Particulate Emissions from Mopeds: Effect of Lubricant and Fuel

BONNEL Pierre, MARTINI Giorgio, KRASENBRINK Alois, DE SANTI Giovanni
European Commission – Joint Research Center
Via Enrico Fermi,1 – 21020 Ispra (VA) – Italy

Abstract

An experimental programme was carried out at the JRC-Ispra with the objective of investigating some aspects related to particulate emissions from mopeds. In particular, part of the experimental programme was focussed on the effect of lubricating oil quality and of alternative fuel (LPG) on particulate emissions.
The emission tests were performed using a suitable chassis dyno and a conventional CVS system on 4 mopeds differing for emission level (Pre-Euro 1 and Euro 1), engine technology and aftertreatment system. Besides the regulated pollutants, particulate emissions were measured and characterized with different techniques. The particulate total mass was measured gravimetrically using the procedure prescribed for diesel vehicles; the mass/size distribution of particulates was also measured by means of a Low Pressure Impactor. Moreover, in steady state conditions (constant speed) the particle number and the number/size distribution was determined using a Scanning Mobility Particle Sizer. The results showed that particulate emissions as well as the effect of the lubricant on them are strongly dependent on engine technology. Furthermore, conversion of mopeds from gasoline to LPG proved to be an effective way to reduce pollutant emissions.

Introduction

The European institutions are preparing the amendment of the Directive 97/24/EC [1] on "Characteristics of two or three-wheel motor vehicles". One of the objectives of the future legislation is to lower the particulate emissions from motorcycles, especially from the ones equipped with two-stroke engines. The main objectives of the present study were to investigate the physical properties of particulate emissions from mopeds and the effects on them of lubricant quality, fuel and engine technology.

Test fleet and test conditions

The test fleet consisted of three mopeds differing for engine and aftetreatment technology. A fourth moped equipped with a LPG conversion kit was tested to investigate the effect of changing the fuel from gasoline to LPG on emissions.

The test fleet is described here below (table 1):

Table 1

Category		*Displacement (cc)*	*Emission Level*	*Main Features*
Moped	**MT001-M-50**	**50**	Pre-Euro1	Standard 2-stroke engine
Moped	**MT002-M-50**	**50**	Euro 1	2-stroke, Direct Injection Engine
Moped	**MT003-M-50**	**50**	Euro 1	2-stroke + Oxidation Catalyst
Moped	**MT004-M-50**	**50**	Euro 1	2-stroke + Oxidation Catalyst + LPG conversion kit
			Euro 1	

Emission were measured over the legislative driving cycle (ECE 47) and at constant speed.

The dilution of the exhaust gas was carried out using a constant volume sampler (CVS) whose flow rate was set to 7.5 m^3/min for the entire testing campaign. The dilution air, taken from the test cell was maintained at constant temperature and humidity (22.5°C, 50%rH) throughout a test. Mass

measurements have been conducted under dynamic conditions (different driving cycles) following the standard procedure for diesel passenger cars. The number size distributions have been obtained using a with a Scanning Mobility Particle Sizer (SMPS) with the same dilution parameters but at constant speeds (40 km/h).
Finally the mass/size distribution was measured with a 11 stage Low Pressure impactor both over the legislative cycle and at constant speed sampling the diluted exhaust from the dilution tunnel.

Results

The effect of the engine technology on particulate emissions was very important; the pre-Euro 1 moped equipped with a conventional 2-stroke engine was by far the most emitting, both in terms of particulate total mass and of particle number.
The moped equipped with the direct injection engine was the one with the lowest particulate emissions; it also exhibited a completely different behaviour compared to the other mopeds. For example, while for the mopeds with conventional 2-stroke engines particulate emissions were lower over the hot part of the cycle than over the cold part, for the direct injection engine particulate emissions were higher over the hot part. Moreover, as shown by the number/size distribution measured at constant speed, the particles emitted by the direct injection moped had a mean diameter smaller than the other two mopeds.
Concerning the effect of the lubricant quality on particulate emissions, two different lubricants were tested: the first one was a low quality lubricant, mineral and with low performance, the second one was a top quality lubricant, full synthetic and with high performance.
The effect of the lubricant tuned out to be more than significant, at least for two mopeds: for the mopeds equipped with a conventional 2-stroke engine an important decrease of particulate emissions was in fact observed. The emissions measured with the lubricant that was originally in these two mopeds were in between the levels measured with the two test lubricants.
The effect of the lubricant was completely different in the case of the moped MT002-M-50, the one equipped with the direct injection engine: the effect was smaller and, moreover, it was opposite compared to the other two mopeds equipped with conventional two stroke engines. Particulate emissions from moped MT002-M-50 increased whit the use of the high quality lubricant and the highest emissions were observed with the factory lubricant.

The different behaviour of the moped MT002-M-50 is surely linked to the direct injection technology and in particular to the different lubrication system. In conventional two stroke engines the lubricant enter into the combustion chamber mixed with the fuel, whereas in the tested direct injection engine the lubricant drips into the air inlet duct and enter into the combustion chamber mixed only with air.

The effect of the lubricant quality was evident also on the number/size distribution and on the mass/size distribution of the particles.

Finally, the use of LPG as fuel in the fourth moped tested lead to a reduction of all the pollutant emissions with the exception of NOx that increased. Particulate emissions were reduced by about 50%

Conclusions

The present study showed that the engine technology has a huge effect on particulate emissions from mopeds. Particulate emissions of the pre-Euro1 moped were very high while the Euro 1 mopeds tested at the JRC showed particulate emission values (g/km) close to those of Euro 3 diesel vehicles

Furthermore, it was observed that the lubricant quality has a significant impact on particulate mass, particle number and size but the effect strongly depends on the engine technology.

The moped equipped with the direct injection engine exhibited a different behaviour compared to conventional two stroke engines.

The LPG conversion kit tested proved to be an effective way to reduce particulate emissions from mopeds

Acknowledgements

These tests have been conducted with the essential contribution from the Vehicle and Engine Laboratory (VELA) staff. The authors also the European association of motorcycle manufacturers (ACEM) for providing test motorcycles.

References

1. *Directive 97/24/EC of the European Parliament and of the Council of 17 June 1997 on certain components and characteristics of two or three-wheel motor vehicles, OJ L 226, pp.1-454, 1997.*

Martini Giorgio, Bonnel Pierre, Krasenbrink Alois, De Santi Giovanni Effect of motorcycle engine technology upon physical properties of nanoparticles, ETH-Conference on Combustion Generated Particles 18th -20st August 2003, Zurich

2. *Astorga-Llorens C., et al.: Chemical characterization of particulate emissions from 2-stroke and 4-stroke motorcycle engines, J. Aerosol Sci., this edition, 2003.*

Particulate Emissions from Mopeds: Effect of Lubricant and Fuel

G. Martini, P. Bonnel, A. Krasenbrink, G. De Santi
Institute of Environment and Sustainability
European Commission – Joint Research Centre
ISPRA (Italy)

- ***Vehicle Emissions Laboratory (VELA) - Institute for Environment and Sustainability***

Main objectives:

The main objective was to contribute to the discussion on the possibility of introducing new limits for particulate emissions from mopeds

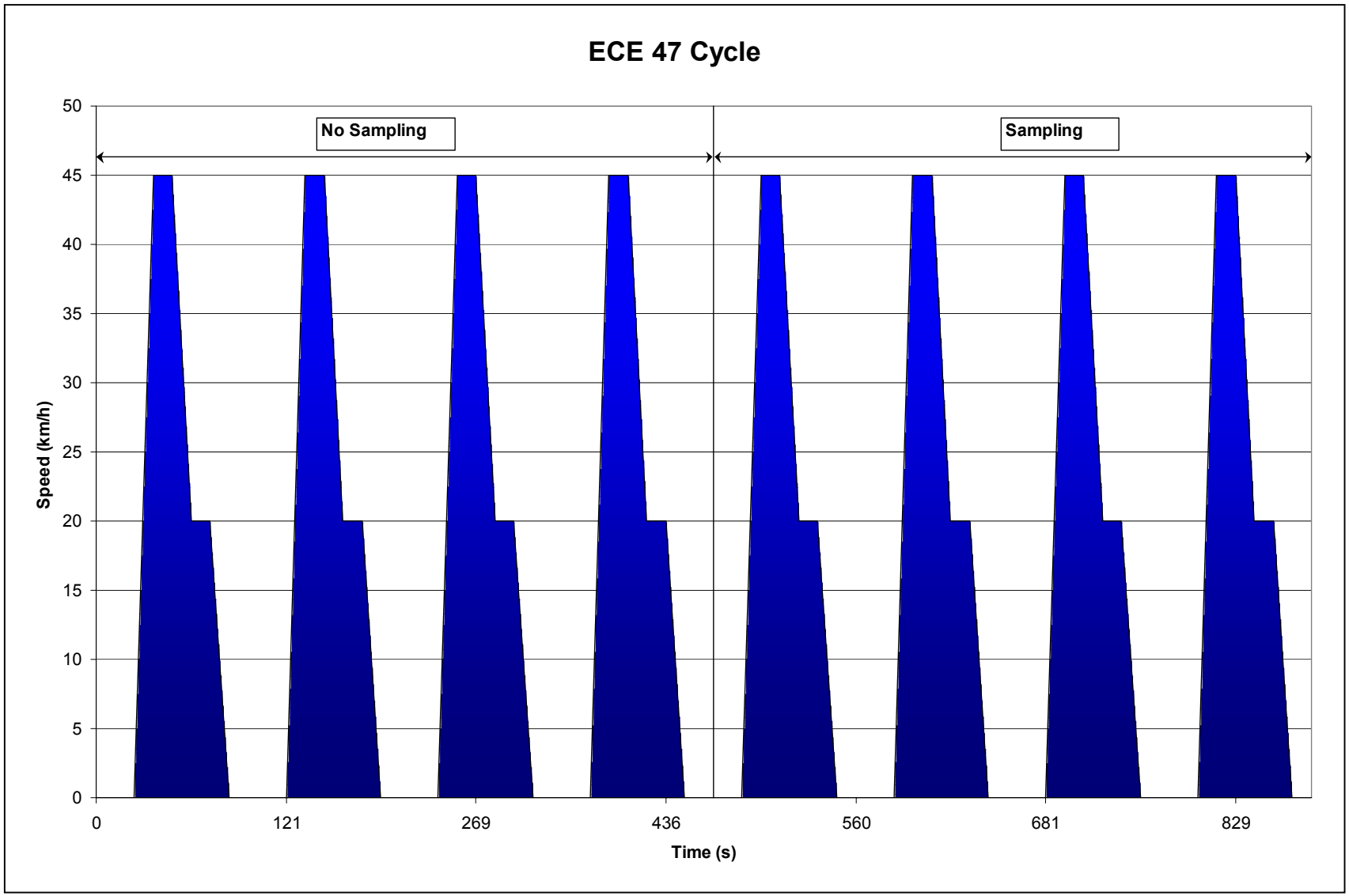
The experimental programme was designed in order to have an understanding of:

- physical properties of particulates emitted by mopeds
- the effect of engine technology on particulate emissions from mopeds
- the effect of the lubricating oil quality on particulates emissions
- the effect on pollutant emissions of a conversion kit to LPG for mopeds

Experimental programme details:

- **Emission tests:**
  - Carried out at the JRC emission test facility
  - Roller bench 48” suitable for testing small two wheelers
  - Conventional CVS system + dilution tunnel

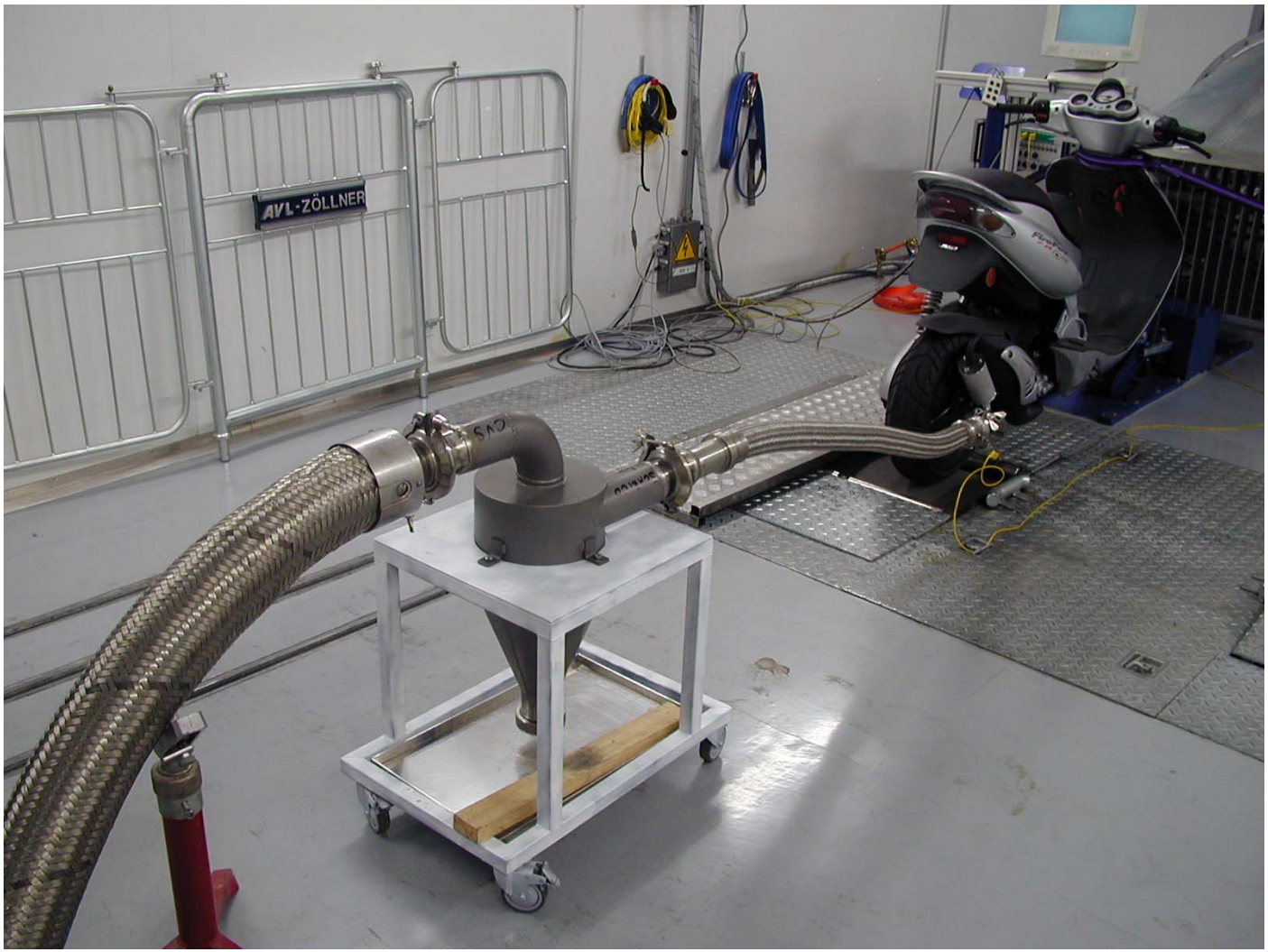
- **Driving Cycle:**
  - ECE 47
  - Emissions were measured during both the “cold part” and the “hot part” of the cycle


ECE 47 Cycle
No Sampling
Sampling
Speed (km/h)
Time (s)
0
5
10
15
20
25
30
35
40
45
50
0
121
269
436
560
681
829

Particulate Emissions Characterisation:

- **Measurement of particulate total mass**
  - The legislative procedure prescribed for Diesel was used to measure particulate total mass
  - In addition, a cyclone was used to avoid contaminating the sampling system and the analysers with very large droplets of lubricant

- **Particulate physical properties:**
  - Number/size distribution (TSI – SMPS)
  - Mass/size distribution (LPI)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Particulate physical properties:

- **Number/size distribution (TSI – SMPS)**
  - *Constant speed (40 km/h)*

- **Mass/size distribution (Low Pressure Impactor)**
  - *11+1 stages*
  - *Volume flow rate: 25 l/min*
  - *Measuring range: 0.0085 μm-16 μm*
  - *Constant speed (40 km/h) and ECE 47 cycle*

Effect of Lubricant on Particulate Emissions

- **Test lubricants**
  - Low quality lubricant (mineral, low content of additives)

    API TC specifications

  - High quality lubricant (full synthetic, high content of additives)

    API TC, JASO FC and ISO-L-EGD specifications

Test Fleet

- **MT001-M-50**
  - *Pre-Euro 1 moped*
  - *Conventional two stroke engine; no after-treatment device*

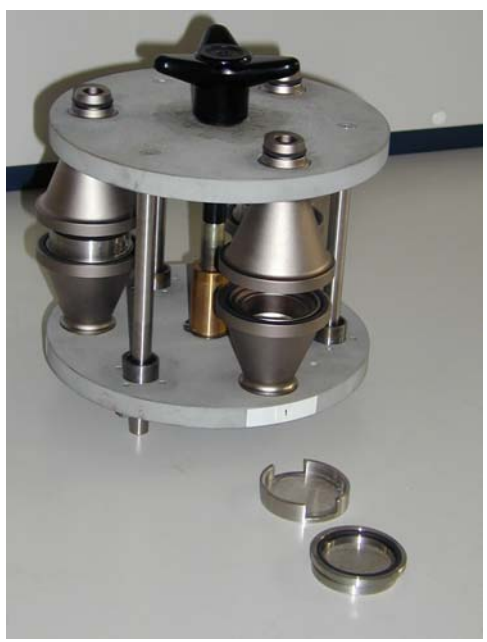
- **MT002-M-50**
  - *Euro 1 moped*
  - *Direct injection engine; no after-treatment device*

- **MT003-M-50**
  - *Euro 1 moped*
  - *Conventional two stroke engine; oxidation catalyst*

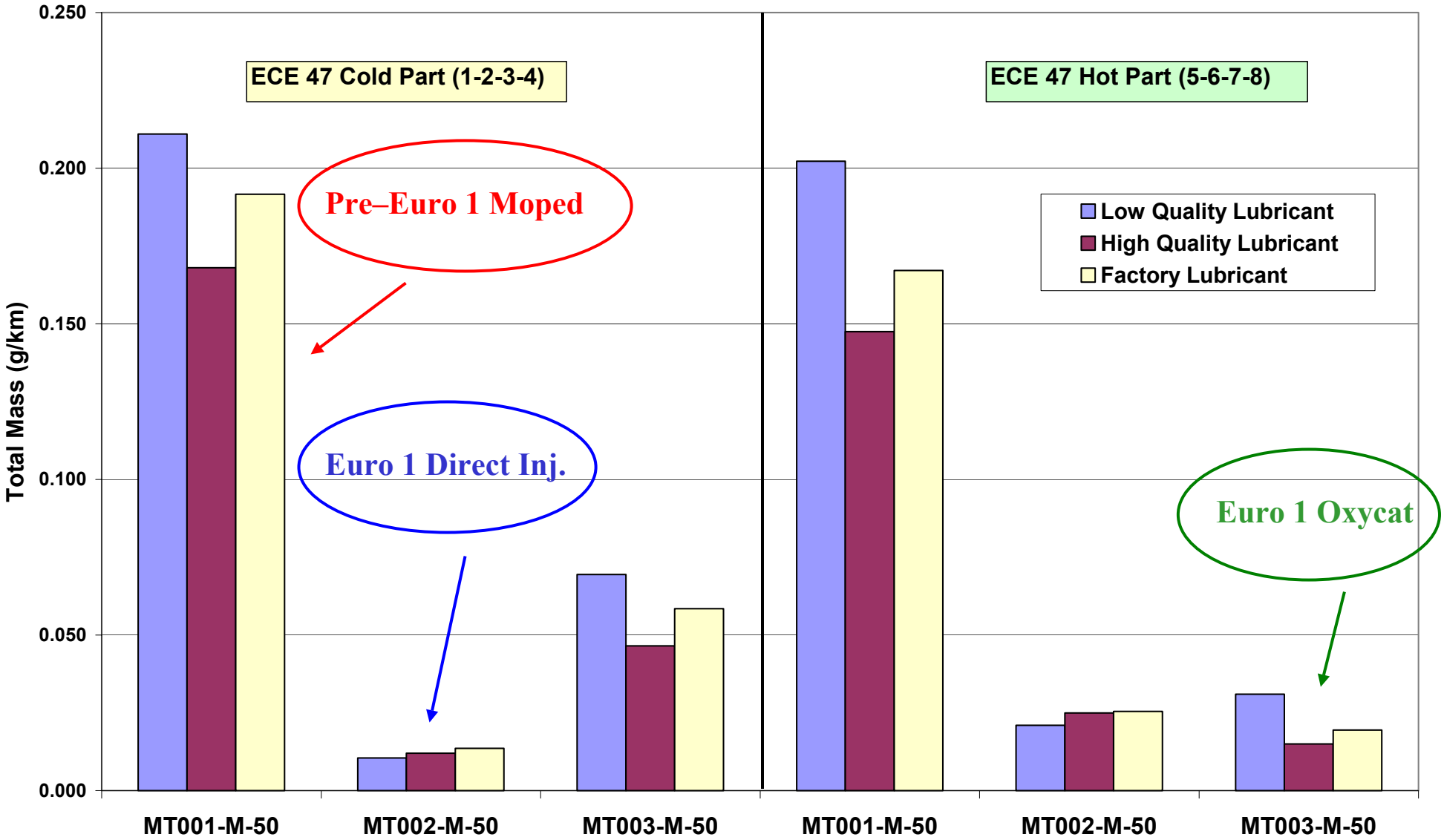
- **MT004-M-50**
  - *Euro 1 moped equipped with a LPG conversion kit*
  - *Conventional two stroke engine; oxidation catalyst*

Effect of Lubricant on PM Emissions

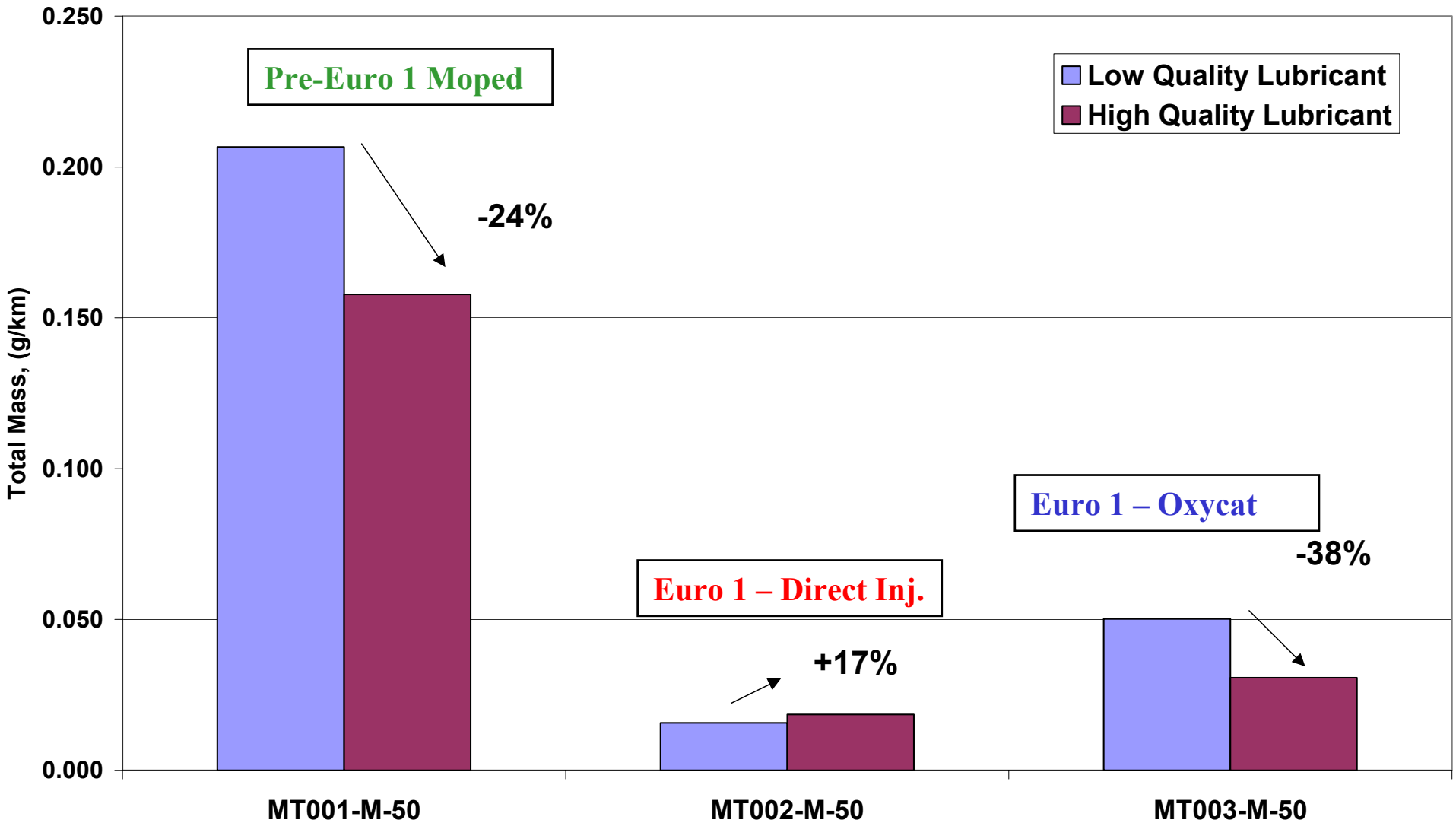
Total Mass



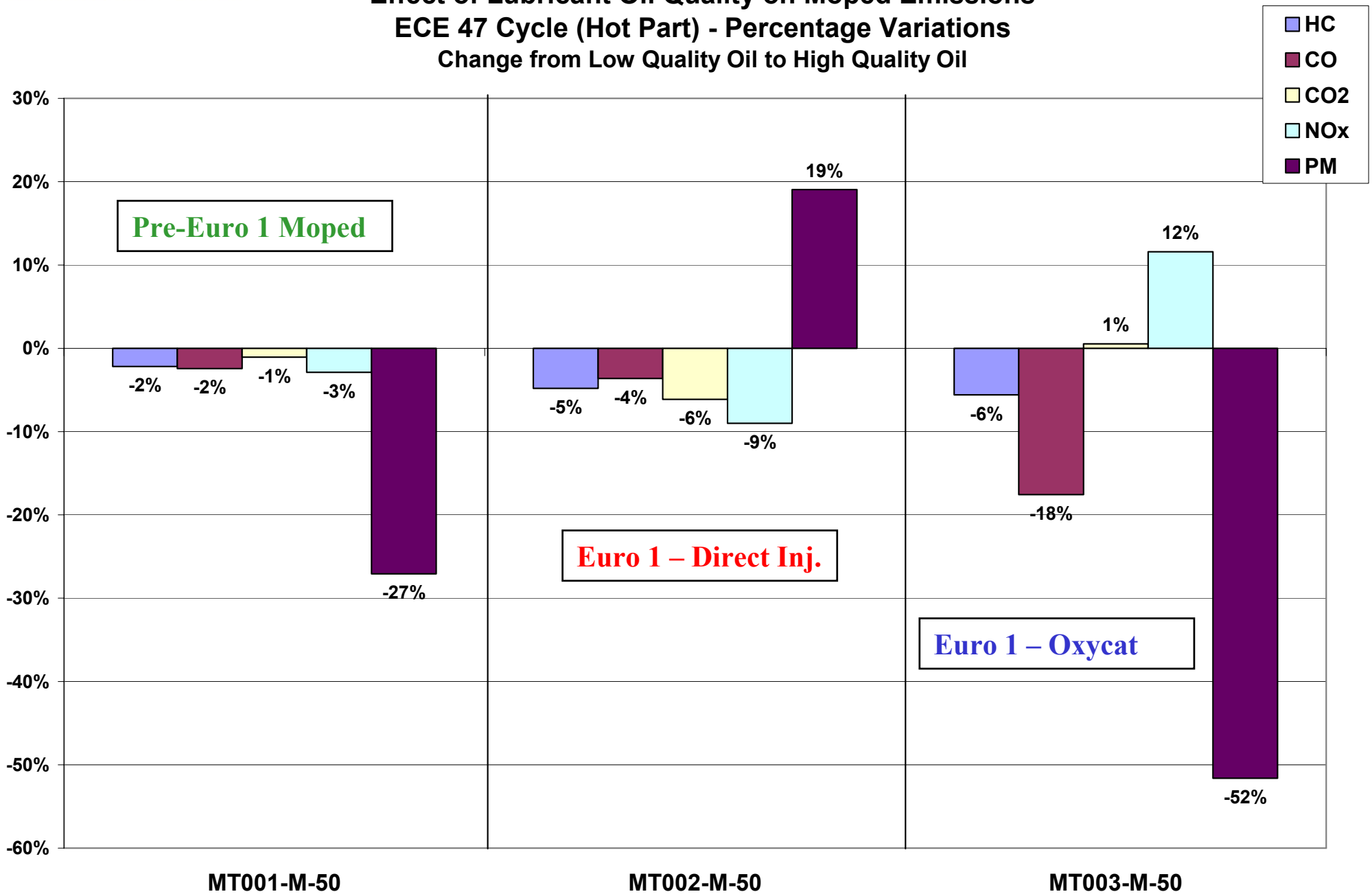
Effect of Lubricating Oil Quality on Moped Emissions
ECE 47 Cycle - Particulates Emissions



Effect of Lubricating Oil Quality on Moped Emissions
ECE 47 Cycle (Whole Cycle) - Particulates Emissions



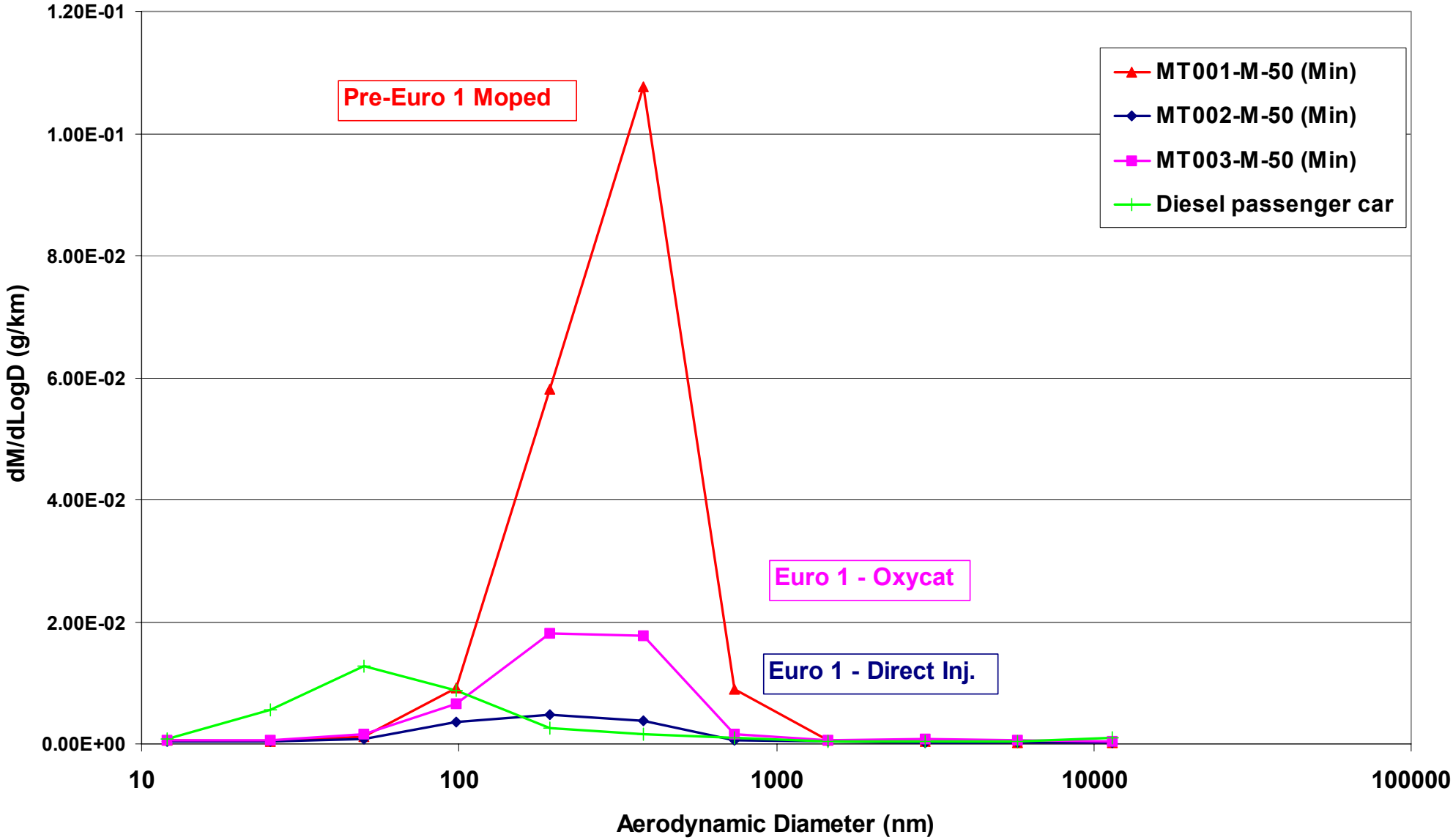
Effect of Lubricant Oil Quality on Moped Emissions
ECE 47 Cycle (Hot Part) - Percentage Variations
Change from Low Quality Oil to High Quality Oil



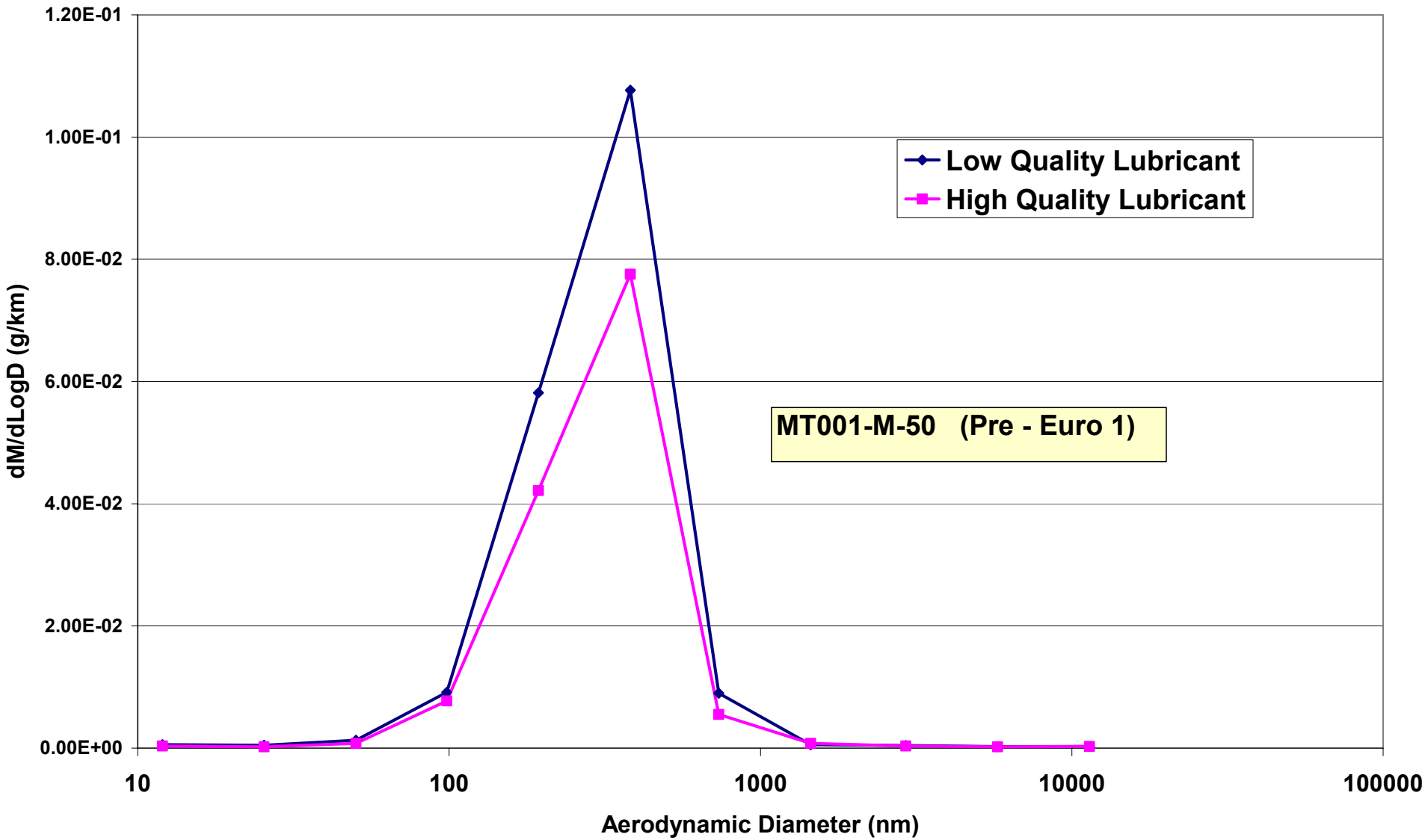
Effect of Lubricant on PM Emissions

Mass/Size Distribution

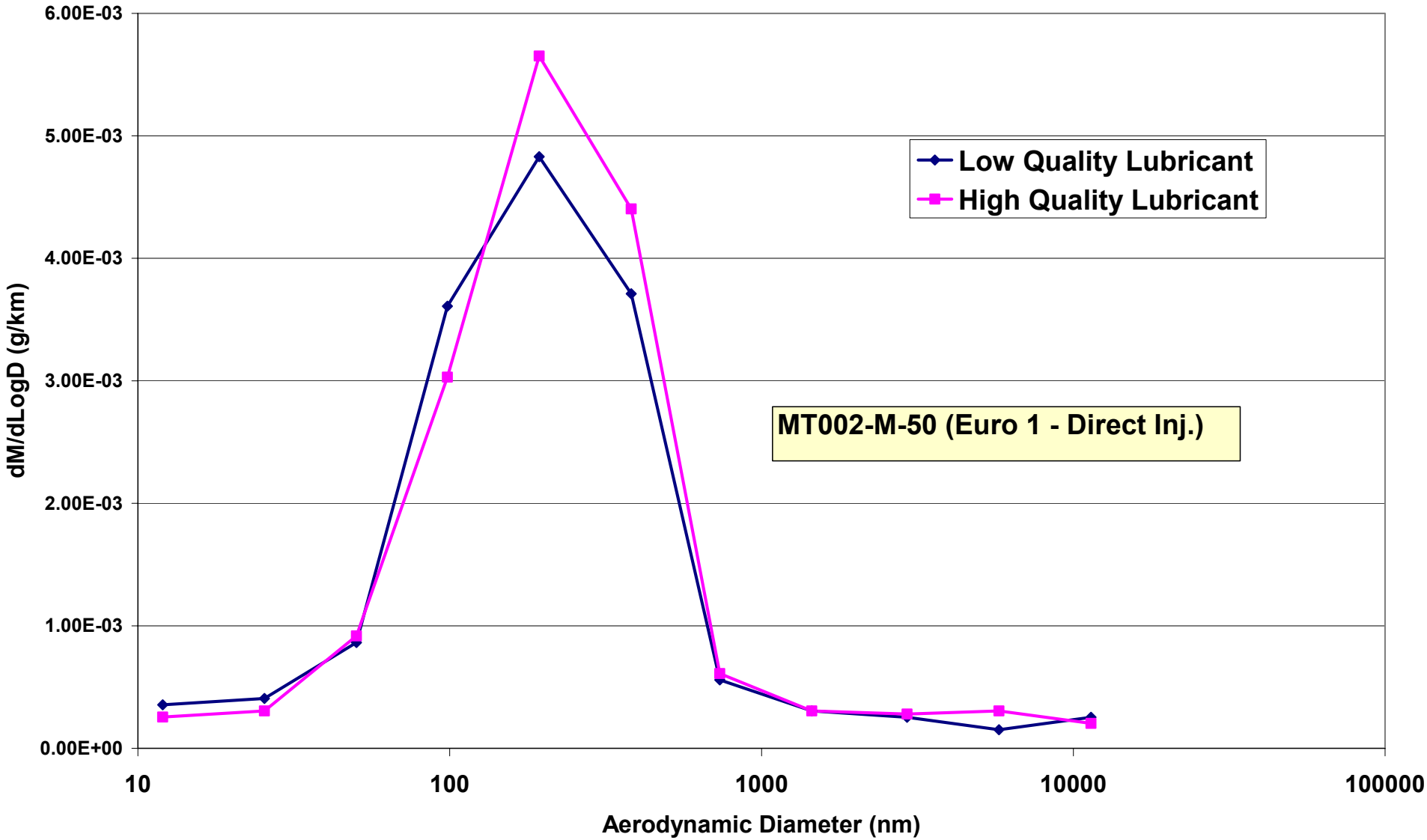
Particulate Emissions from Mopeds
ECE 47 Cycle - Mass/Size Distribution (LPI 11 stages)



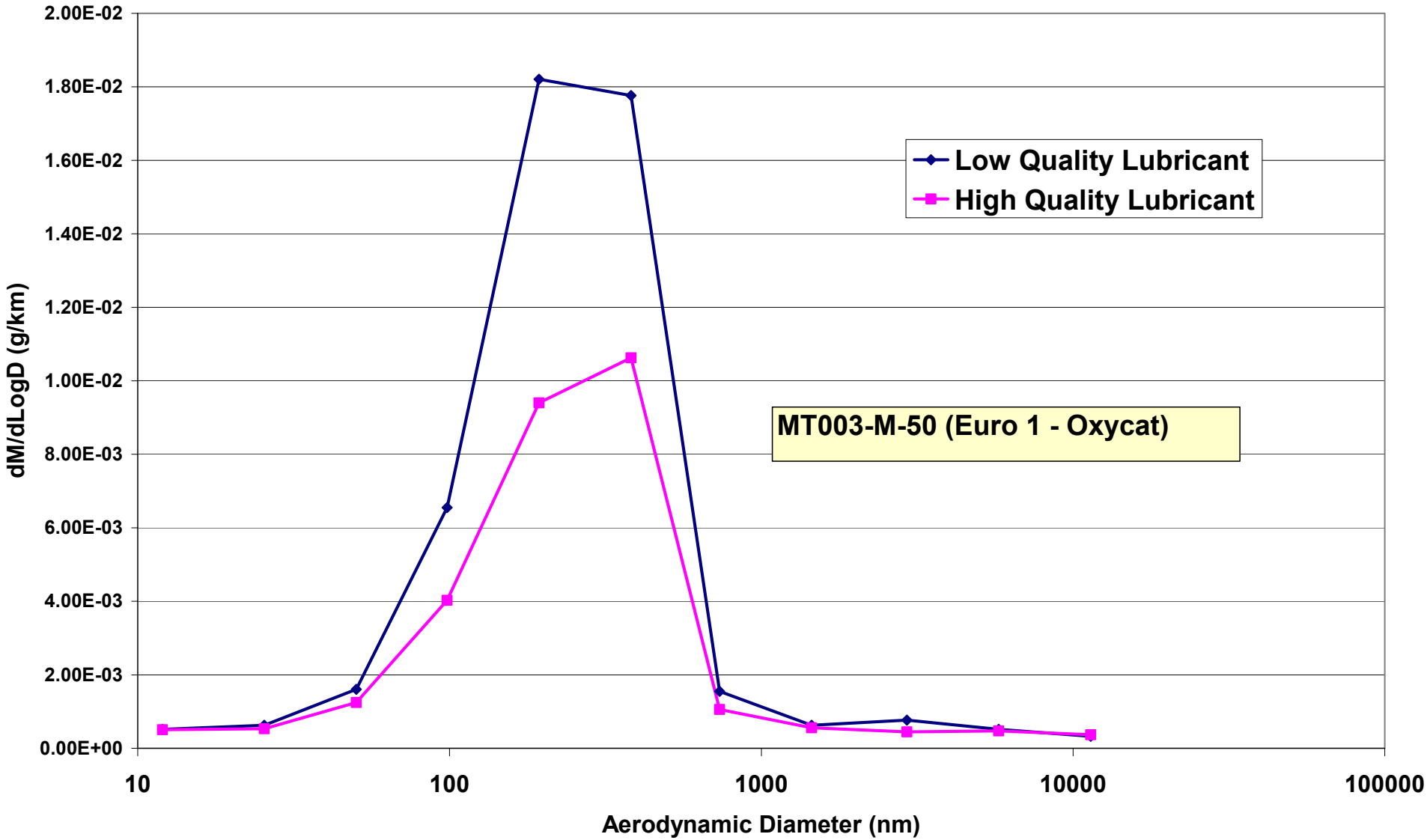
Effect of Lubricating Oil on Particulate Emissions
ECE 47 Cycle - Particulate Mass/Size Distribution (LPI 11 stages)



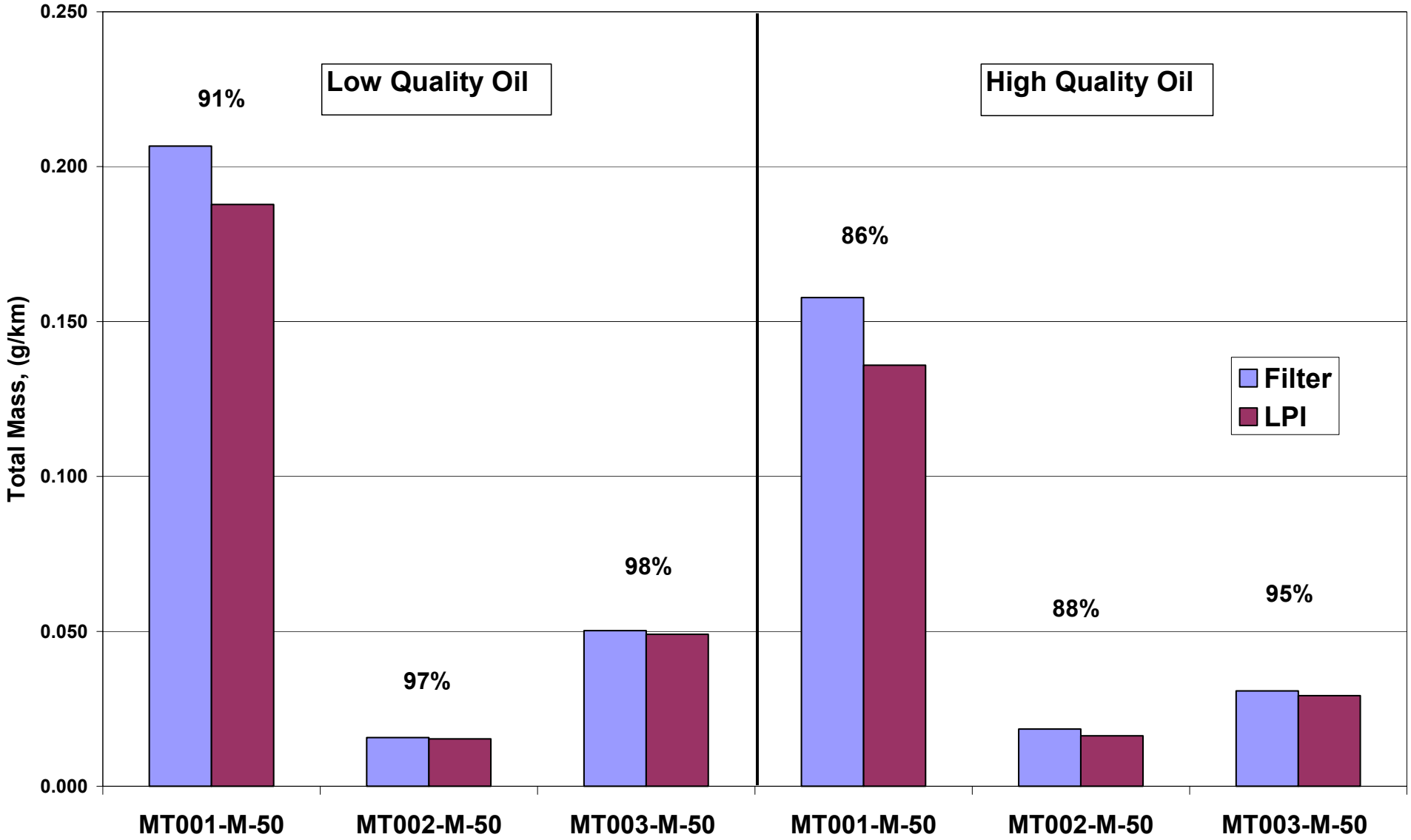
Effect of Lubricating Oil on Particulate Emissions
ECE 47 Cycle - Particulate Mass/Size Distribution (LPI 11 stages)



Effect of Lubricating Oil on Particulate Emissions
ECE 47 Cycle - Particulate Mass/Size Distribution (LPI 11 stages)



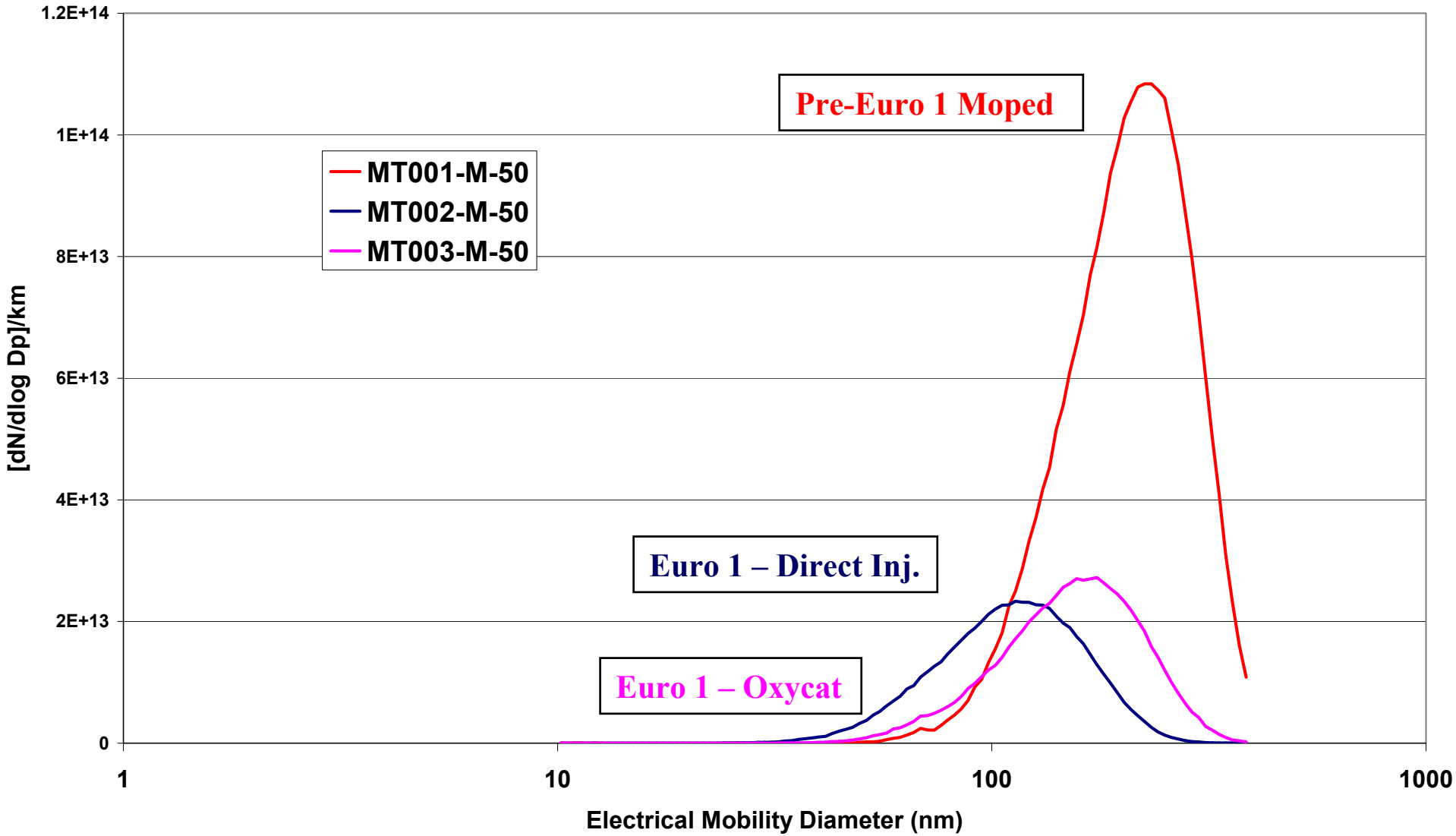
Particulate Emissions from Mopeds
Total Mass - Filter vs LPI



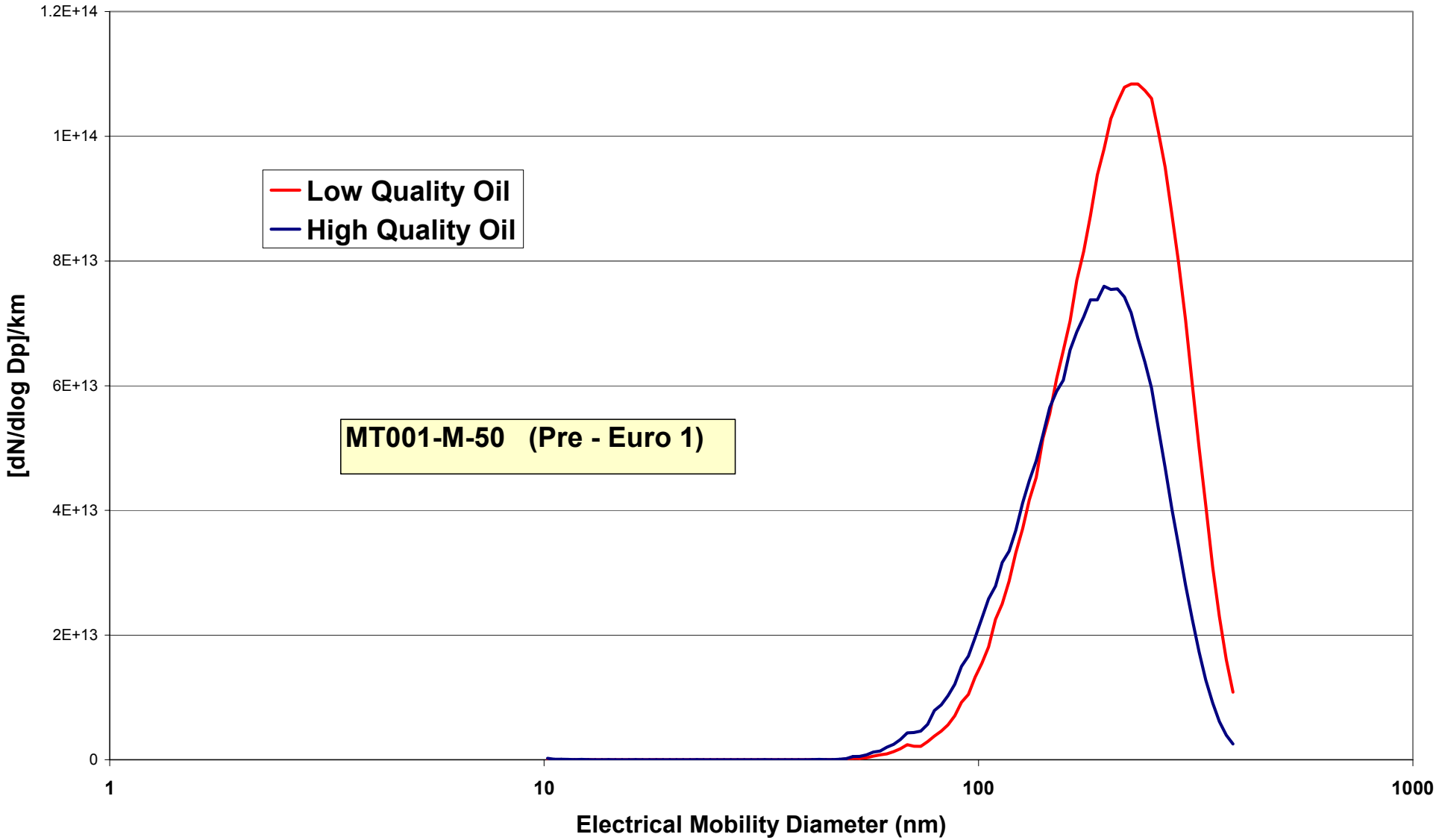
Effect of Lubricant and Fuel on PM Emissions

Number/Size Distribution

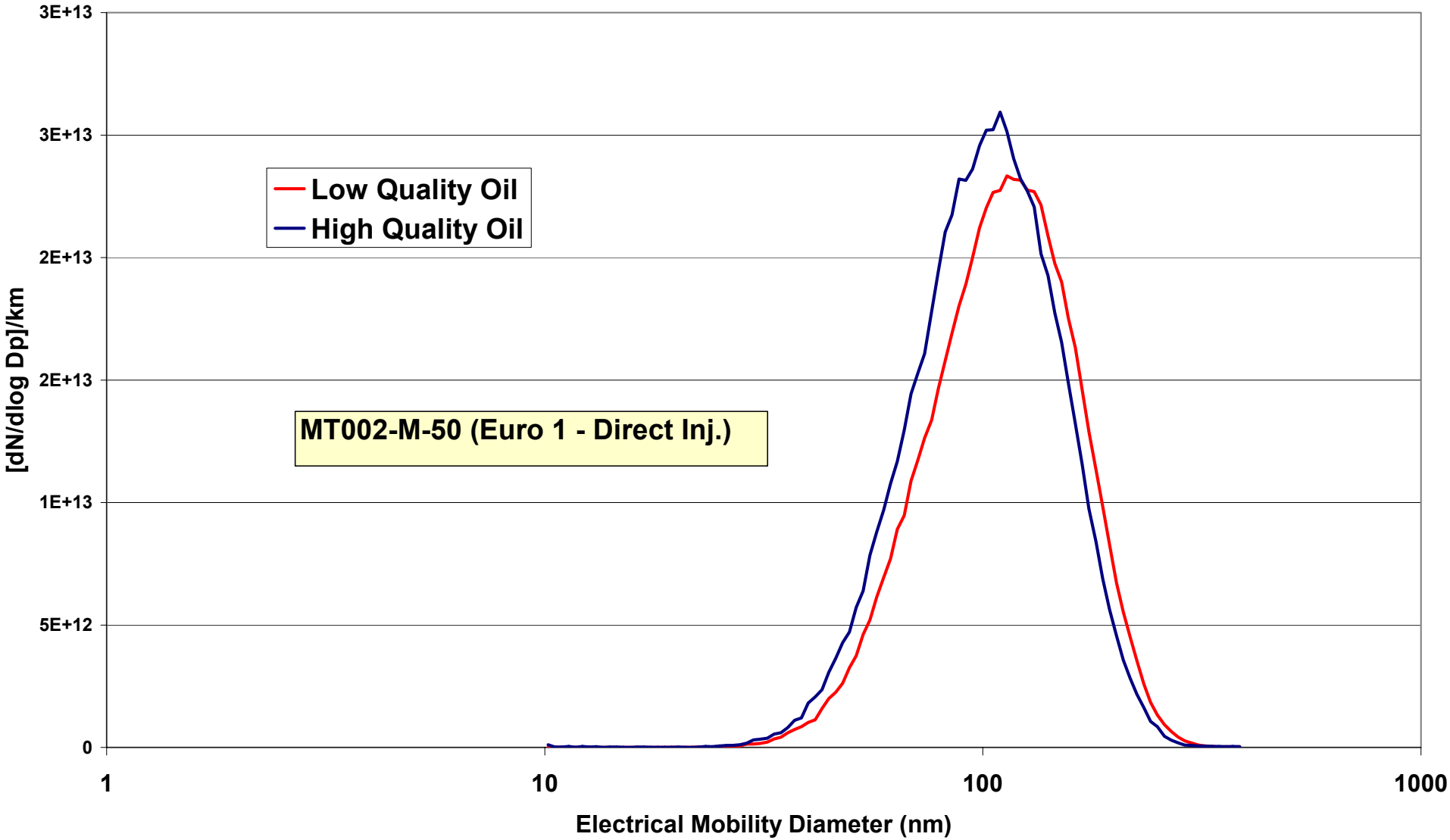
Particulate Emissions from Mopeds
Number/Size Distribution - Constant Speed: 40 km/h
Low Quality Oil



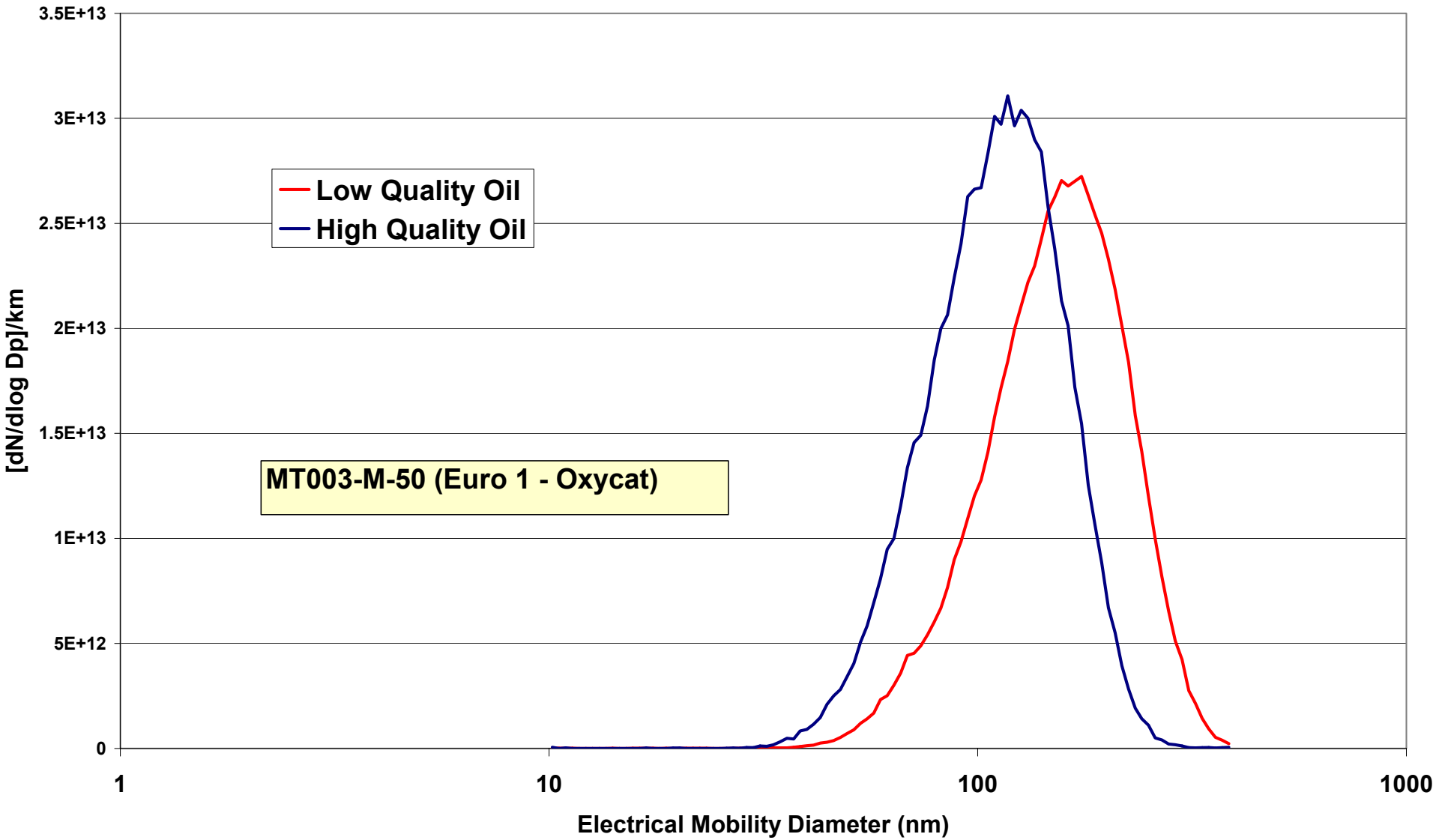
Effect Of Lubricating Oil on Particulate Emissions
Number/Size Distribution - Constant Speed: 40 km/h



Effect Of Lubricating Oil on Particulate Emissions
Number/Size Distribution - Constant Speed: 40 km/h

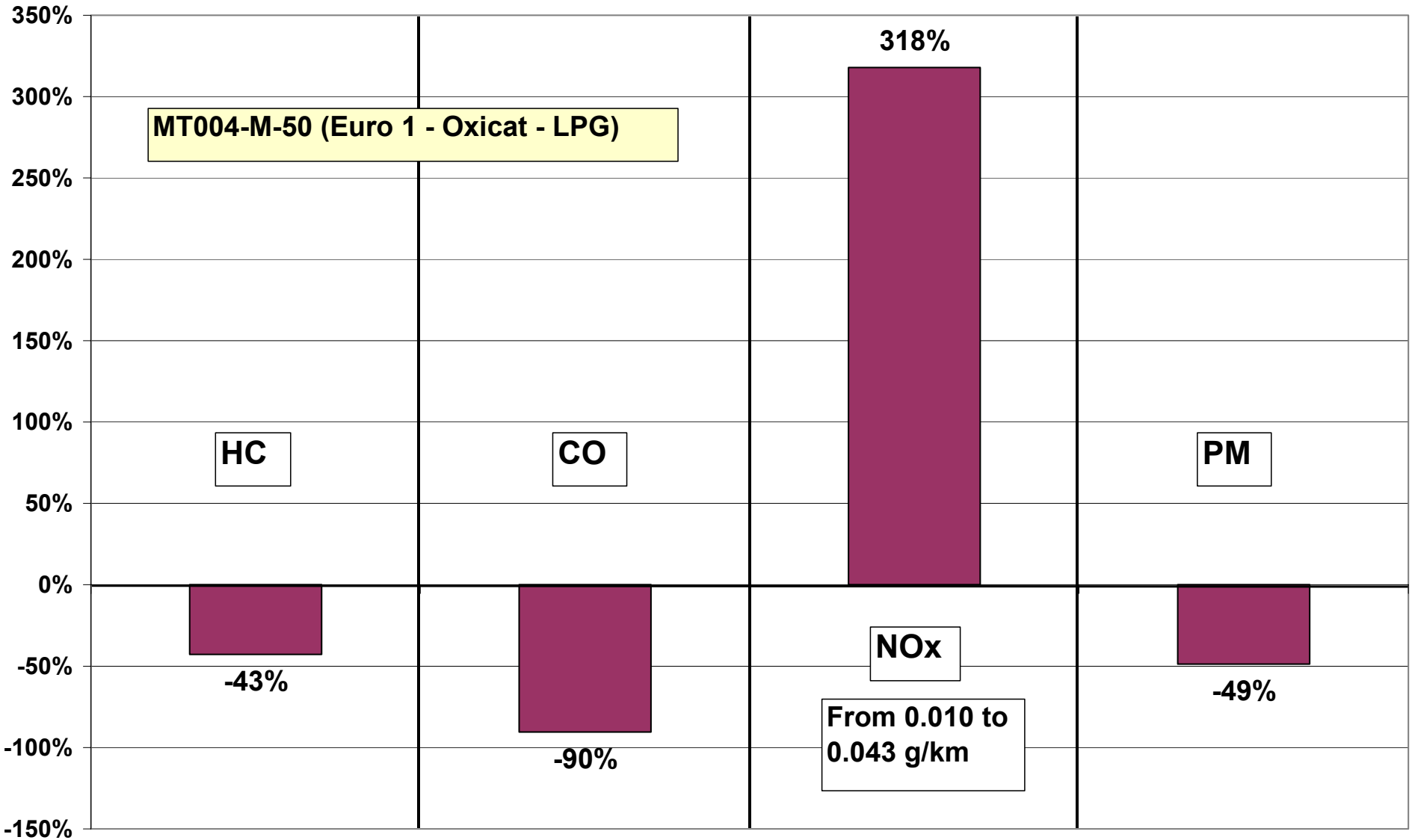


Effect Of Lubricating Oil on Particulate Emissions
Number/Size Distribution - Constant Speed: 40 km/h

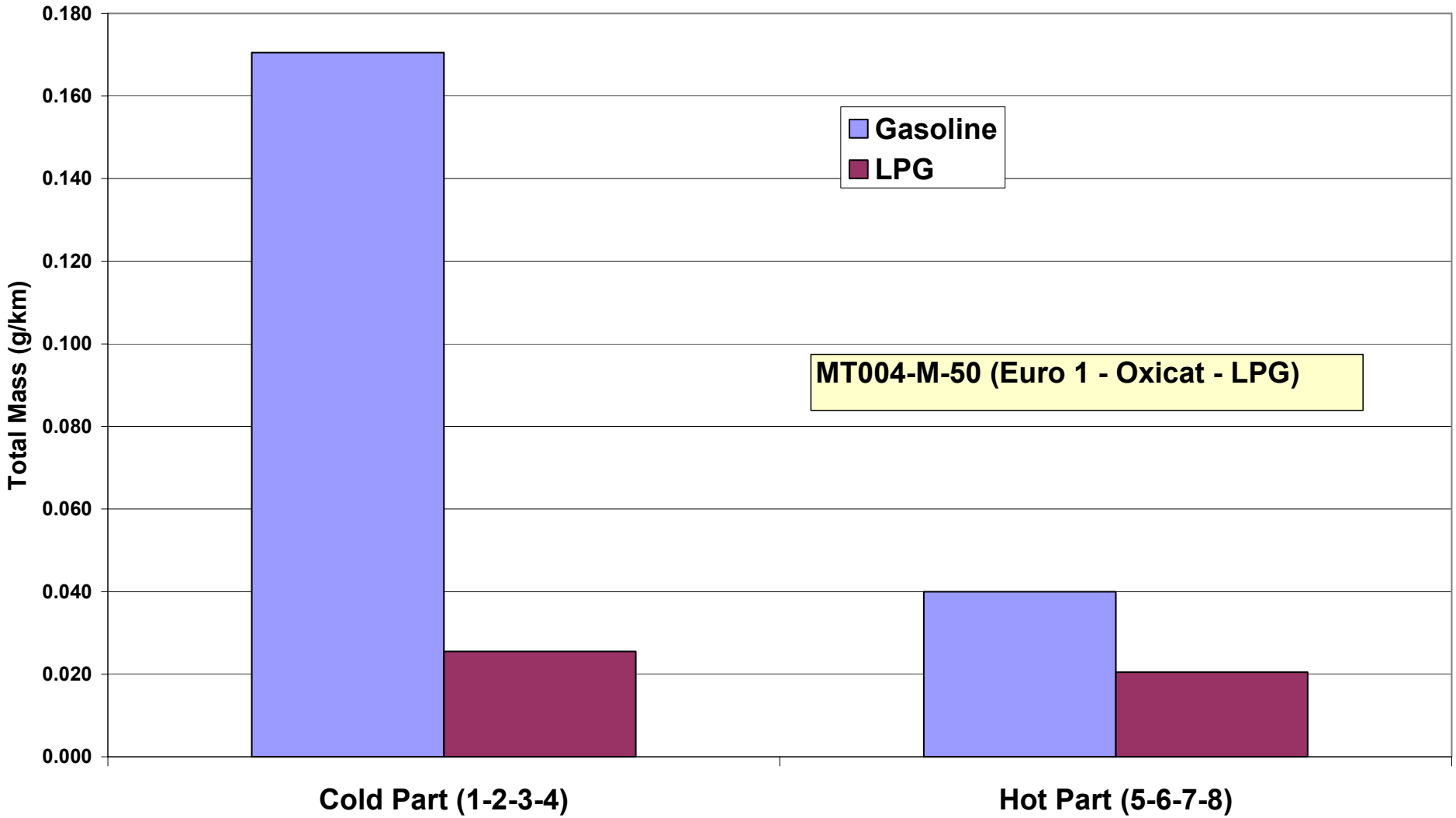


Effect of Conversion to LPG on Emissions of Moped

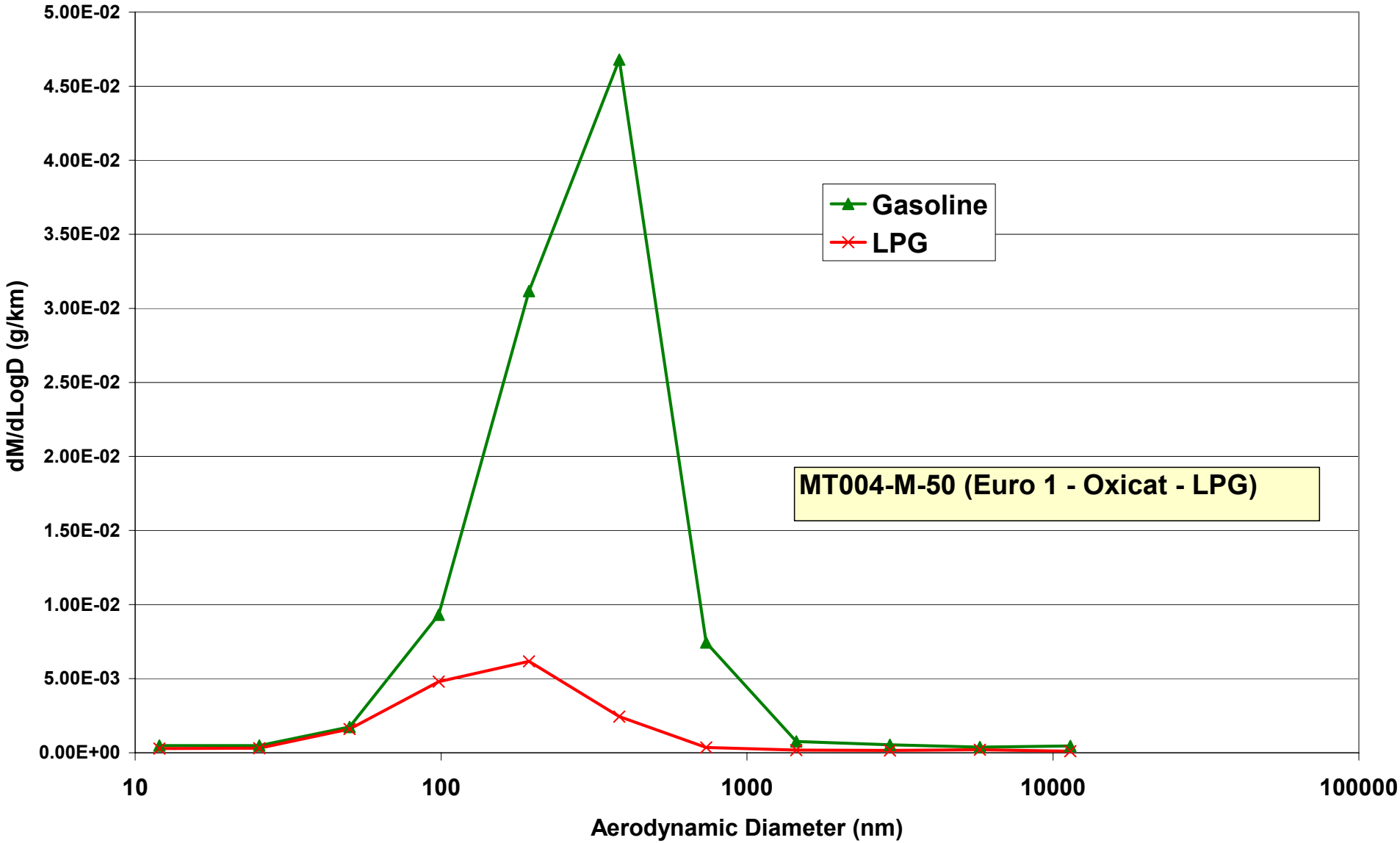
Effect of LPG on Emissions
ECE 47 Cycle (Hot Part) - Percentage Variations



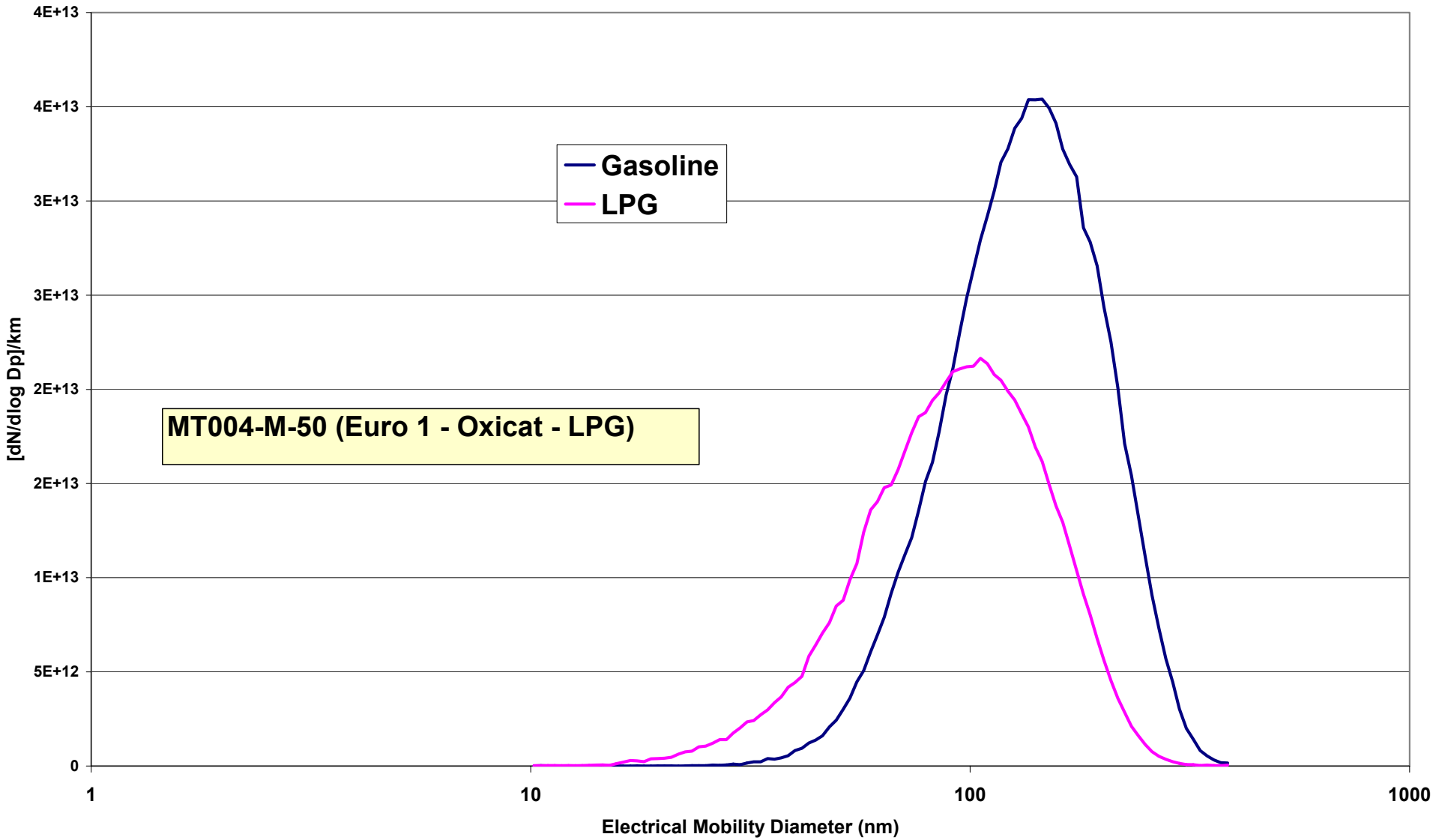
Effect of LPG on Emissions
ECE 47 Cycle - Particulate Emissions



Effect of LPG on Particulate Emissions
ECE 47 Cycle (Whole Cycle) - Mass/Size Distribution (LPI 11 stages)



Effect Of LPG on Particulate Emissions
Number/Size Distribution - Constant Speed: 40 km/h



Conclusions:

- The engine technology has a huge effect on particulate emissions from mopeds
- The Euro 1 mopeds tested at the JRC showed particulate emission values (g/km) close to those of Euro 3 diesel vehicles
- The lubricant quality has a significant impact on particulate mass, particle number and size
- The effect of lubricant quality depends on the engine technology
- The moped equipped with the direct injection engine exhibited a different behaviour compared to conventional two stroke engines
- The LPG conversion kit tested proved to be an effective way to reduce particulate emissions from mopeds