HEAVY DUTY VEHICLE IN-USE EMISSION PERFORMANCE

Nils-Olof Nylund
Markku Ikonen
Juhani Laurikko

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OUTLINE

- Background
  - HD engine emission legislation
- Why complete vehicle (chassis dynamometer) testing?
- New heavy-duty emission laboratory at VTT
- Ongoing transit bus emission evaluation
  - Methodology
  - Preliminary results
  - Conclusions

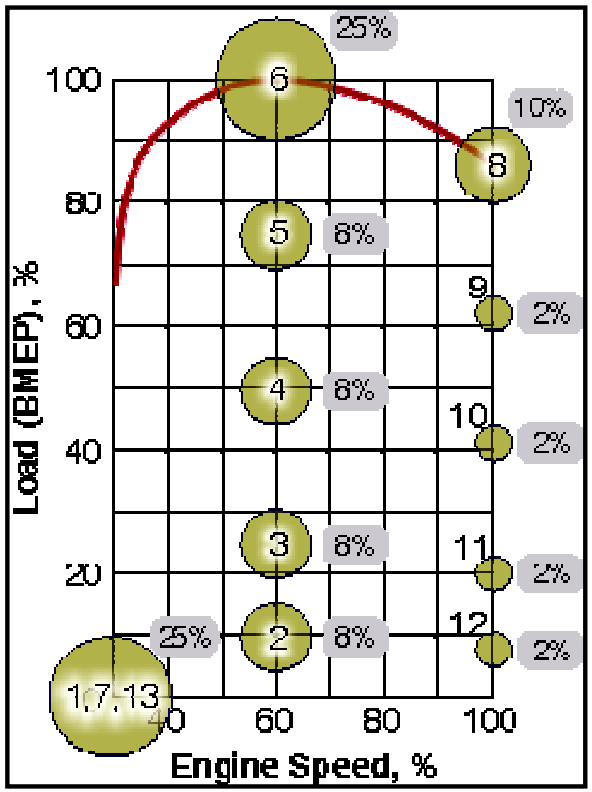
BACKGROUND

- HD engine emission certification is based on engine testing
  - Engines are run in dynamometers using specified load patterns
- In the US: HD Transient cycle used for several years
- In Europe: steady-state testing (ECE-R49, ESC) is supplemented by transient testing (ETC, directive 1999/96/EC)
- Transient testing represents real-world conditions better
- However, engine testing does not take the whole vehicle into account

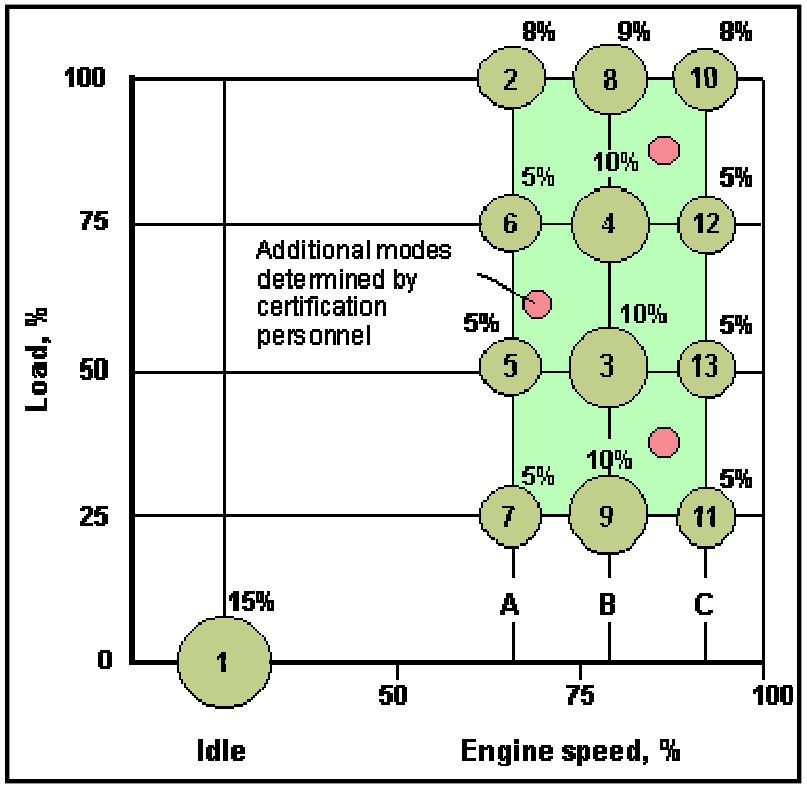
BACKGROUND, EUROPEAN HD LEGISLATION

- European HD emission legislation
  - ECE-R49 replaced by ESC in 2000

ECE-R49



ESC



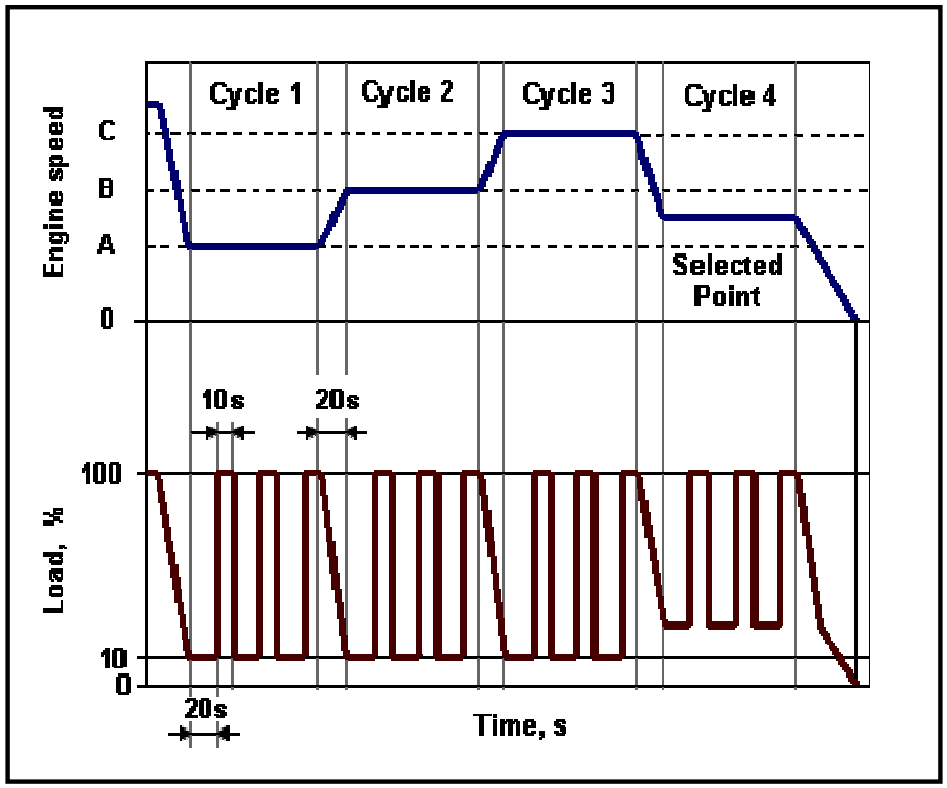
Numbers in circles indicate measuring order

Size of circles indicate weighting factors

BACKGROUND, EUROPEAN HD LEGISLATION

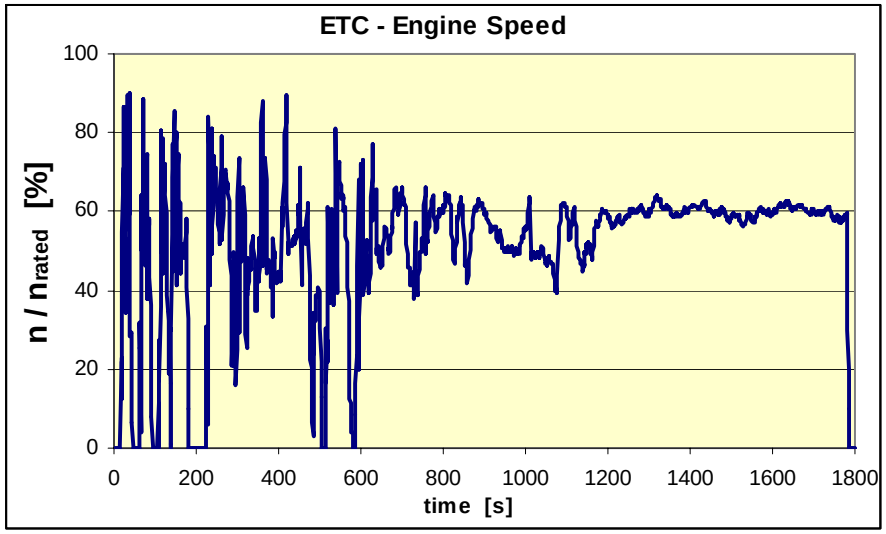
- European HD emission legislation
  - Starting 2000, ESC supplemented by ELR and ETC

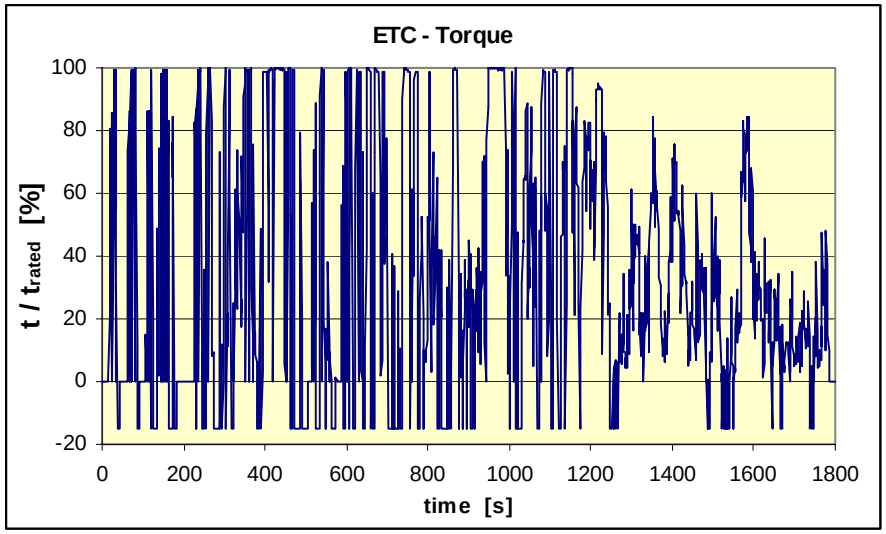
ELR



Opacity test, constant engine speeds, load is increased rapidly

BACKGROUND, EUROPEAN HD LEGISLATION





2000: Diesel engines:

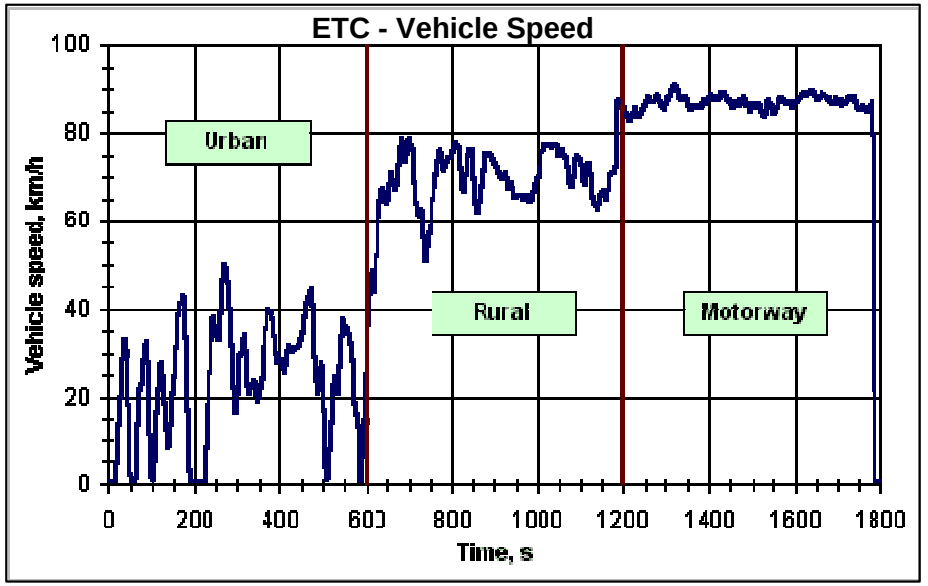
ETC is required in addition to ESC and ELR, if advanced (=NO_X and/or PM) emission aftertreatment is utilized

Gas engines:

ETC only

2005: Diesel engines: ETC required for all

Gas engines: ETC only



WHY COMPLETE VEHICLE TESTING ?

- Engine testing does not account the properties of the vehicle
  - Vehicle weight and loading
  - Driving resistance at different speeds and road conditions
  - Transmission properties etc.
- Evaluation of in-use vehicle emissions presents a problem
  - Dismounting engines from in-use vehicles for testing is costly
- Do the standardized engine test cycles represent real-life driving?
  - Complete vehicle testing easily enables comparison of different driving patterns

NEW HEAVY-DUTY EMISSION LABORATORY AT VTT

- New Heavy-Duty laboratory was commissioned in 2002
  - Road-simulation chassis dynamometer for complete vehicle testing
    - In-use vehicle emission performance
    - Evaluation of different real-life driving cycles
    - Emission deterioration evaluation along with vehicle aging
  - Transient type engine dynamometer with fast response
    - ETC testing
    - High performance engine testing
  - Full-flow CVS system
    - Secondary tunnel
    - Particle collector
  - Exhaust emission analyzer set for regulated emissions
- The expertize and wide variety of instrumentation for unregulated emission measurements, gained with LD vehicles, can now be harnessed for HD vehicles

NEW HEAVY-DUTY EMISSION LABORATORY AT VTT

- Road-simulation chassis dynamometer
  - Manufacturer Froude Consine Ltd, UK
  - Roller diameter 2.5 m
  - Inertia simulation 2 500 - 30 000 kg
  - Max axle weight 20 000 kg
  - Max wheelforce ±20 000 N (speed range 0 - 54 km/h)
  - Max power absorption 300 kW (speed range 54 - 110 km/h)
  - Fast and precise IGBT control for good transient load response
  - Driver's Aid with programmable driving cycles

NEW HEAVY-DUTY EMISSION LABORATORY AT VTT

- Transient type engine dynamometer
  - Manufacturer Froude Consine Ltd, UK
  - Model Froude AC 570 F
  - Max power 570 kW (1700 - 4000 rpm)
  - Max torque 3200 Nm (150 - 1700 Nm)
  - Installed on air-cushioned floating pedestal
  - Fast and precise IGBT control for good transient load response

NEW HEAVY-DUTY EMISSION LABORATORY AT VTT

- Full-flow CVS system Pierburg CVS-120-WT
  - Pierburg CVS-120-WT
  - Multiple (3) CFV-venturi system
  - Maximum flow 120m^3/min
  - Tunnel dimensions 8000 * 450 mm
  - Secondary tunnel VT-458
  - Particle collector PS2000 C
- Gas analyser set Pierburg AMA 4000
  - HFID THC 0 - 1000 ppm
  - HFID CH_4 0 - 3000 ppm
  - HCLD NO_X 0 - 10000 ppm
  - NDIR CO_2 0- 20 %
  - NDIR CO 0- 2500 ppm
  - NDIR CO_2tracer 0 - 20 %
  - Shared use for both dynos

NEW HEAVY-DUTY EMISSION LABORATORY AT VTT

- The emission and fuel economy measurements for HD engines and vehicles are accredited in accordance with EN ISO/IEC 17025

FINAS AKKREDITOINTI
SUOMI FINLAND

T125 (EN ISO/IEC 17025)

TRANSIT BUS EMISSION EVALUATION

- National transit bus emission evaluation is underway
  - Scheduled for 2002 - 2004
  - Emission factors will be generated for about 50 in-use vehicles
  - Vehicles represent different age groups, fuels and technologies
    - From Euro 1 to Euro 5 / EEV (Environmentally Enhanced Vehicle)
    - Both diesel and natural gas are included
    - Diesel buses with and without exhaust aftertreatment
    - Natural gas buses with aftertreatment, both lean-burn and stoichiometric
  - Regulated emissions (CO, THC, NO_X, PM) for all vehicles
- Additionally, on IANGV's assignment, comprehensive emission analyses for a few newest technology natural gas and diesel buses
  - Particulate size distribution
  - Chemical and biological characterization of particulates
  - Hydrocarbon speciation
  - Aldehydes
  - Semivolatile hydrocarbons
  - Anions (sulfates and nitrates)

TRANSIT BUS EMISSION EVALUATION

- Selection of buses:

Basic Vehicles	"Speciality Vehicles"	Newest CNG technology
- Euro 1, Euro 2, Euro 3 - Volvo, Scania, Mercedes	- CRT - Oxycat - Old (1996 -1998) CNG technology	- Volvo lean-burn - M-B EEV lean-burn - Iveco stoichiometric - MAN stoichiometric

- Diesel references for the newest CNG technology buses:
  - Euro 3 Scania:
    - without aftertreatment
    - with oxycat
    - with CRT

TRANSIT BUS EMISSION EVALUATION

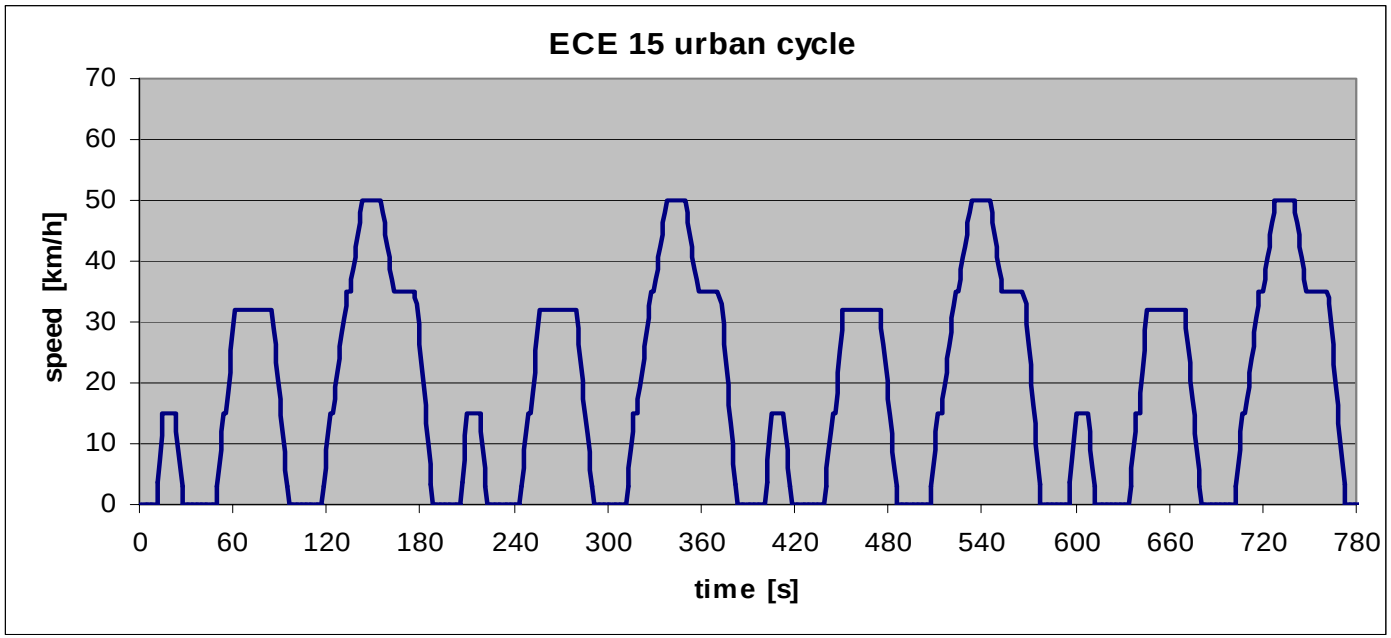
- Bus selection criteria, for the general part:
  - Most common bus types (cover most of the kilometers)
  - At least one representative from all “speciality” types
  - Several units of same bus type to evaluate consistency and stability
  - A few buses repeatedly every year to evaluate ageing/deterioration
- Bus selection criteria, for the IANGV part:
  - Several newest technology NG buses, both lean-burn and stoichiometric
  - Relevant new diesel counterparts for reference

TRANSIT BUS EMISSION EVALUATION, METHODOLOGY

- Driving cycles
  - ECE15 urban cycle for passenger cars (European)
  - Braunschweig bus cycle (European)
  - Orange County bus cycle (US, SAE J2711)
- Vehicle loading
  - Tests with half-loaded vehicles, some checkpoints unloaded
- Test fuels
  - Natural gas of high methane content (98 %), sulphur free (no odorant)
  - Low-sulphur (about 30 ppm) commercial diesel

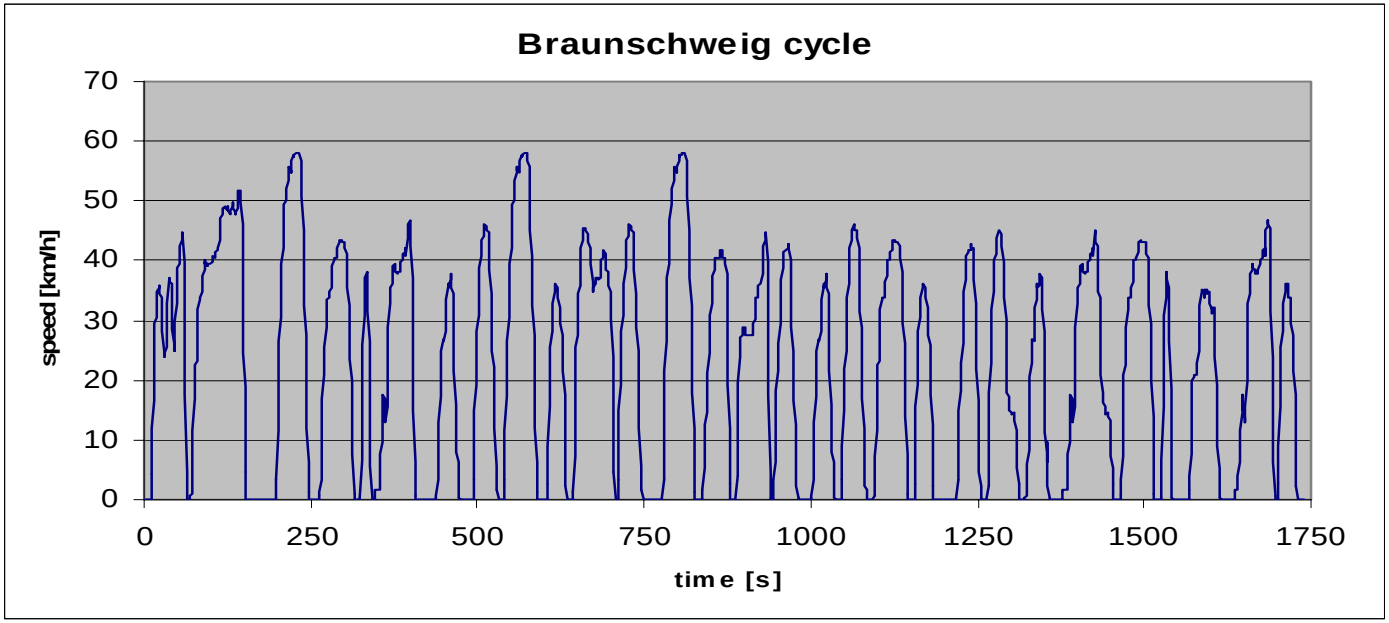
TRANSIT BUS EMISSION EVALUATION, METHODOLOGY

- ECE15 urban cycle
  - duration 780 s
  - length 4.052 km
  - average speed 18.7 km/h
  - max speed 50 km/h
  - share of idle 31 %



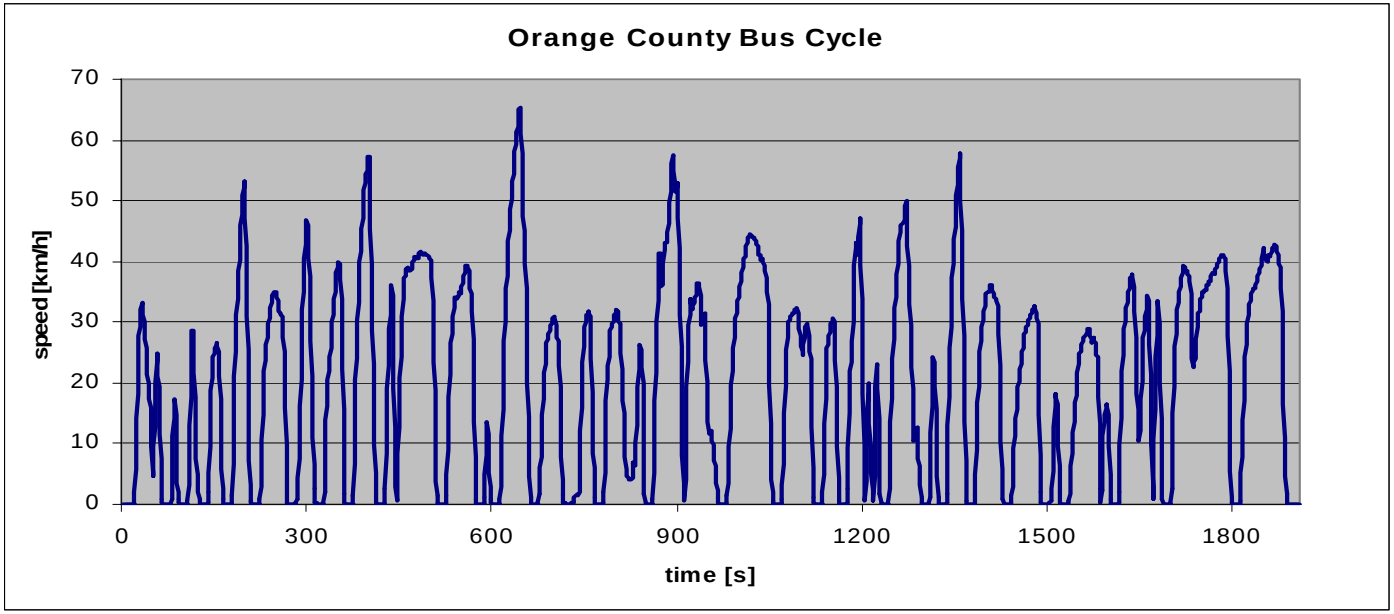
TRANSIT BUS EMISSION EVALUATION, METHODOLOGY

- Braunschweig urban bus cycle
  - duration 1740 s
  - length 10.873 km
  - average speed 22.5 km/h
  - max speed 58.2 km/h
    share of idle 25 %



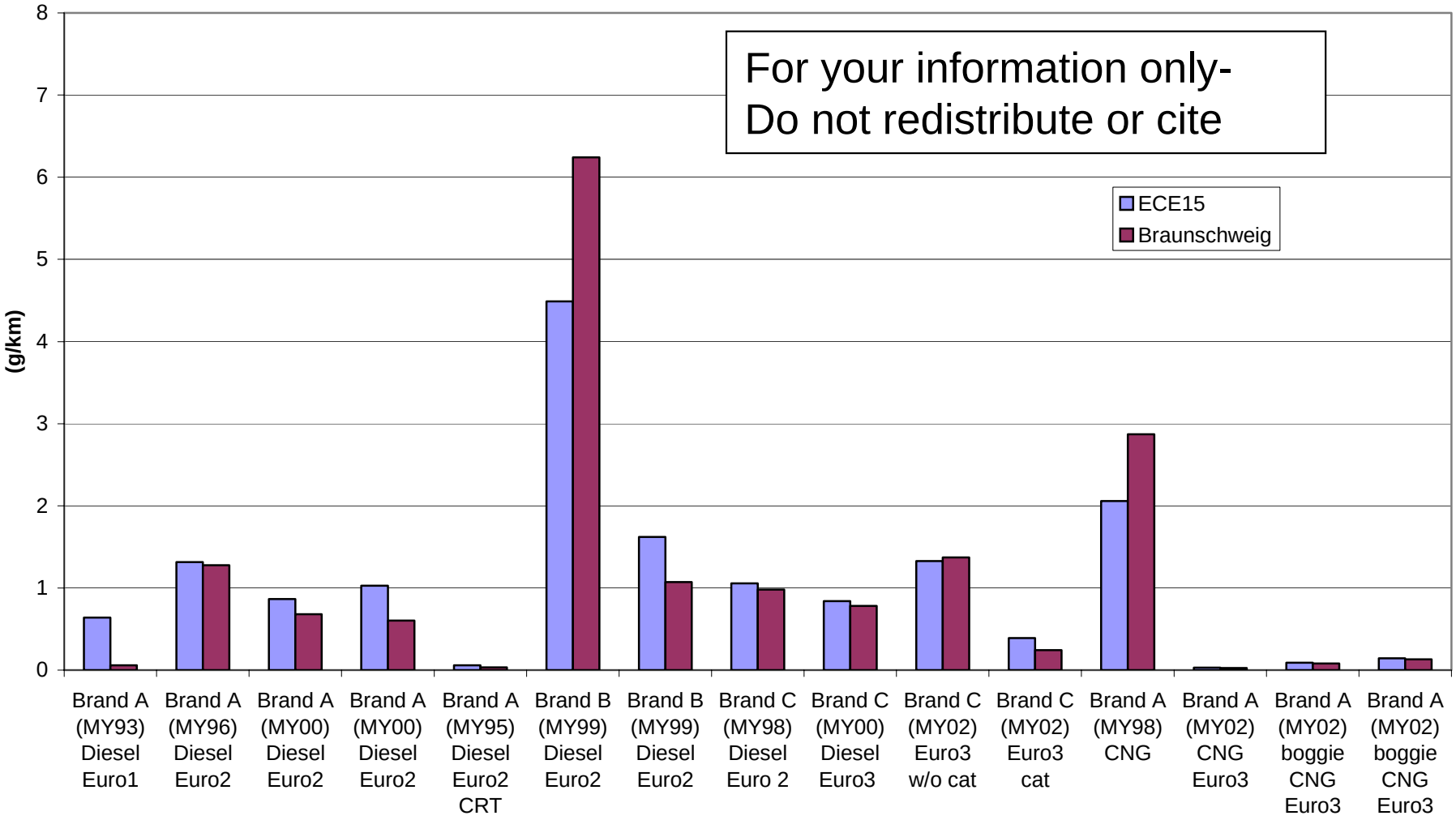
TRANSIT BUS EMISSION EVALUATION, METHODOLOGY

- Orange County bus cycle
  - duration 1909 s
  - length 10.526 km
  - average speed 19.9 km/h
  - max speed 65.4 km/h
  - share of idle 21 %



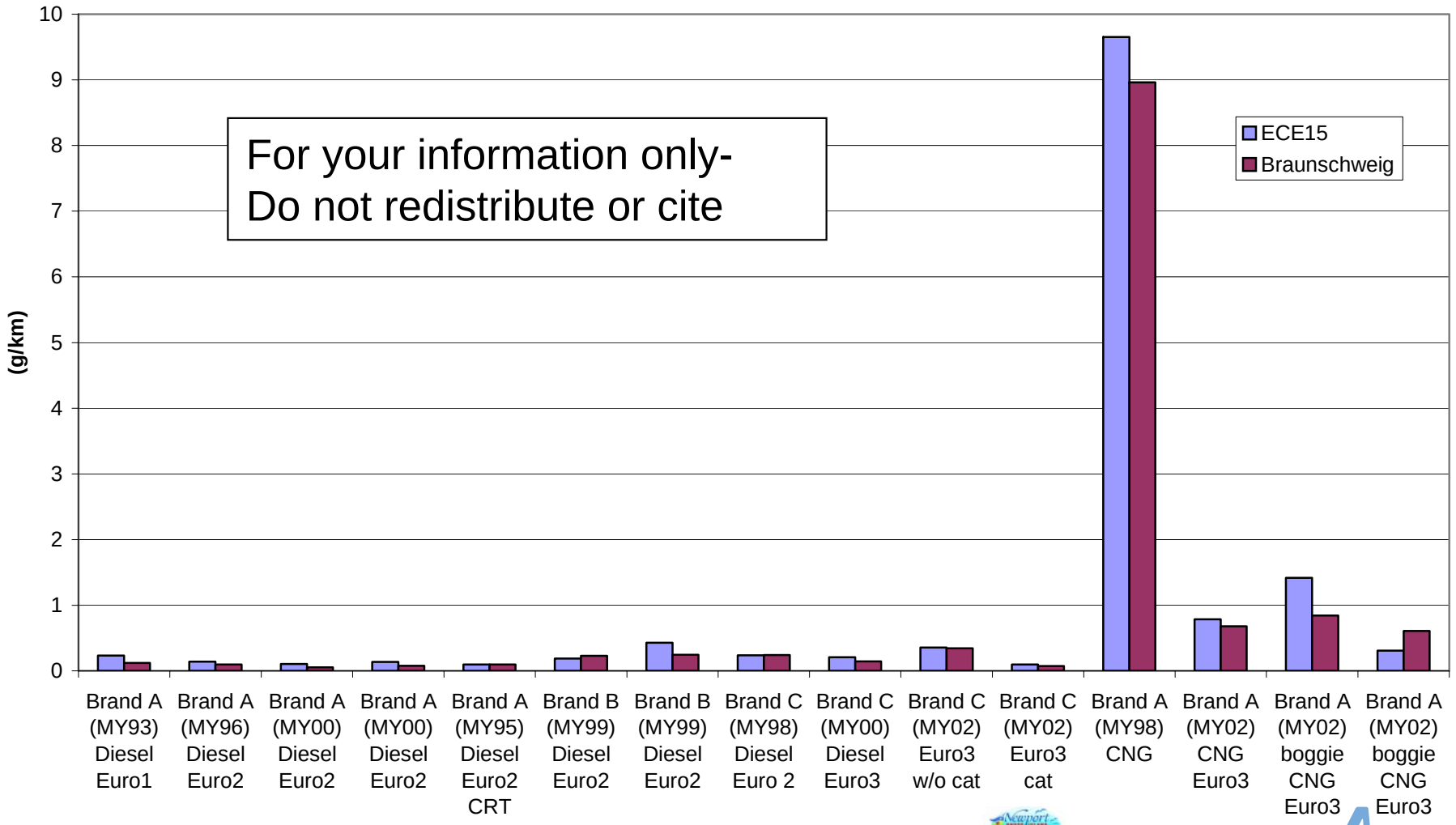
TRANSIT BUS EMISSION EVALUATION, PRELIMINARY RESULTS

CO EMISSIONS



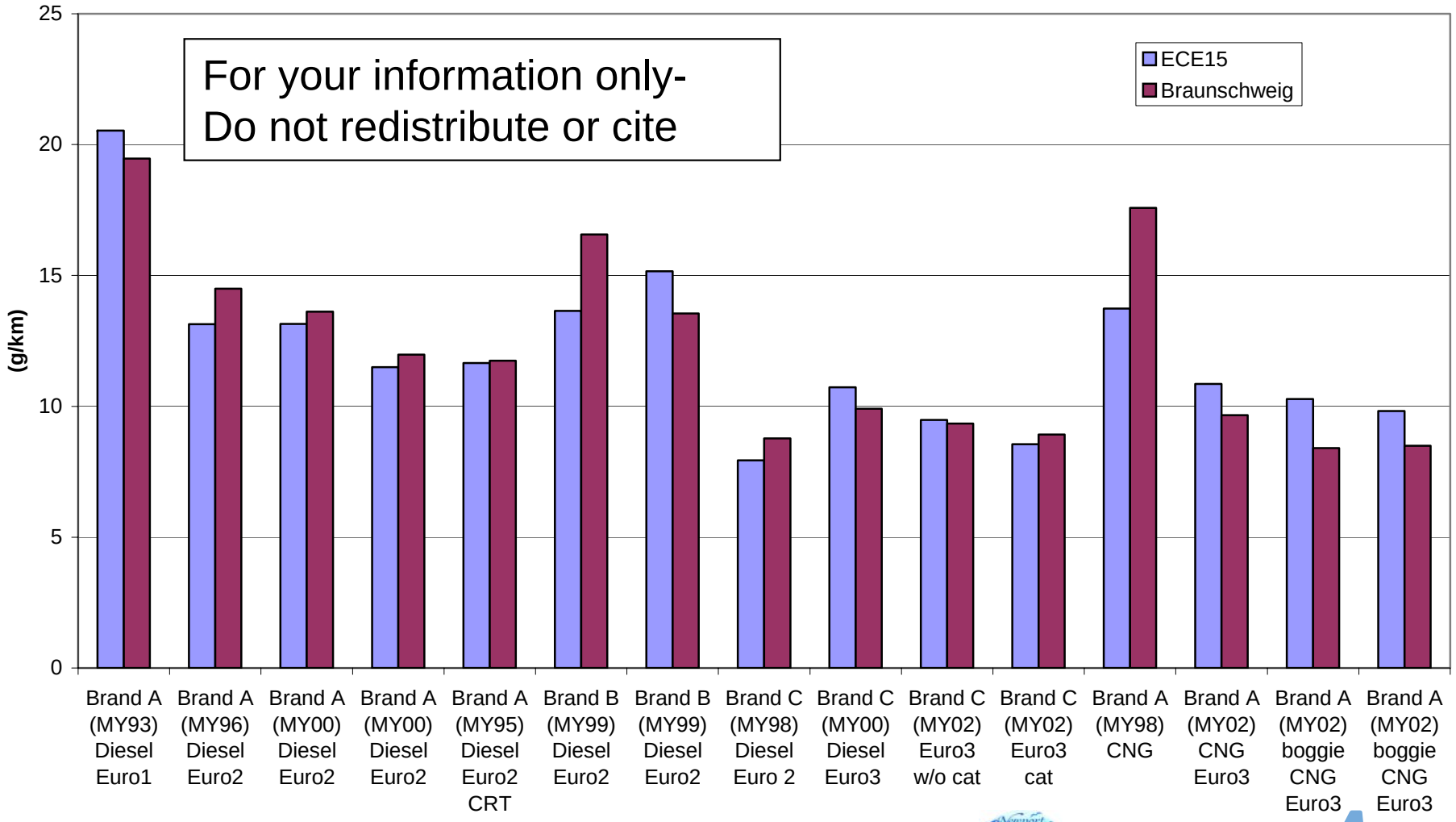
TRANSIT BUS EMISSION EVALUATION, PRELIMINARY RESULTS

THC EMISSIONS



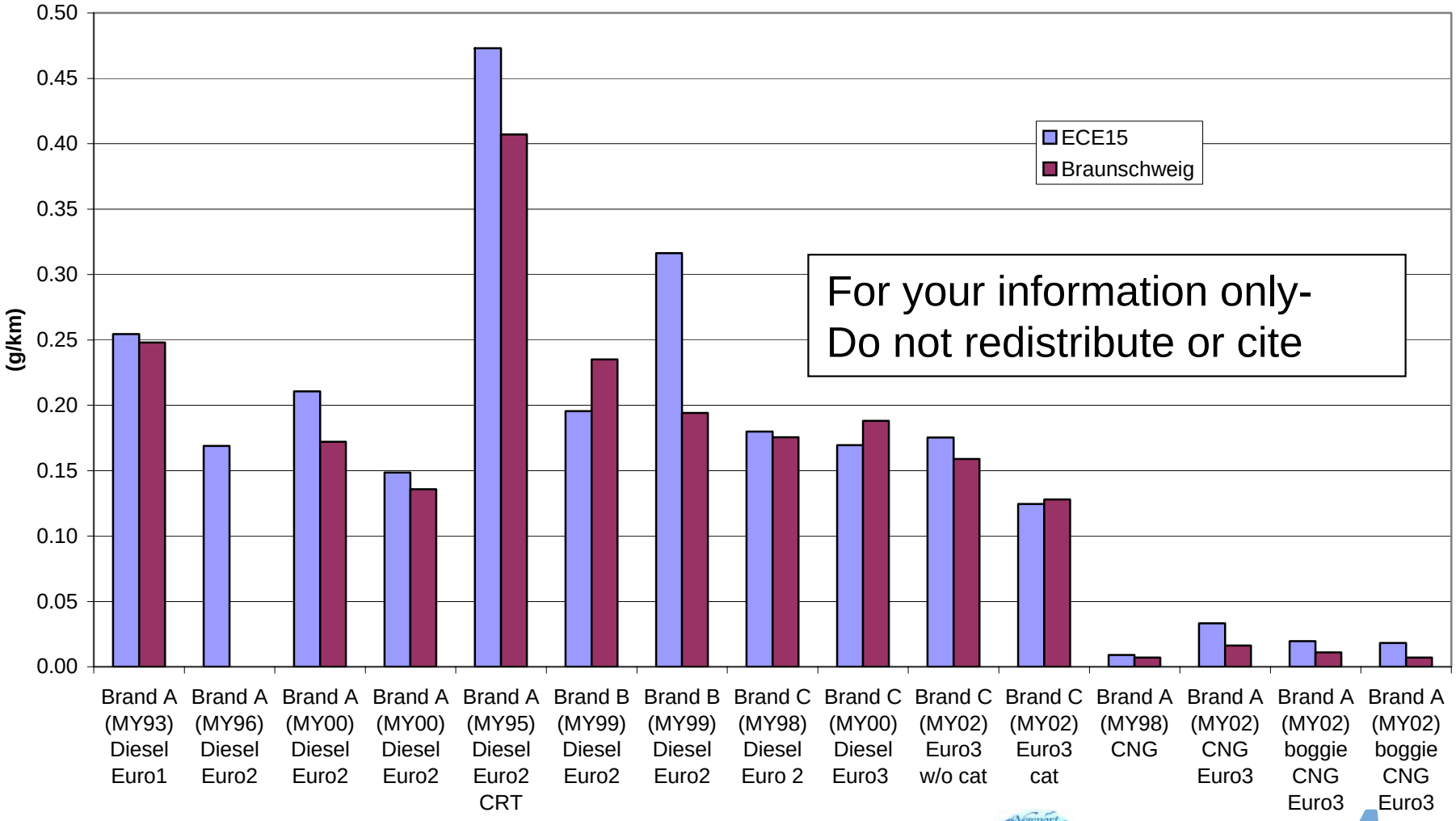
TRANSIT BUS EMISSION EVALUATION, PRELIMINARY RESULTS

NO_X EMISSIONS



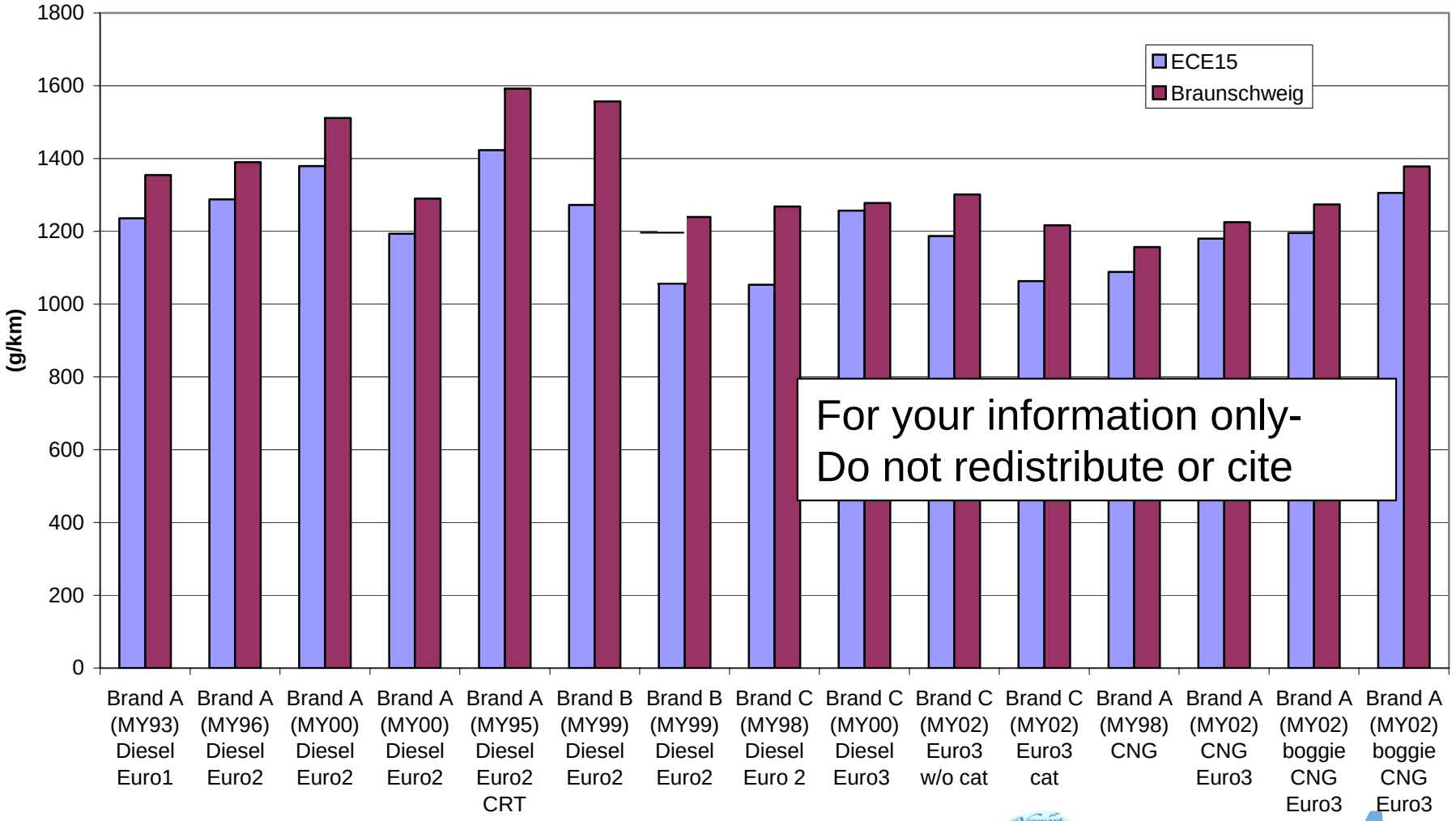
TRANSIT BUS EMISSION EVALUATION, PRELIMINARY RESULTS

PM EMISSIONS



TRANSIT BUS EMISSION EVALUATION, PRELIMINARY RESULTS

CO_2 EMISSIONS



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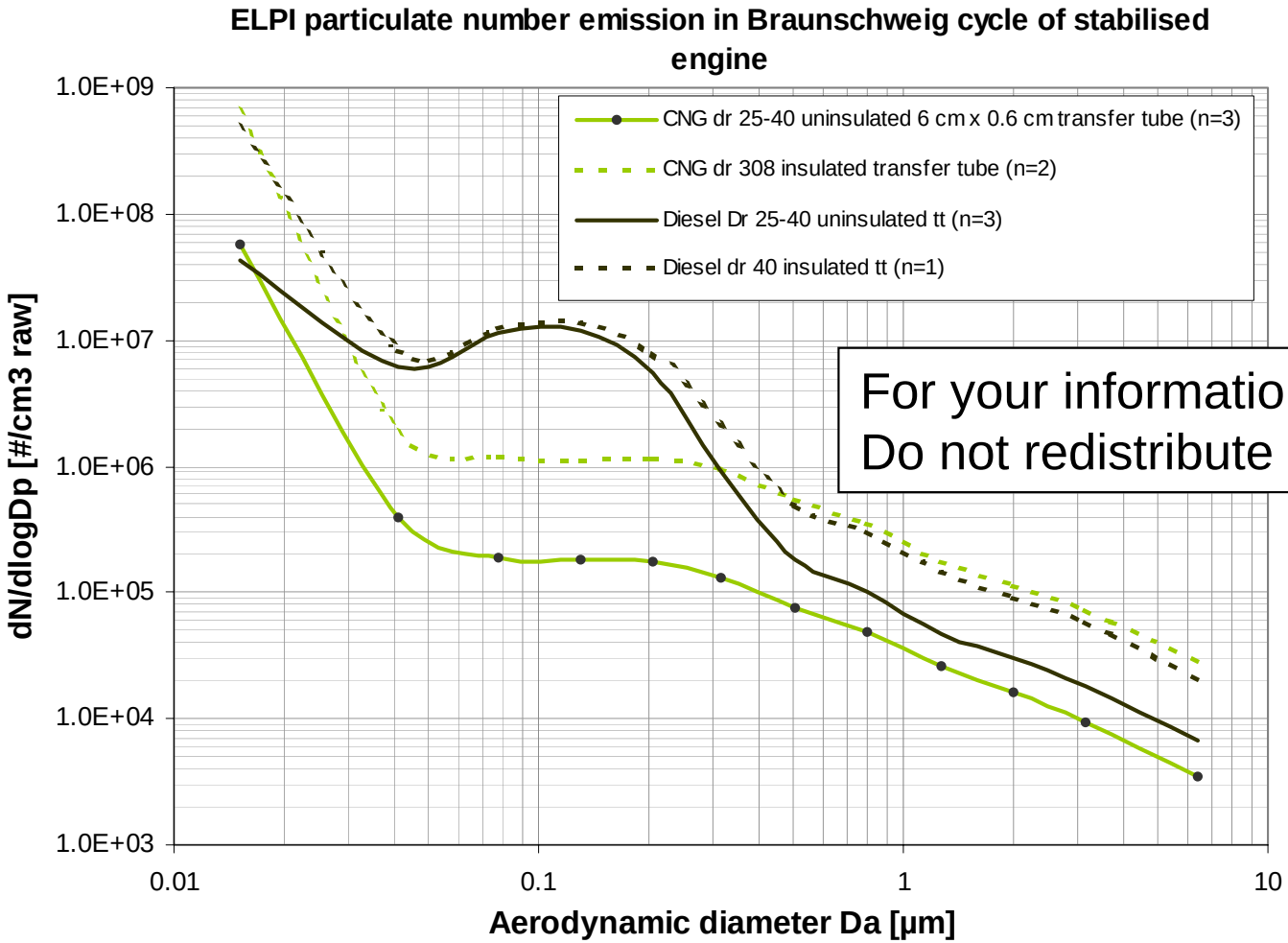
TRANSIT BUS EMISSION EVALUATION, PRELIMINARY RESULTS

Particulates, ELPI (Electrical Low Pressure Impactor) instument

Euro 3 Diesel w/o cat vs. lean-burn NG w. cat



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TRANSIT BUS EMISSION EVALUATION, CONCLUSIONS

- Driving cycle (smooth ECE15 or harsh Braunschweig) has surprisingly small effect on emissions
  - Some vehicles emit less in ECE15, others in Braunschweig
- THC emissions of old (1998) CNG bus were high - ineffective catalyst, NMHC was not measured
- NO_X results seemed to decrease along with newer Euro standards
- CRT bus emitted high PM, poorly maintained CRT? (needs further investigation)
- PM emissions of natural gas buses low, ECE15 results might be too high due to diesel soot carryover in dilution tunnel
- No significant difference in CO_2 between Euro 3 diesel and Euro 3 natural gas buses
- CO_2 was higher in Braunshweig cycle in all buses tested
- Natural gas emitted significantly less around 0.1µm particulates