Effects of Diesel Particle Filters on Performance of In-Use Buses

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Leonid Tartakovsky, Rafael Fleischman, Ran Amiel
Technion – Israel Institute of Technology

Jan Czerwinski
Labs for IC-Engines & Exhaust Emission Control, University of Applied Sciences, Switzerland

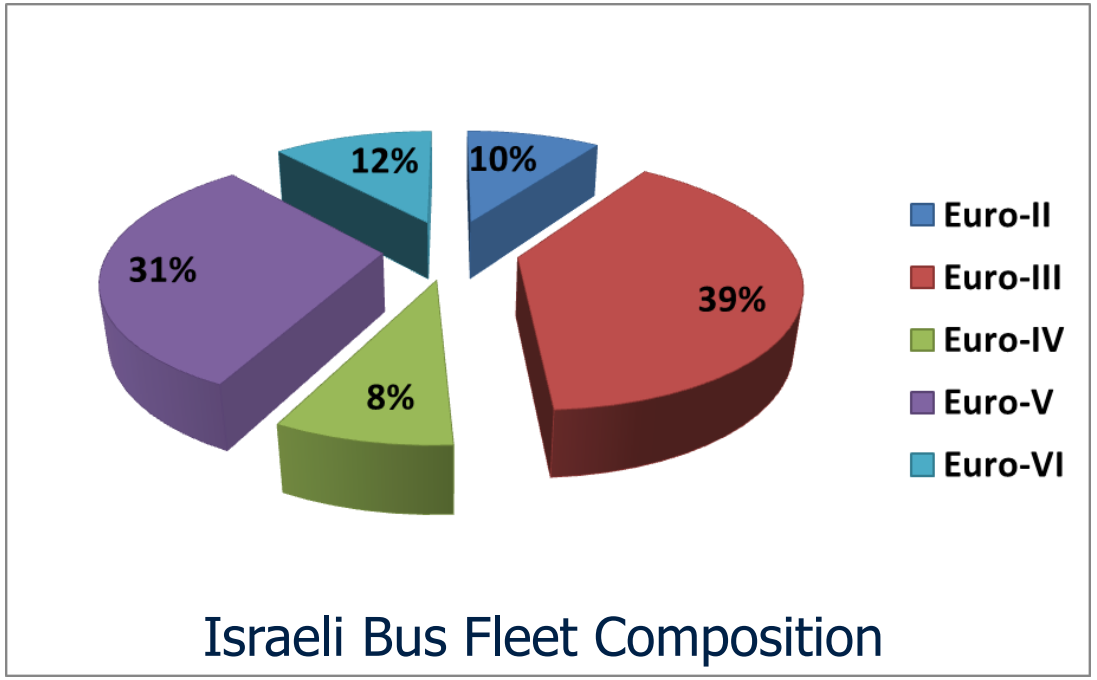
Andreas Mayer
TTM – Technik Thermische Maschinen, Switzerland

Motivation

- Particle emissions: dangerous to human health
- Nanoparticles: even more dangerous
  - Penetrate the cell membranes and enter into the blood stream
  - Reach brain and other organs
- Road transport: main source of air pollution in Israel's population centers
- Public transportation: based almost entirely on diesel engines

DPF retrofitting

- Diesel engine buses may be kept in service for 15 years or more
- Emission control technologies become obsolete
  - Old buses turn into big polluters
- Retrofitting with Diesel Particulate Filter (DPF):
  - Cost-effective measure to reduce particulate matter emissions



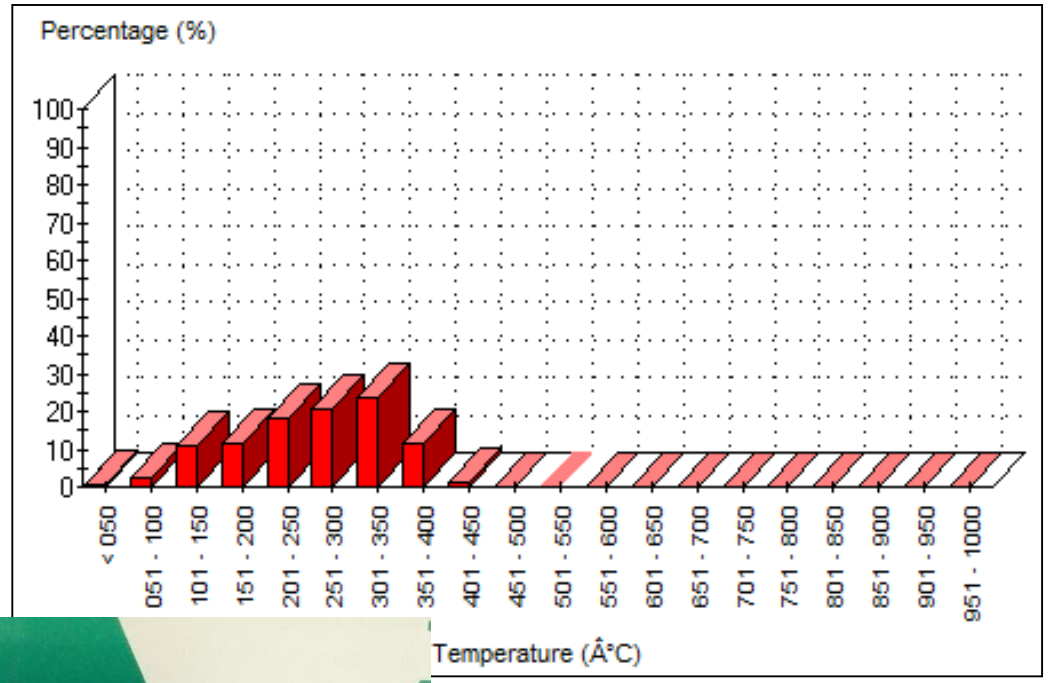
Israeli Bus Fleet Composition

Research Goals

- Evaluate the reduction in nanoparticle emissions of in-use diesel buses retrofitted with DPF
- Assess the impact of retrofitting on the buses performance in real-world usage conditions

DPF selected

- Temperature profile
- CRT (Continuously Regenerating Trap)
  - Collected soot is continuously oxidized by NO_2 (generated in an oxidation catalyst upstream of the filter)
- VERT-certified
- 3 different manufacturers



Buses tested

- 18 in-use Euro III buses
  - 9 urban Man NL313F buses
  - 9 intercity Mercedes-Benz OC500 coaches
- 3 different topographies
  - Flat terrain – Tel Aviv area
  - Hilly terrain – Jerusalem area
  - Combined terrain – Haifa area
- Control group of 18 identical vehicles in identical routes

Evaluated parameters

- PN concentrations and size distribution
  - Calculation of PM

$$m_i = \rho \frac{\pi d_i^3}{6} n_i$$

  - Upstream and Downstream DPF
  - Calculation of DPF filtration efficiencies (number and mass based)

$$PNFE = \frac{\left(TPN_B - TPN_A\right)}{TPN_B} \cdot 100 \qquad PMFE = \frac{\left(TPM_B - TPM_A\right)}{TPM_B} \cdot 100$$

- Effect on fuel consumption
- Effect on backpressure

Particulate Number measurement procedure

- 3 measuring rounds:
  - shortly after DPF installation
  - 4 months later
  - 10 months later
- 4 Operating Modes:
  - Low idle
  - High idle
  - Full Load, 85% rated speed
  - Free acceleration

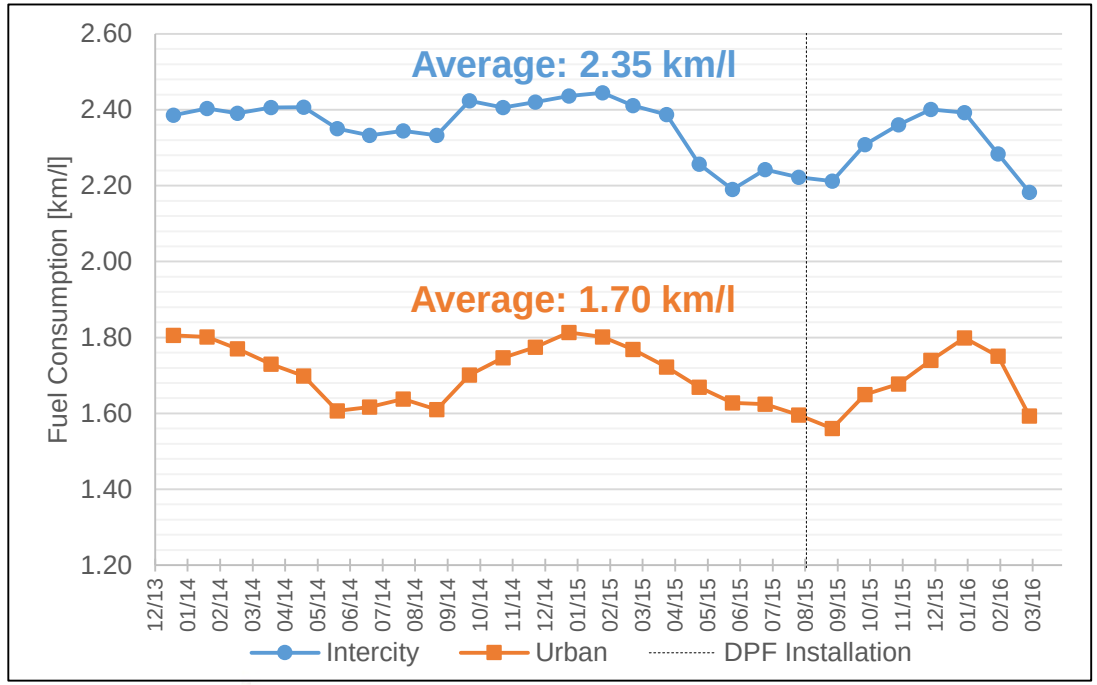
Particulate Number Measurement: Experimental Setup

- Particle Sizer:
  - **EEPS 3090 TSI Inc.**
- Sample dilution and conditioning:
  - **379020A-30 TSI Inc.**
- ECE-PMP-Protocol
  - Sampling temperature: 300°C
  - Particles above 23 nm were considered

Fuel Consumption

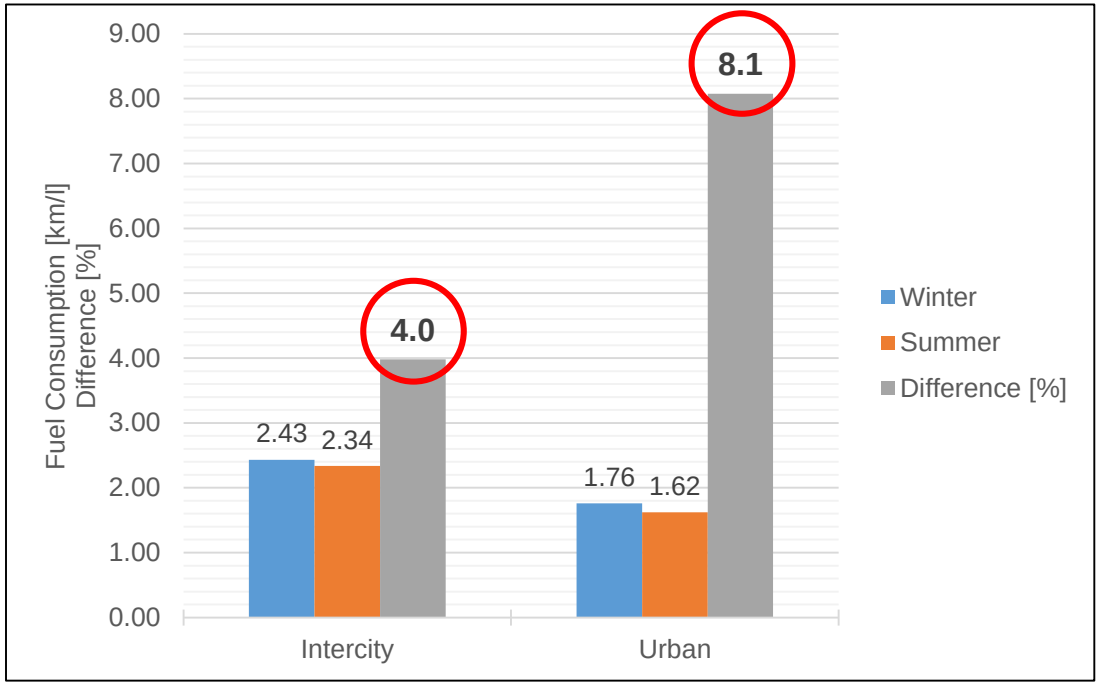
Urban vs. Intercity

- Pilot: 18 buses
- Intercity coaches: better fuel efficiency



Seasonal variation

- Pilot & Control: 36 buses
- Hot summer: Air conditioning



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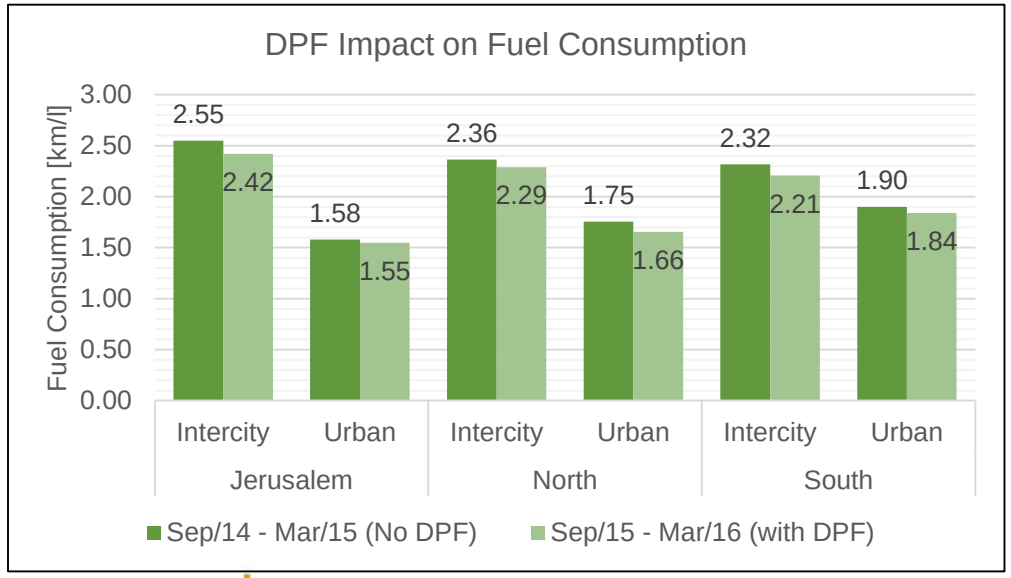
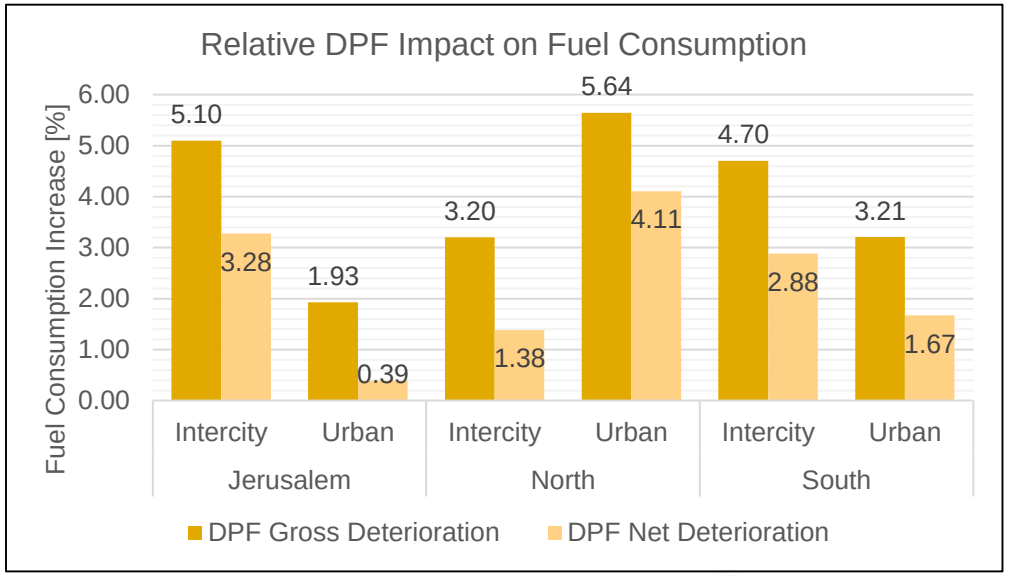
DPF effect on fuel consumption

- Evaluation of average natural deterioration of fuel efficiency due to vehicle aging
  - Equal periods, both without DPF retrofit (Pilot & Control: 36 buses)
  - Intercity: **1.82%** (per year)
  - Urban: **1.54%** (per year)
- Evaluation of DPF effect on fuel consumption
  - Equal periods, without and with DPF retrofit (Pilot: 18 buses)

Average increase of fuel consumption due to DPF:

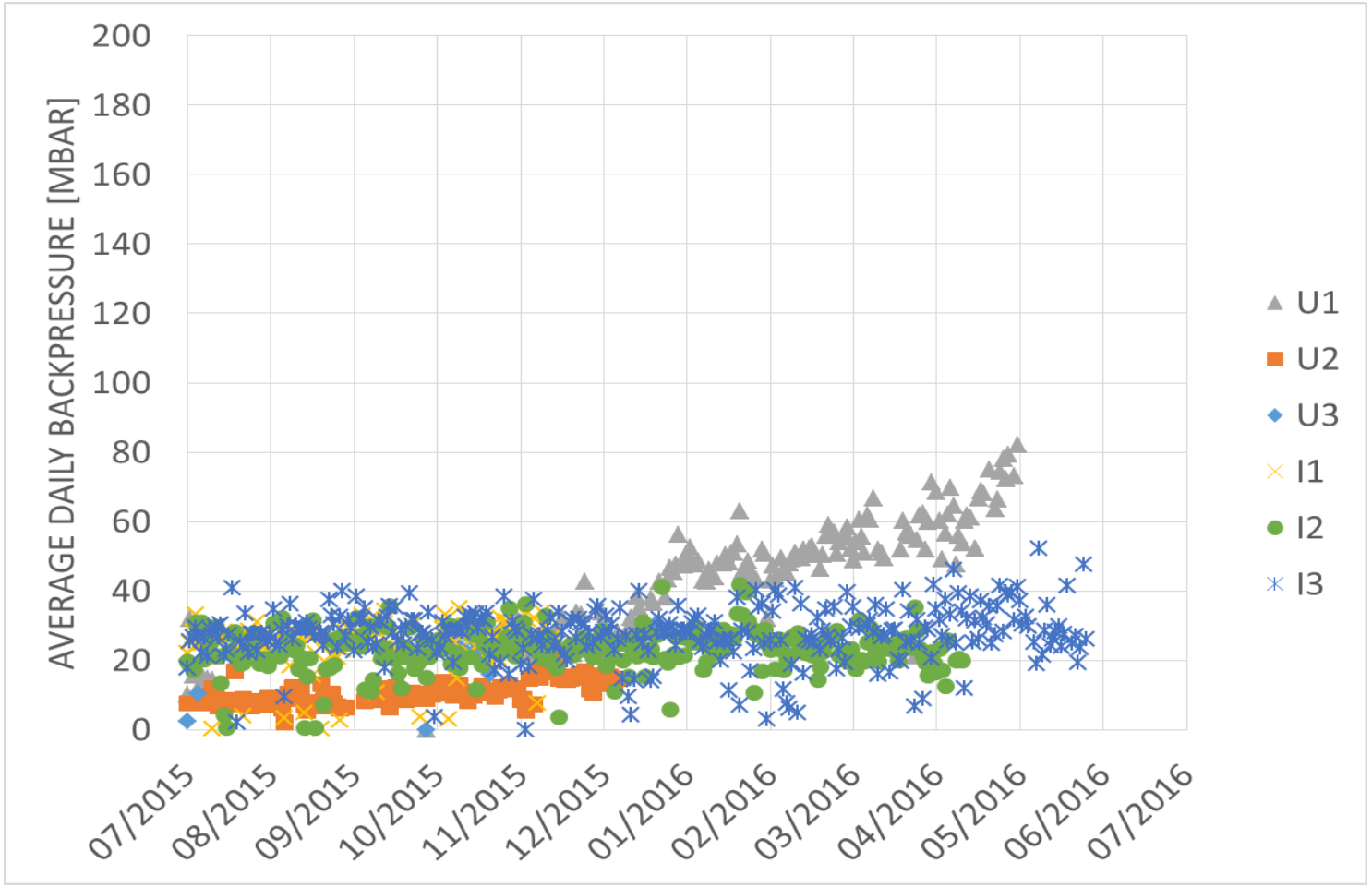
- Intercity: **2.5%**
- Urban: **2.1%**



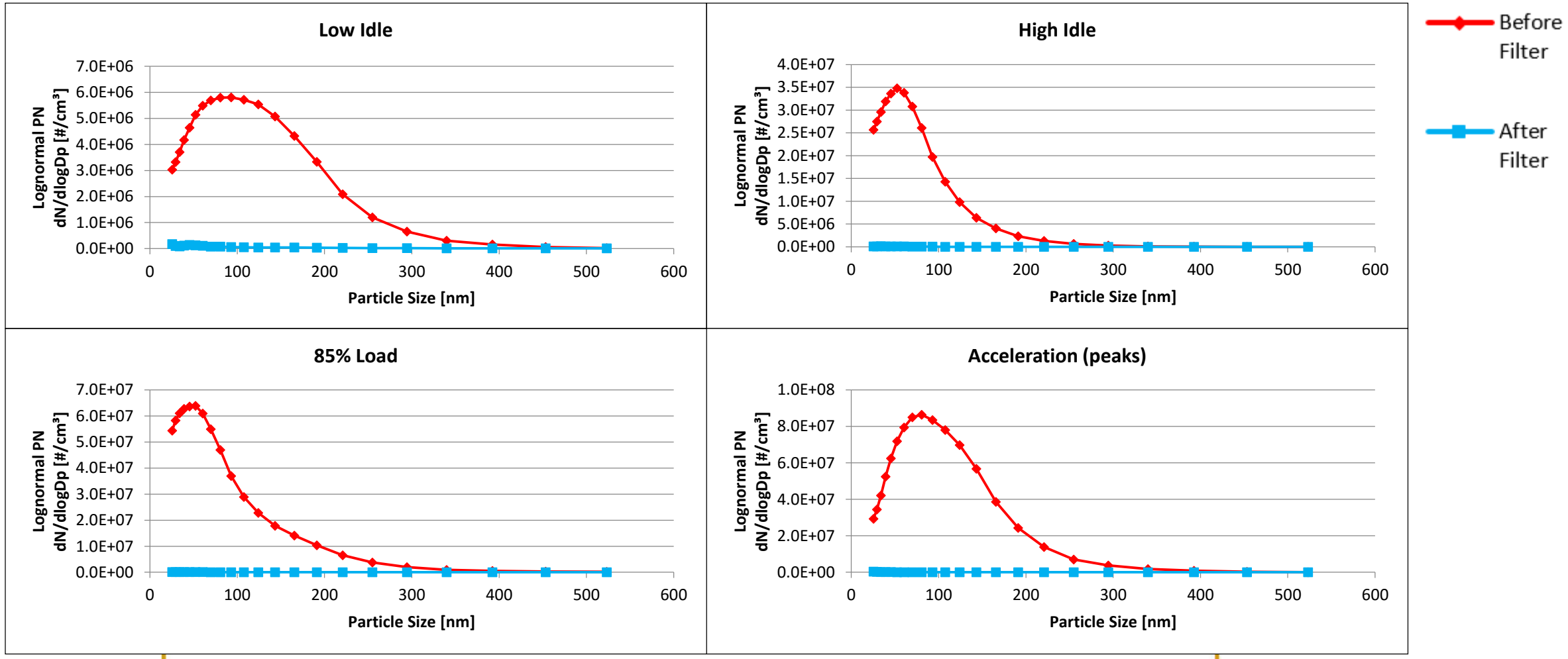


Backpressure

- Pressure sensors were installed upstream the DPF
- Pressure sensors frequency: 10 Hz
- Limit pressure increase: 150 mbar



Nanoparticle size distribution (IntercityI3)



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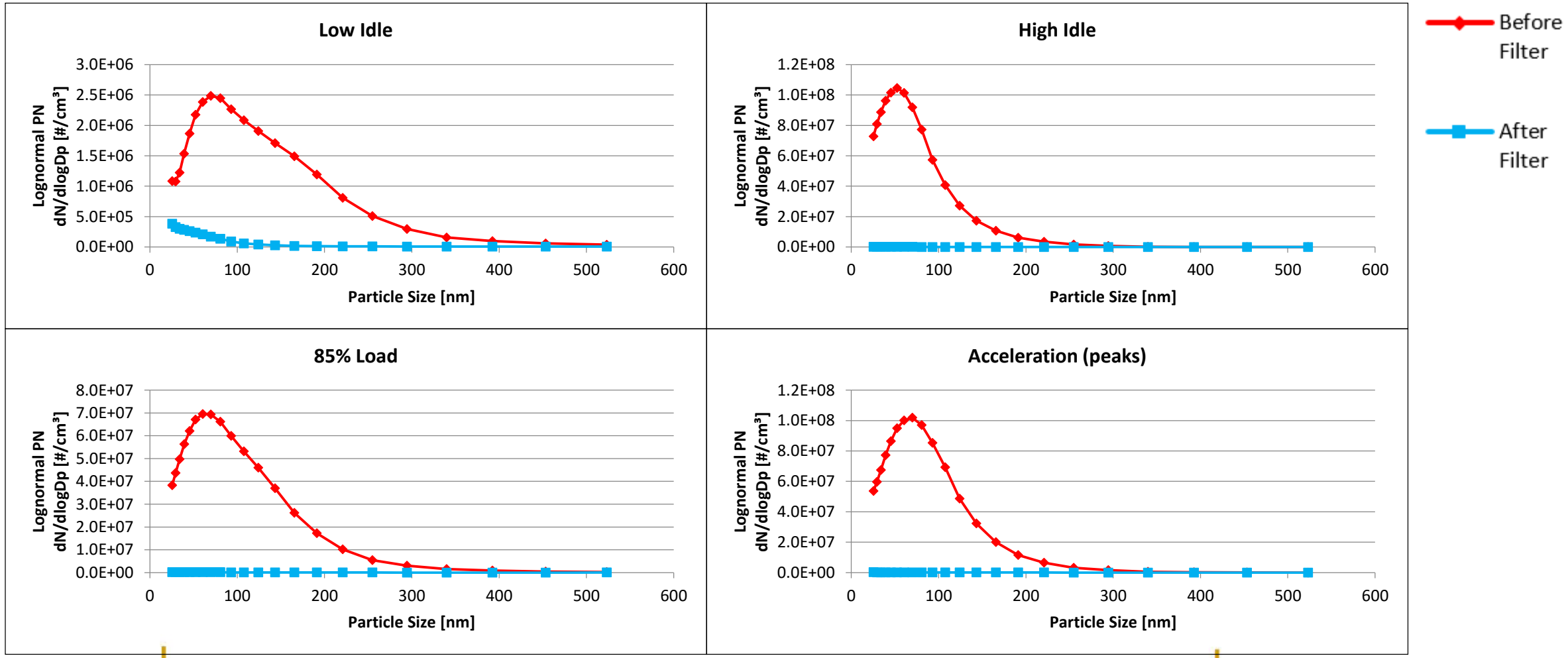
Nanoparticle size distribution (Urban U3)



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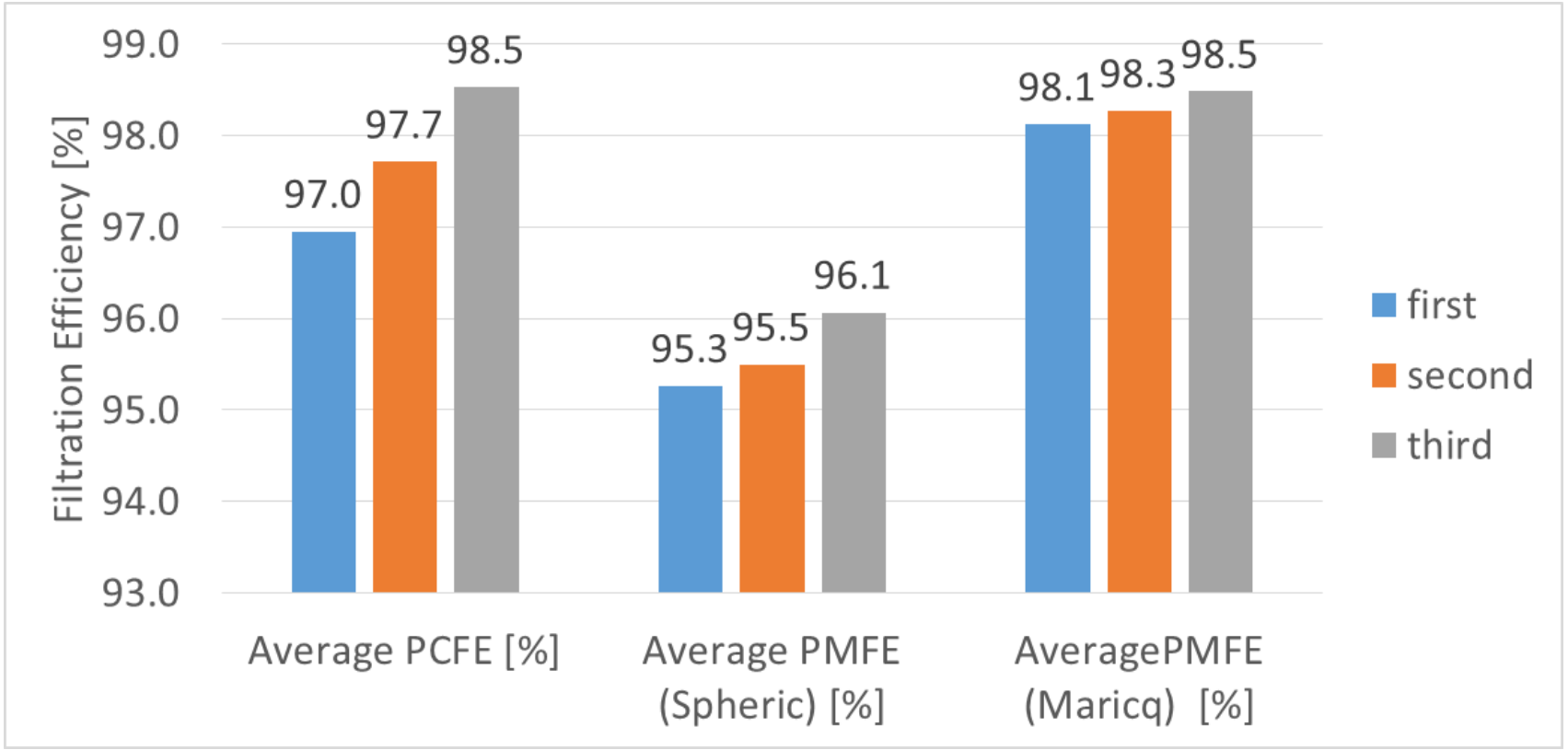
Filtration Efficiency



Particle count filtration efficiency > 97%

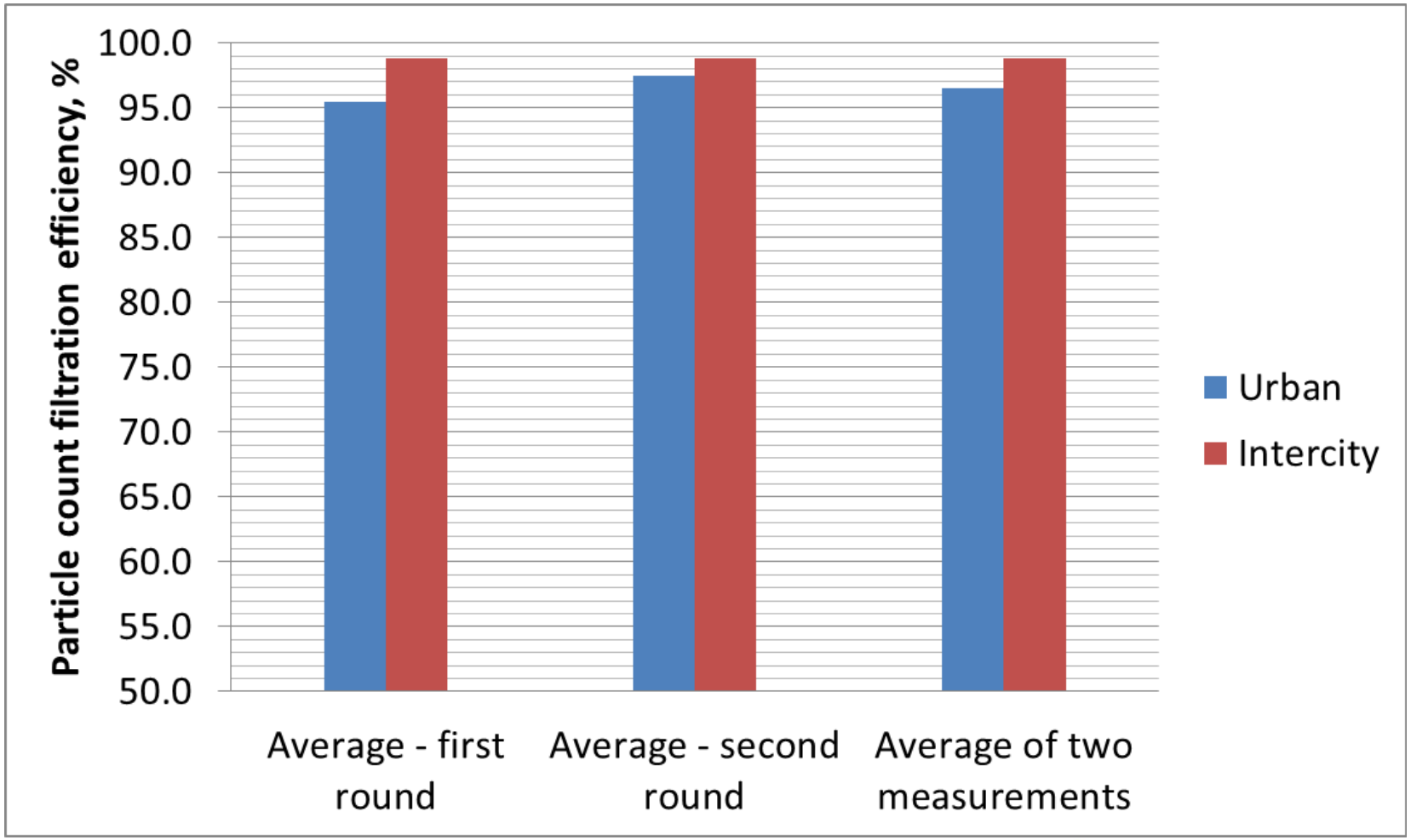
PCFE for intercity and urban buses

- Higher PCFE for Intercity buses

Average PCFE:

Intercity: **98%**

Urban: **96%**



Conclusions

- Average particle count filtration efficiency of the tested DPFs: **98%** and **96%** for intercity and urban buses, respectively
- Low idle regime: slightly lower filtration efficiencies
- Increase in fuel consumption due to air conditioning: **4%** and **8.1%** for intercity and urban buses, respectively
- Increase of fuel consumption due to DPF retrofitting: **2.5%** and **2.1%** for intercity and urban buses, respectively
- Backpressure increase values: below **80 mbar** after 11 months of buses operation
- No deterioration in vehicle drivability was reported
- No unusual repairs or changes in maintenance operations

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Thank you!

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Further info:

Leonid Tartakovsky tartak@technion.ac.il