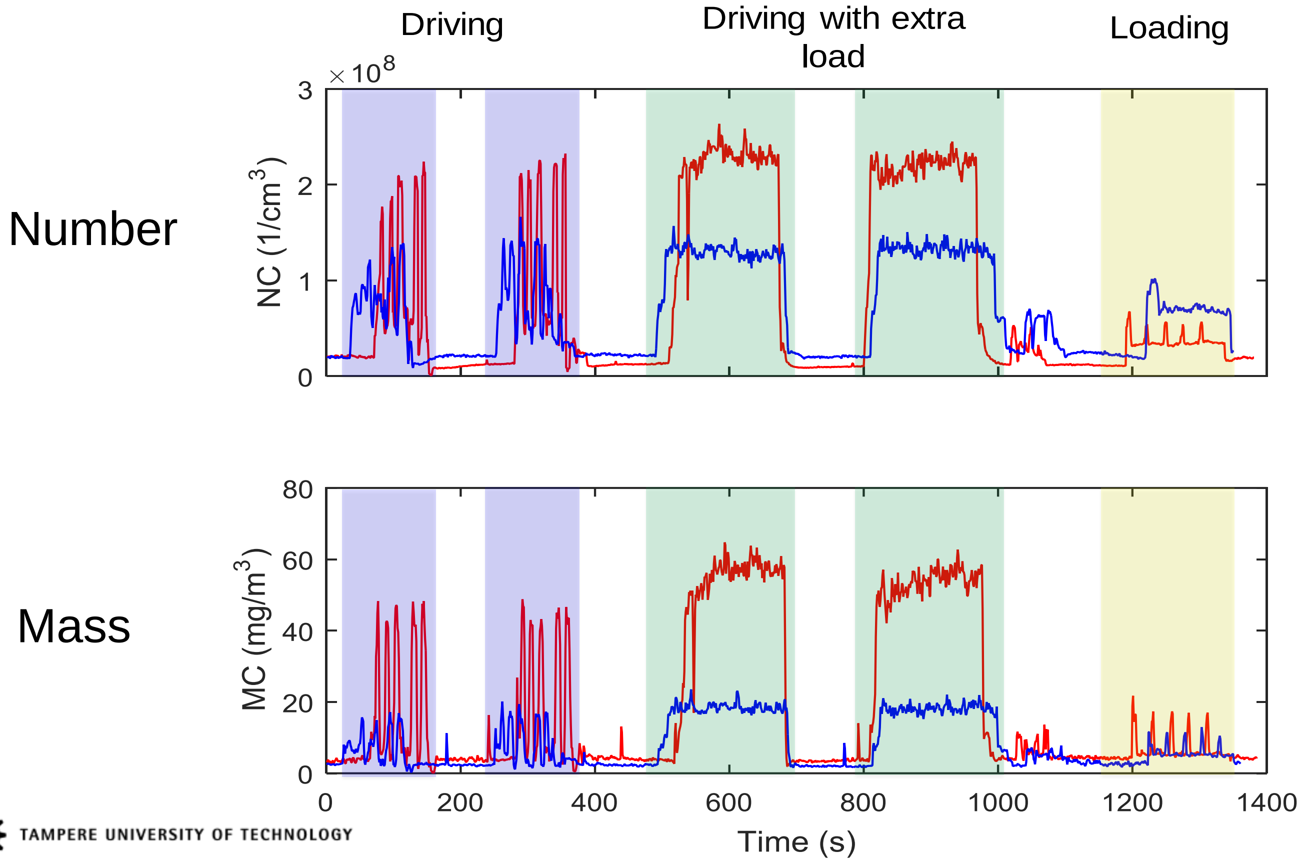
Determining dilution ratio

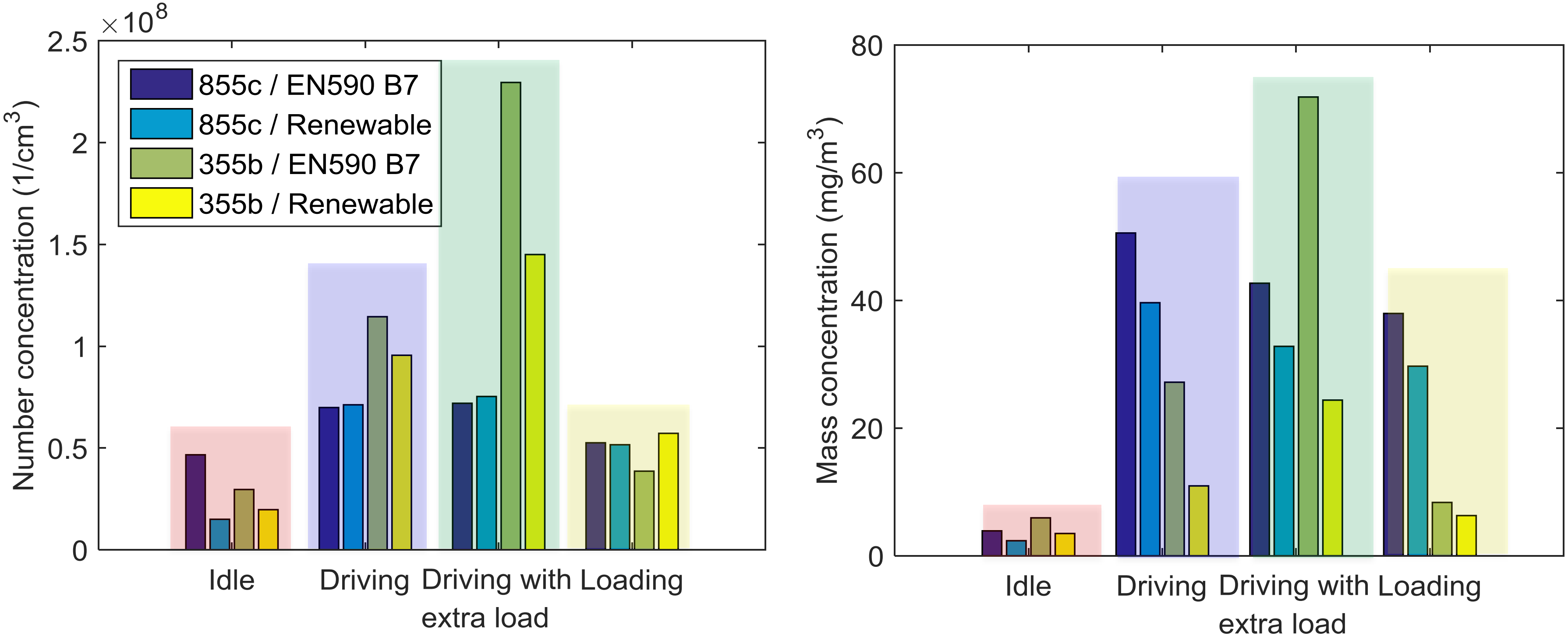


In the end we used constant dilution ratios for each test

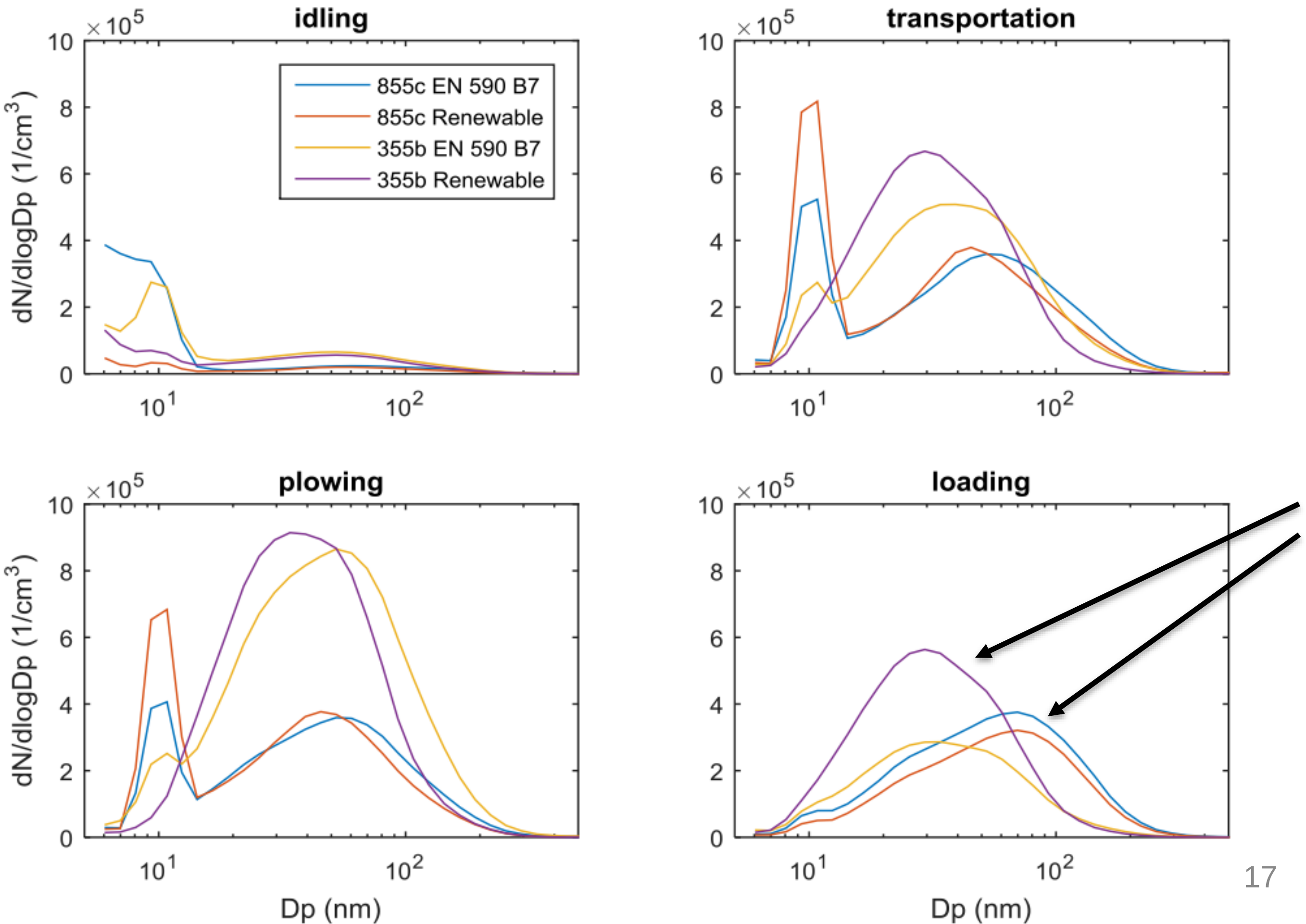
Exhaust particle number concentration (NC) and mass concentration (MC) during the test cycle for the 355b loader using EN590 B7 and Neste MY Renewable Diesel



Exhaust particle number and mass concentrations during different activities



Particle size distributions from EEPS



In general:

Larger soot mode particles with EN590

Effects of fuel in particle emissions when changing the fuel

Changes are calculated using units #/(kWh_fuel) ja mg/(kWh_fuel)

Machine	Cycle point	Number of particles, change EN 590 => Renewable Diesel (%)	Particle mass, change EN 590 => Renewable Diesel (%)
Wille 855	Idling	-65	-35
	Transportation	-3	-25
	Plowing	+6	-22
	Loading	-6	-25
Wille 355	Idling	-26	-35
	Transportation	-7	-55
	Plowing	-22	-58
	Loading	+48	-28

Summary

- Reduction of particle number emissions was observed in most activities when fuel was changed to renewable
- Reduction in mass emission was observed for both loaders during all activities, which is a result of the smaller average particle size
- The smaller particle size may arise from the higher cetane number (79 vs. 57) and lower aromatic content (0.3 vs. 15 wt-%)