Insights into air quality from large-scale tailpipe emissions measurement of passenger cars

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Agenda

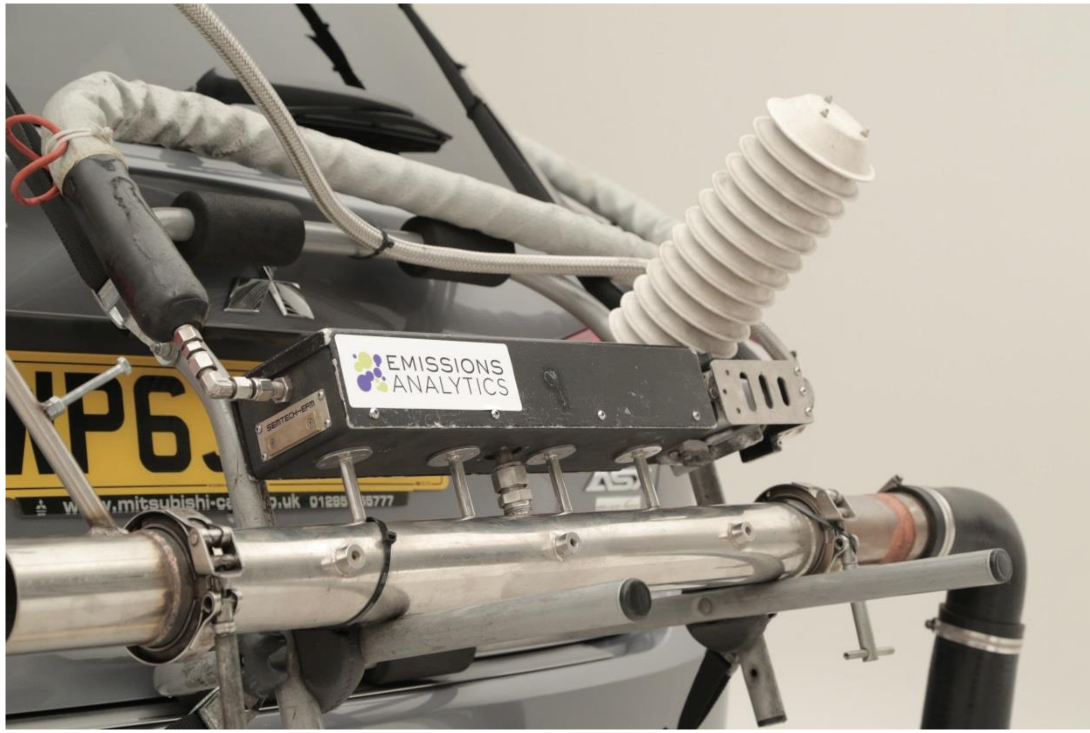
- Background and credentials
- Intensive PEMS testing in practice
- Performance tracking database
- Insights on NO_x
- Fuel economy context
- Comparison to Real Driving Emissions legislation
- Future trends and issues

Emissions Analytics' credentials

- Founded in 2011
- Headquartered in Winchester, with operations in London and Los Angeles
- 10 employees, currently expanding in EU
- Specialist in PEMS testing and data analysis
- Almost 1000 vehicles tested
- RDE-compatible testing conducted since 2011
- Expert in cycle design and testing strategies to meet multiple and complex objectives
- Works with OEMs, Tier 1 suppliers, fuel and chemical companies, regulators, consultancies, consumer media

Benefits of PEMS

- Real on-road testing using PEMS is a powerful research method
- Authentic and cost effective
- Works on all vehicle types
- No permanent vehicle modification required
- Flexible location
- High rate of data acquisition – 1 Hertz
- Precision approaching laboratory levels



Equipment (1)

EMISSIONS ANALYTICS

- SEMTECH-DS and Ecostar-FEM
- Portable Emissions Measurement System connects to tailpipe
  - Captures emissions for CO_2, CO, NO, NO_2, total hydrocarbons
  - At 1 Hertz
- Air temperature, pressure, humidity
- GPS for speed and altitude
- Engine data via CANBUS
- Fuel economy derived via carbon balance
- Ecostar weighs approximately 50kg including auxiliary batteries

Equipment (2)

- Pegasor Mi2
- Real-time tailpipe concentrations
- No filter papers
- Particle mass and number
- Sub-23nm particles

- Flexible, economic, real-world data collection
- Challenges around calibration and repeatability

EMISSIONS ANALYTICS

INTENSIVE PEMS TESTING

Objectives

- On-going, real-time performance monitoring programme
- Air quality, greenhouse gases, fuel economy
- Independent
- Authentic: production vehicles, public highway
- Create feedback loop into better engineering, regulation and purchase decisions
- To ensure beneficial outcomes are achieved

Activity

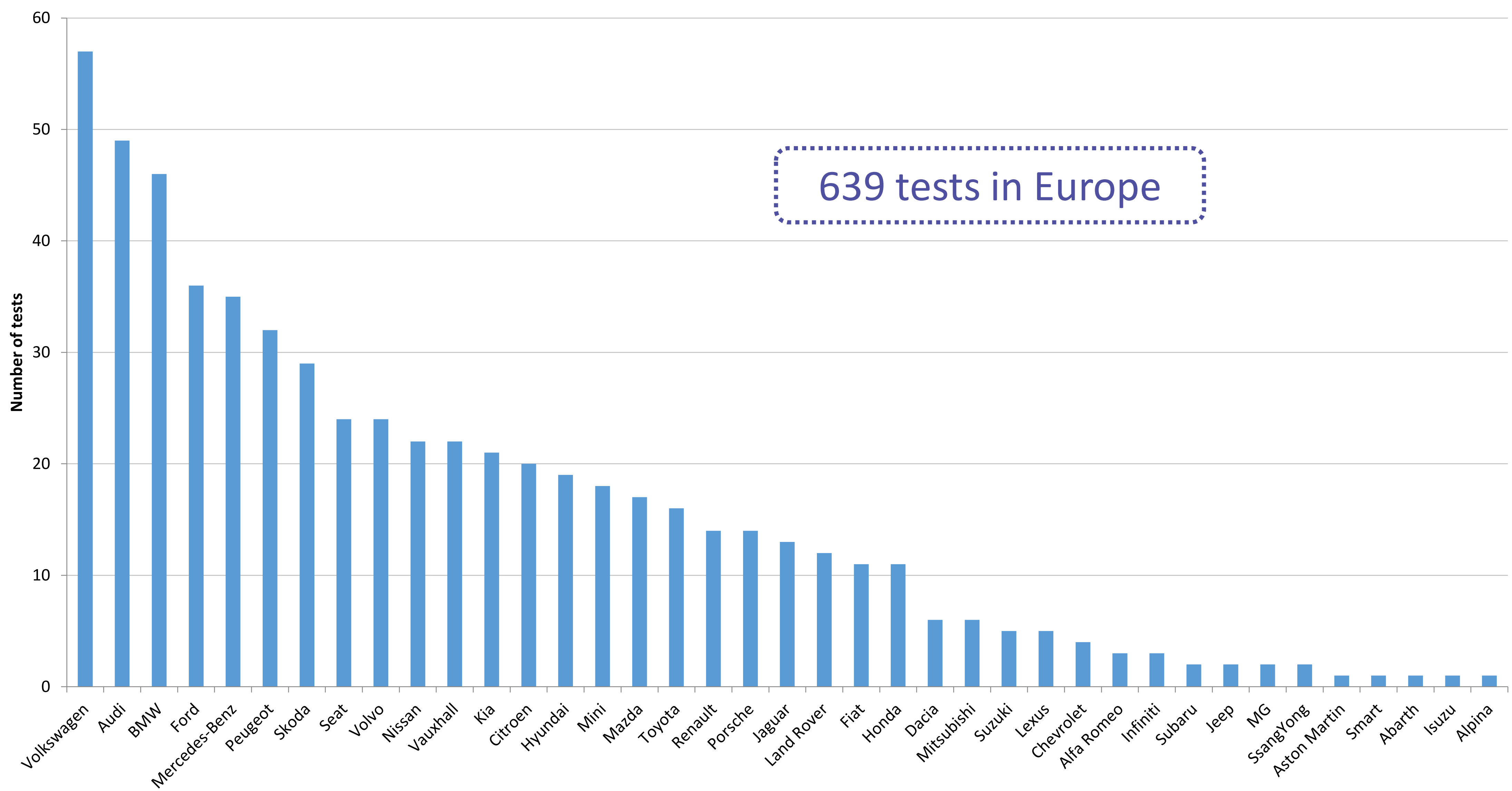
- 200-250 passenger cars tested per year in EU
  - Similar in US
- Testing primarily in London, but flexible location
- New, commercially available vehicles
- Typically 2,000km+ on odometer
- Fixed weight addition
- Proprietary route based on typical driving
- 2.5-3 hour test

- New programme for light commercial underway

EMISSIONS ANALYTICS

PERFORMANCE TRACKING DATABASE

By manufacturer



Engine, powertrain, Euro stage

Model Year	Diesel	Petrol	Total
2011	17	13	**30**
2012	105	71	**176**
2013	103	73	**176**
2014	113	84	**197**
2015	39	21	**60**
Total	**377**	**262**	**639**

Engine size (litres)	Diesel	Petrol	Total
0-1	0	8	**8**
1-2	136	172	**308**
2-3	189	50	**239**
3-4	46	20	**66**
4-5	4	9	**13**
5+	0	5	**5**
Total	**375**	**264**	**639**

Euro Stage	Diesel	Petrol	Total
Euro 5	311	217	**528**
Euro 6	66	45	**111**
Total	**377**	**262**	**639**

Real-time benchmarking

EMISSIONS ANALYTICS

Home / AQ Ranking / Segments

All Tests | Euro 5 Only | Euro 6 Only

Mini Car (A) | Small Car (B) | Medium Car (C)
Large Car (D) | Executive Car (E) | Luxury Car (F)
Sport Utility/Off-road Vehicle (J) | Multi-purpose Car (M) | Sports Coupe (S)

All Segments

NO_x | Official NO_x | Exceedance Factor | Urban fNO_2 | Rural fNO_2 | Motorway fNO_2 | Combined fNO_2 | Cold Start Uplift | DPF Regen Uplift

Gasoline

#	Manufacturer	NO_x	MoM	YoY
1	Honda*	0.003	1 –	1 –
2=	Mitsubishi*	0.009	2 –	2 –
2=	Nissan*	0.009	2 –	7 ▲
4	Volvo*	0.011	4 –	
5	Mazda	0.012	5 –	5 –
6	Peugeot	0.020	7 ▲	6 –
7	Volkswagen	0.021	8 ▲	8 ▲

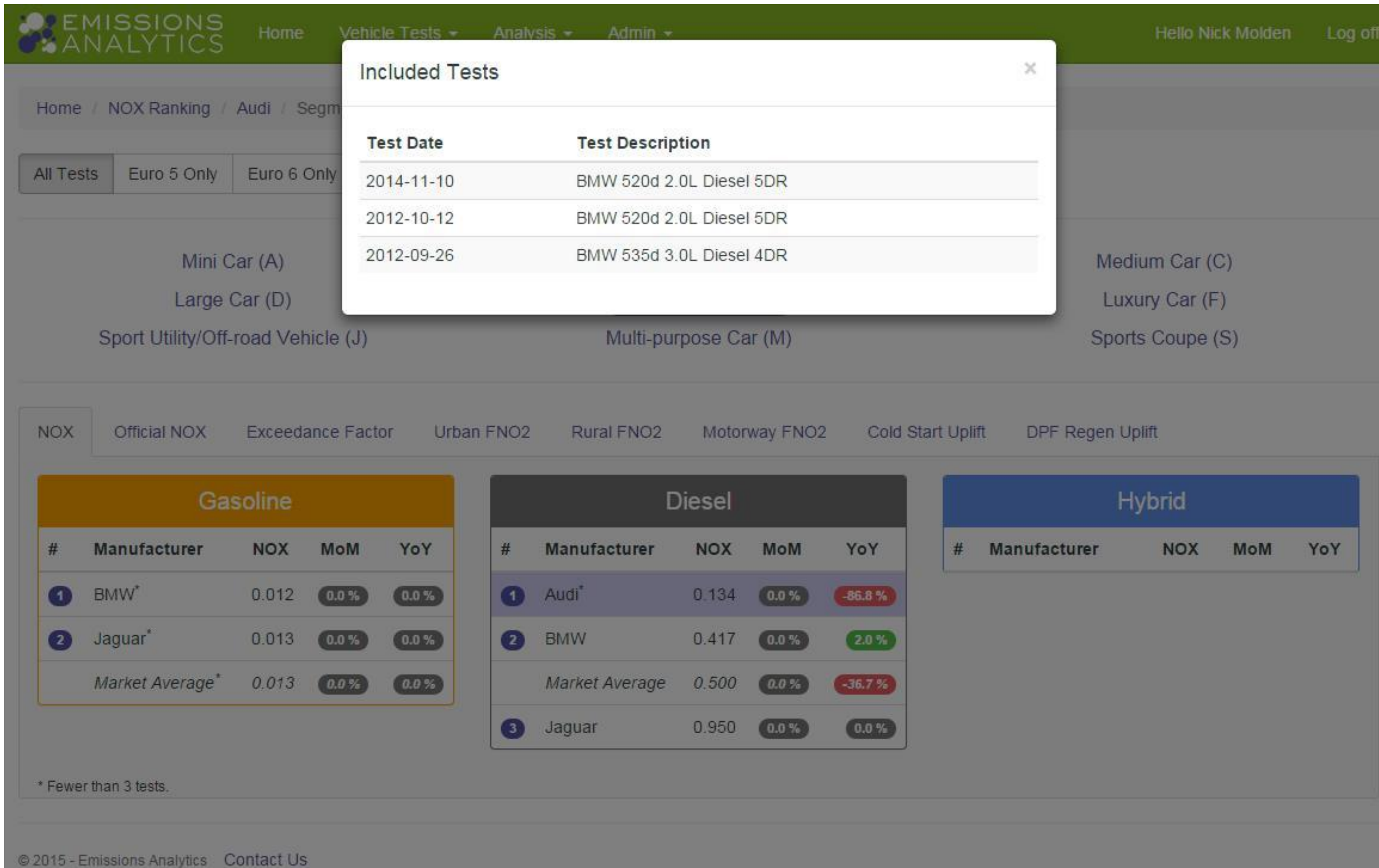
Diesel

#	Manufacturer	NO_x	MoM	YoY
1	Mitsubishi*	0.274	1 –	1 –
2	Mazda	0.293	2 –	2 –
3	Mercedes-Benz	0.406	3 –	15 ▲
4	Audi	0.422	4 –	10 ▲
5	Volkswagen	0.458	6 ▲	16 ▲
6	Honda	0.484	5 ▼	3 ▼
7	Citroen	0.503	7 –	4 ▼

Hybrid

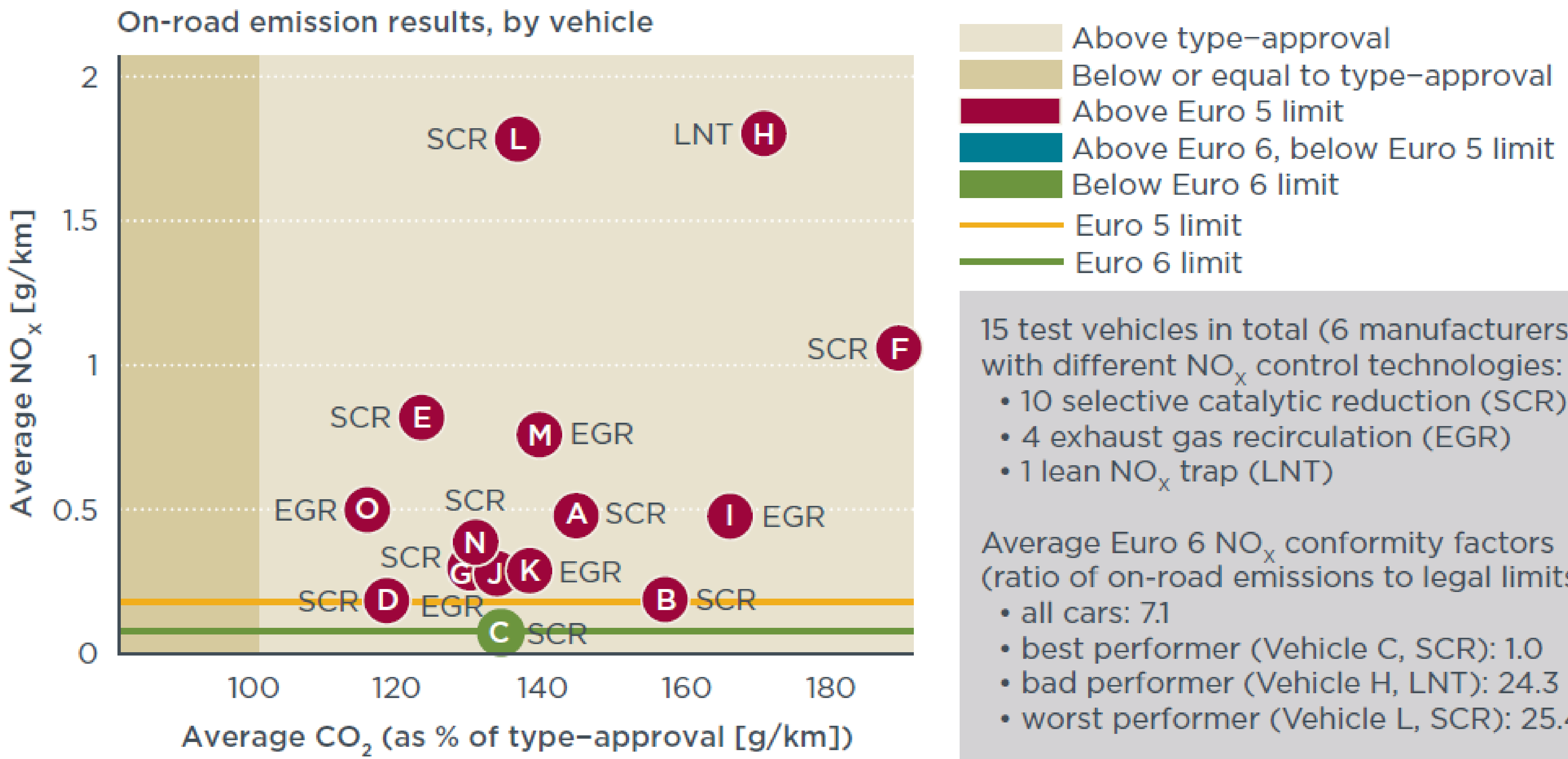
#	Manufacturer	NO_x	MoM	YoY
1	Toyota*	0.005	1 –	1 –
	Market Average	*0.050*		
2	Mercedes-Benz*	0.094	2 –	

Drill-down to individual datasets



INSIGHTS ON NO_x

ICCT report

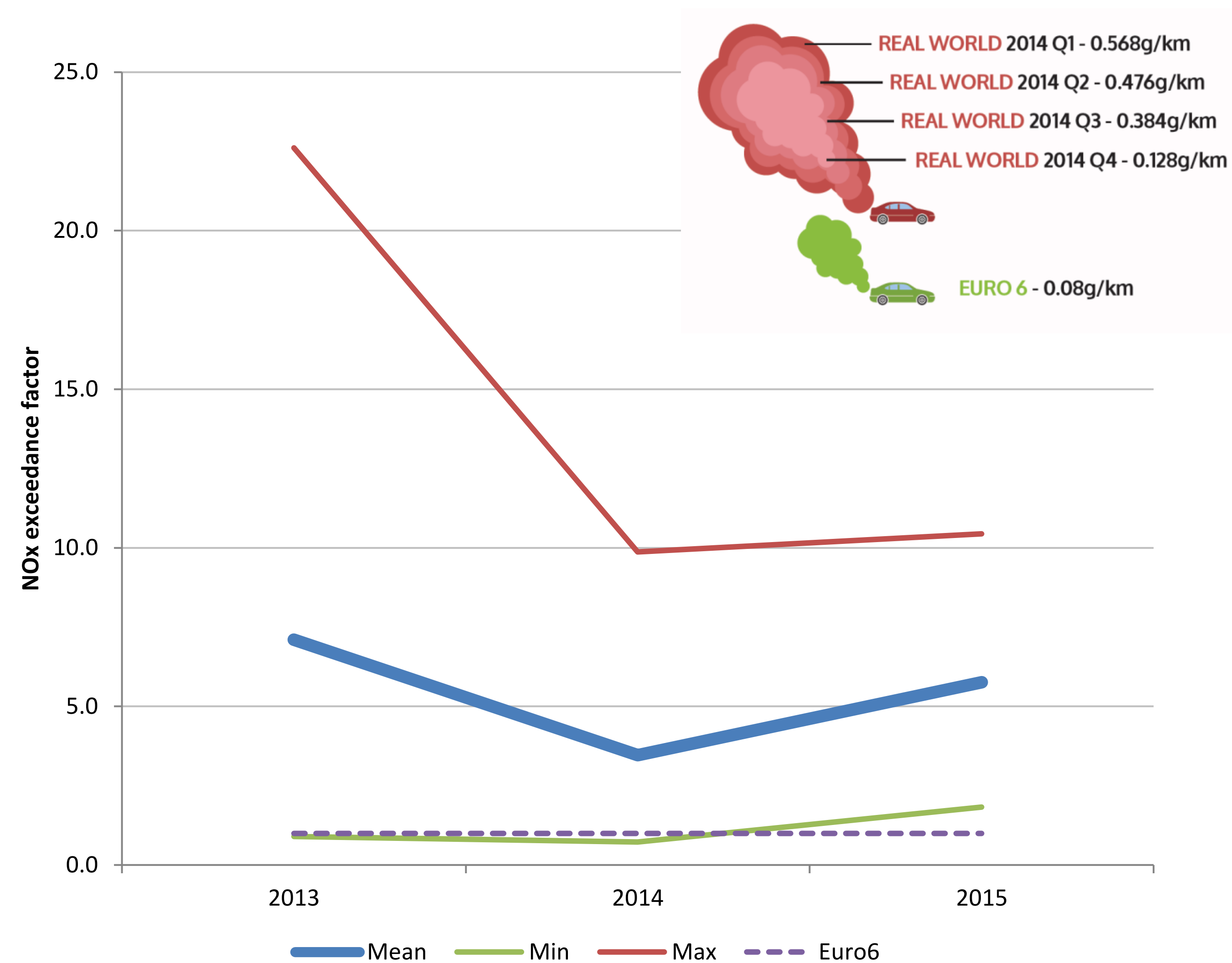


15 test vehicles in total (6 manufacturers), with different NO_x control technologies:
- 10 selective catalytic reduction (SCR)
- 4 exhaust gas recirculation (EGR)
- 1 lean NO_x trap (LNT)

Average Euro 6 NO_x conformity factors (ratio of on-road emissions to legal limits):
- all cars: 7.1
- best performer (Vehicle C, SCR): 1.0
- bad performer (Vehicle H, LNT): 24.3
- worst performer (Vehicle L, SCR): 25.4

Euro 6 latest trends

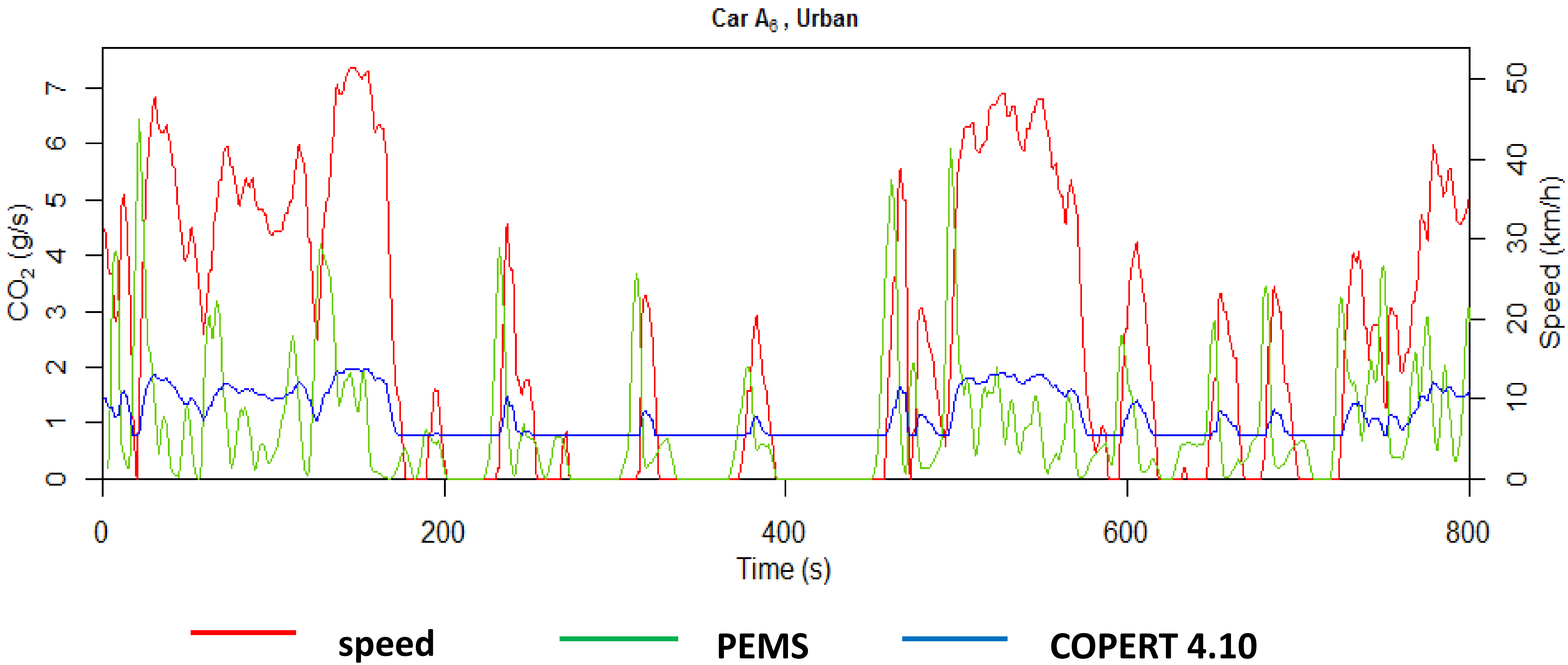
- Early Euro 6 passenger cars exceeded regulatory levels by 7.1 times – ICCT
- Early evidence of gap closing, especially towards end of 2014
- Further analysis required
- Best performers meet standard
- SCR dominant solution
- Spread reducing, but still wide



COPERT study

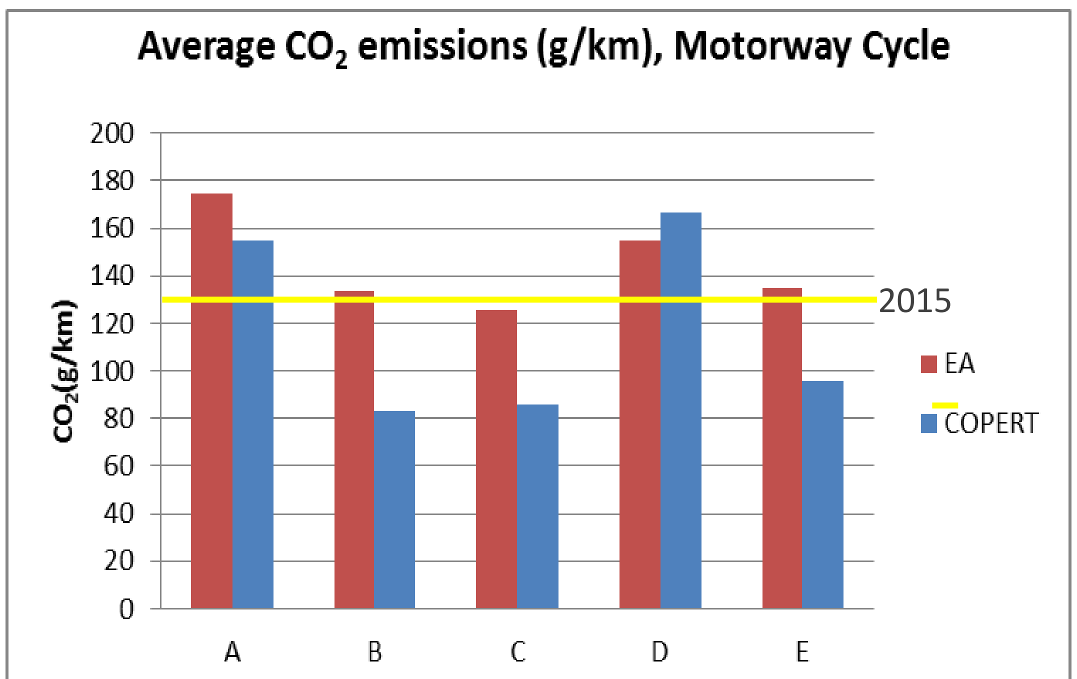
- Joint project with Imperial College London
- February 2015
- 5 Euro 5/6 passenger cars
- Detailed comparison with COPERT v4.10 and v4.11 models
- To assess effectiveness for policy and planning
- Euro 5 to Euro 6 performance compared to regulated levels
- Analysis of fraction of NO_x and NO_2

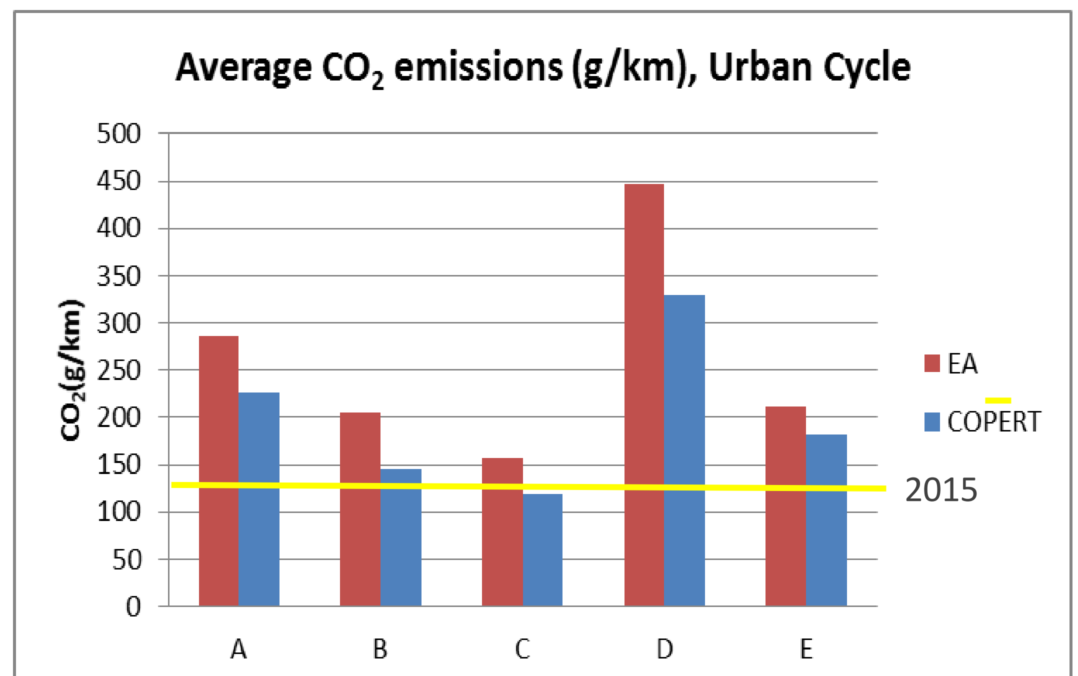
CO_2 comparison



COPERT results – CO_2

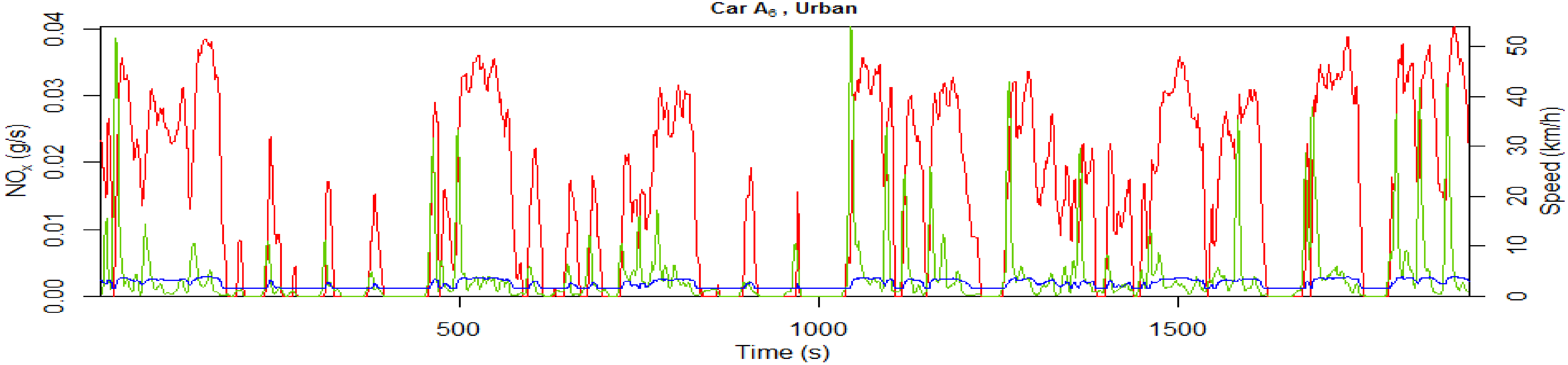
- Only one vehicle met the 2015 limit (130g/km) on one cycle
- Some improvement suggested from Euro 5 to 6 in urban driving
- COPERT has tendency to underestimate CO_2





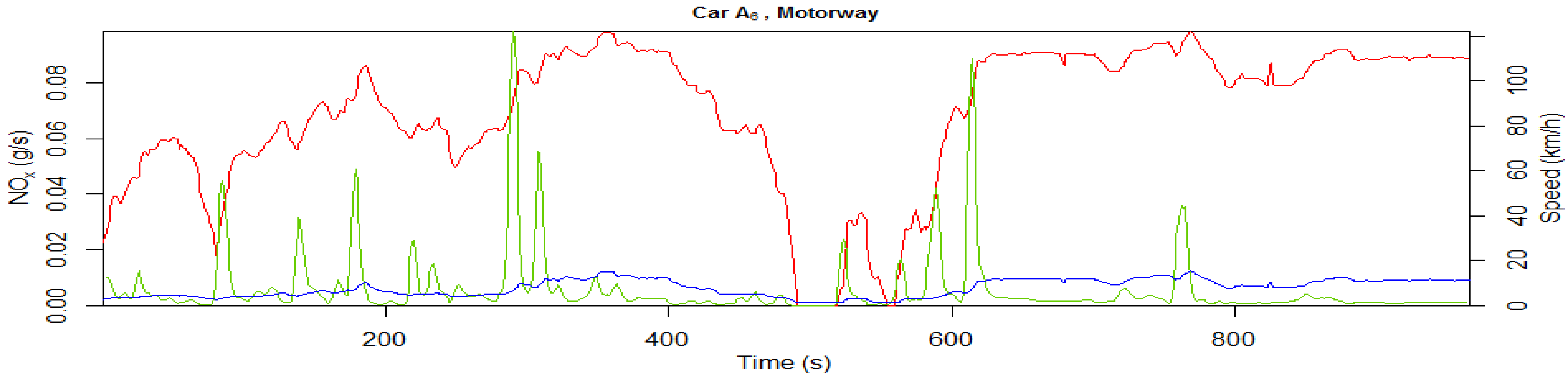
Euro 6: A, B, C
Euro 5: D, E

NO_x comparison



speed **PEMS** **COPERT 4.10**

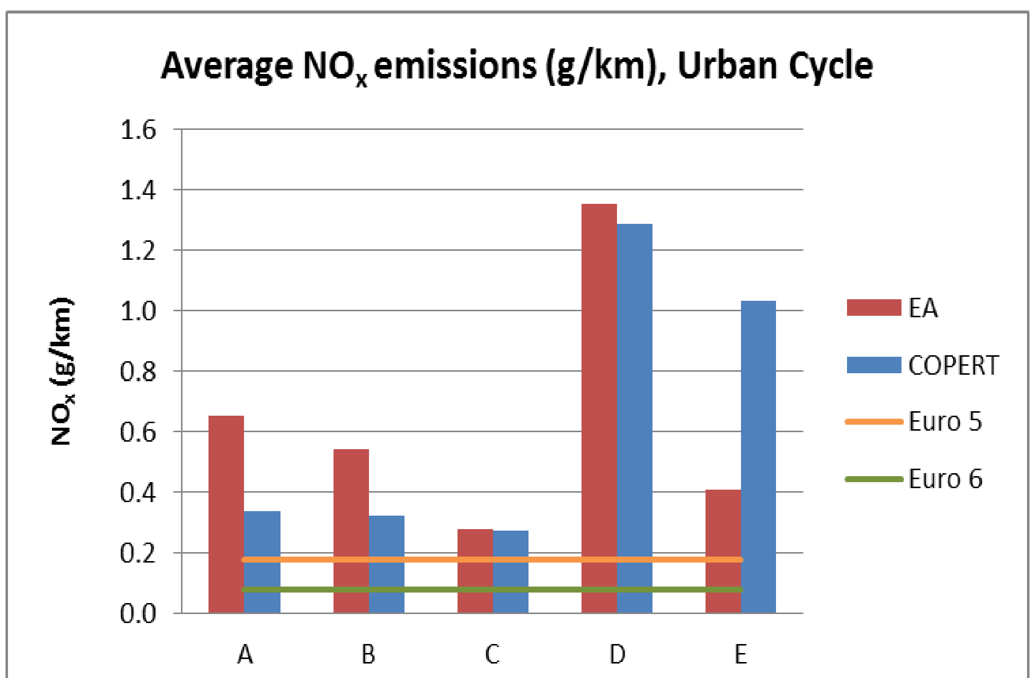
NO_x comparison

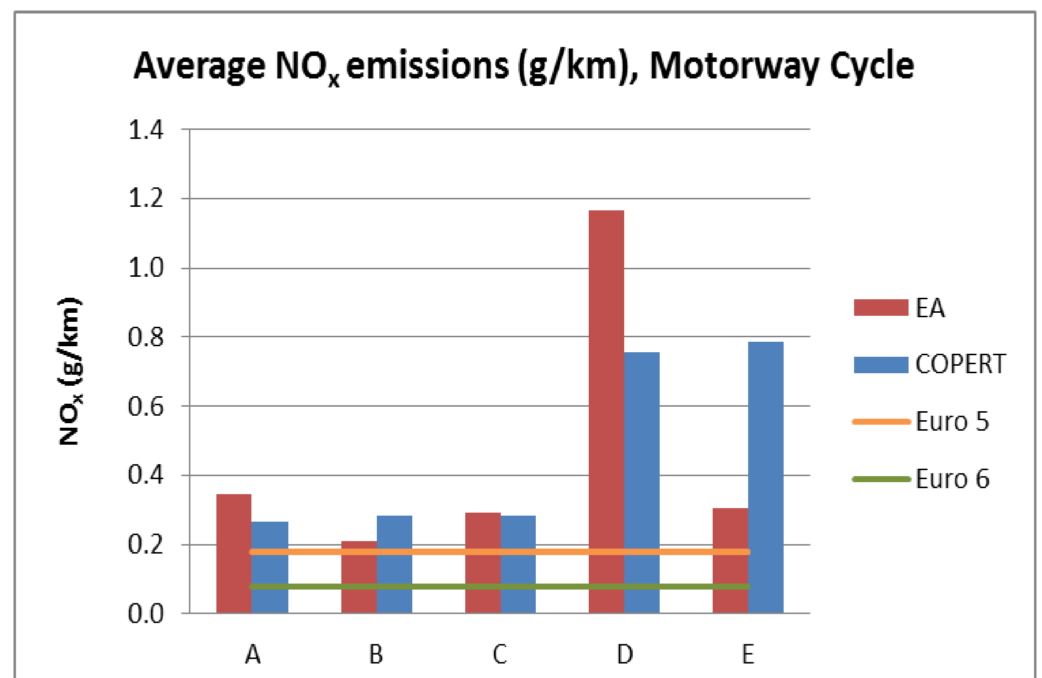


speed PEMS COPERT 4.10

COPERT results – NO_x

- COPERT better on average, but lacks resolution for road and model type
- Euro 6 significantly lower on average than Euro 5
- High inter-vehicle NO_x variability
- All vehicles above regulated level in both urban and extra-urban

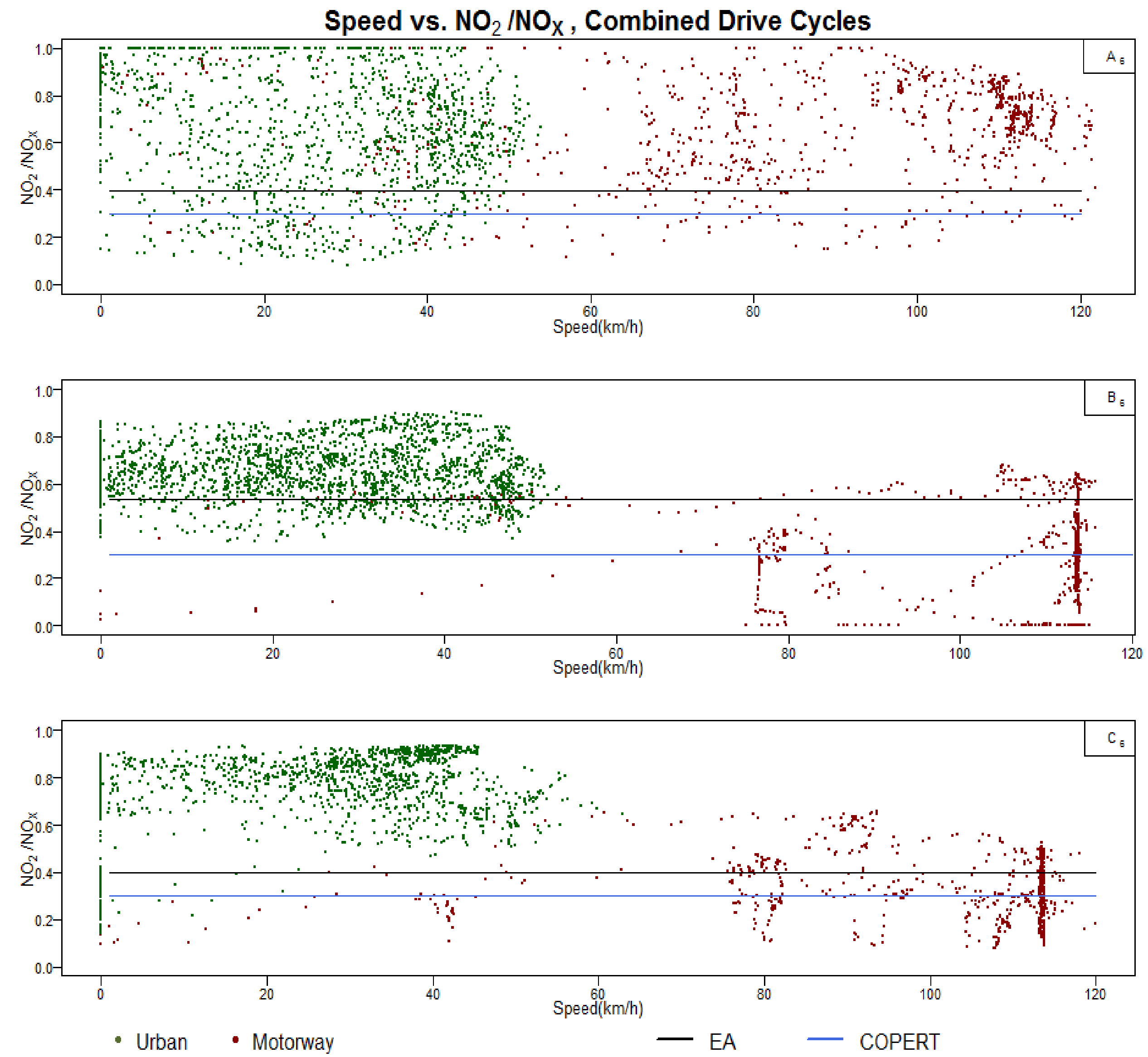




Euro 6: A, B, C
Euro 5: D, E

COPERT results – NO_2

- No consistent relationship between fNO_2 ratio and speed
- Variance between different models
- COPERT consistently underestimates primary NO_2 emissions in urban areas where public exposure is greatest
- Implies high primary fraction of NO_2 in urban areas, up to ~90%
- COPERT v4.11 assumes a ratio of 30% for Euro 6 diesel cars
- Danger of meeting NO_x target but not solving air quality problem



NO_x headline statistics

- From Emissions Analytics' database, at OEM level
- Over 350 tests

	Diesel Euro 5	Diesel Euro 6	Gasoline Euro 5/6
Real-world NOx (g/km)	0.718	0.405	0.049
Average Conformity Factor	4.0	5.1	0.8
fNOx – minimum	27	17	0
fNOx – mean	44	48	24
fNOx – maximum	71	80	72

COMPARISON TO RDE

Comparison with RDE

- Many similarities, some differences
  - RDE before RDE…
  - RDE-compatible
- Test ~50% longer in time
  - Economies of scale
- Town/rural/motorway defined by continuous route-segments
- Range of driving modes tested, but avoiding extended conditions
- Prescribed weight addition
- Separation of cold start and DPF regeneration
- Controlled use of air conditioning, no other auxiliary systems
- Maximum speed 110km/h

Future trends and issues

EMISSIONS ANALYTICS

- Optimisation of dosing strategies
- Limitations of some deNO$_x$ systems
- Inclusion of cold start are more extreme ("extended") driving important
- Switch back to petrol to lower NO$_x$, but growing fuel economy and CO_2 penalty?
- Together with fuel economy and other technologies such as GDI – some 3 times over limit – need for mitigation
- In-use compliance will be critical
- Emissions Analytics are expanding tracking programme of fuel economy and NO$_x$, to measure progress and trade-offs

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