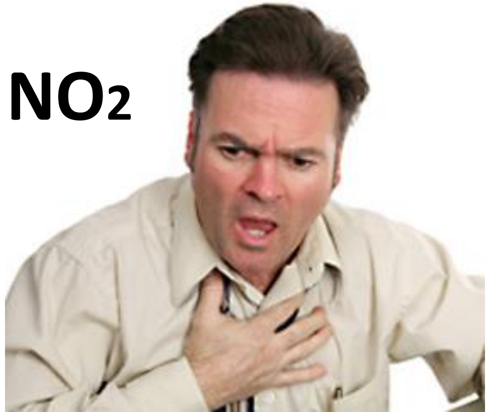
Integrated Assessment Modelling in the UK: with a focus on the transport sector & NO_2

Helen ApSimon, Tim Oxley, Rosalind O’Driscoll, Mike Holland and Audrey de Nazelle

Imperial College, London

NO_2



Analysis of PEMS data

courtesy of Emissions Analytics

PhD work by Ros O'Driscoll-> paper " A portable emissions measurement system(PEMS) study of NOx and primary NO2 from Euro 6 diesel passenger cars and comparison with COPERT 4v11 emission factors."

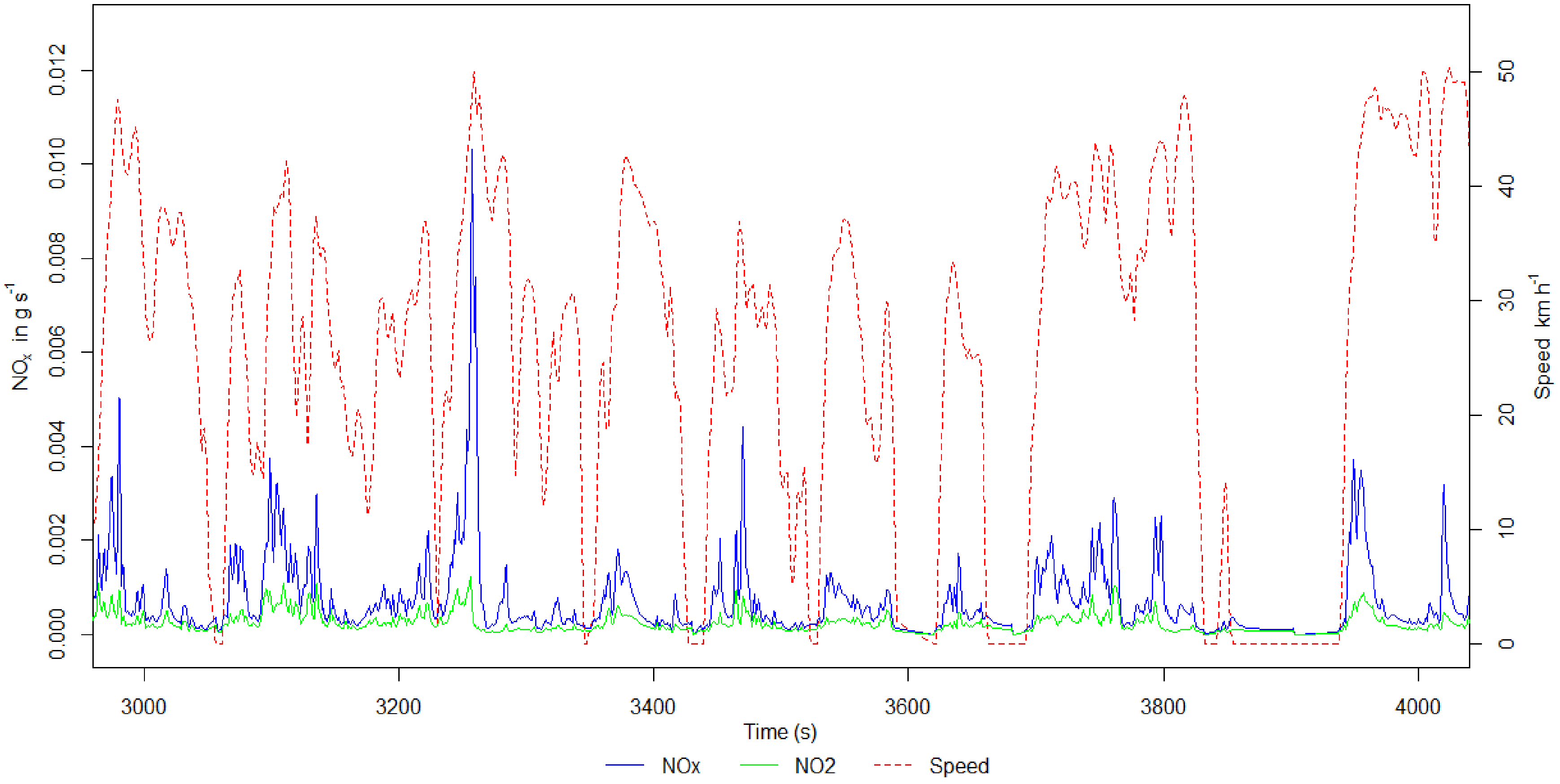
39 Euro 6 diesel cars mix of EGR, LNT,SCR

Test route mix of urban and motorway driving

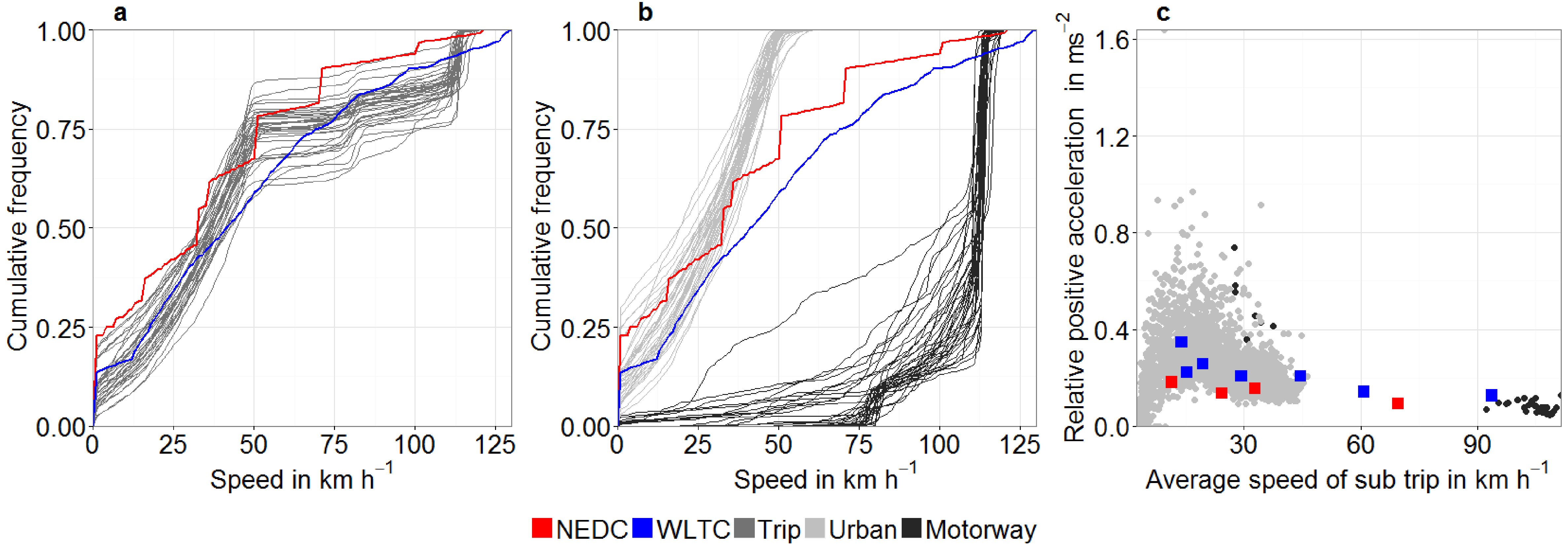
Measurements NOx, primary NO2 (and CO2)

Example of PEMS data

NB strong peaks in NOx associated with acceleration

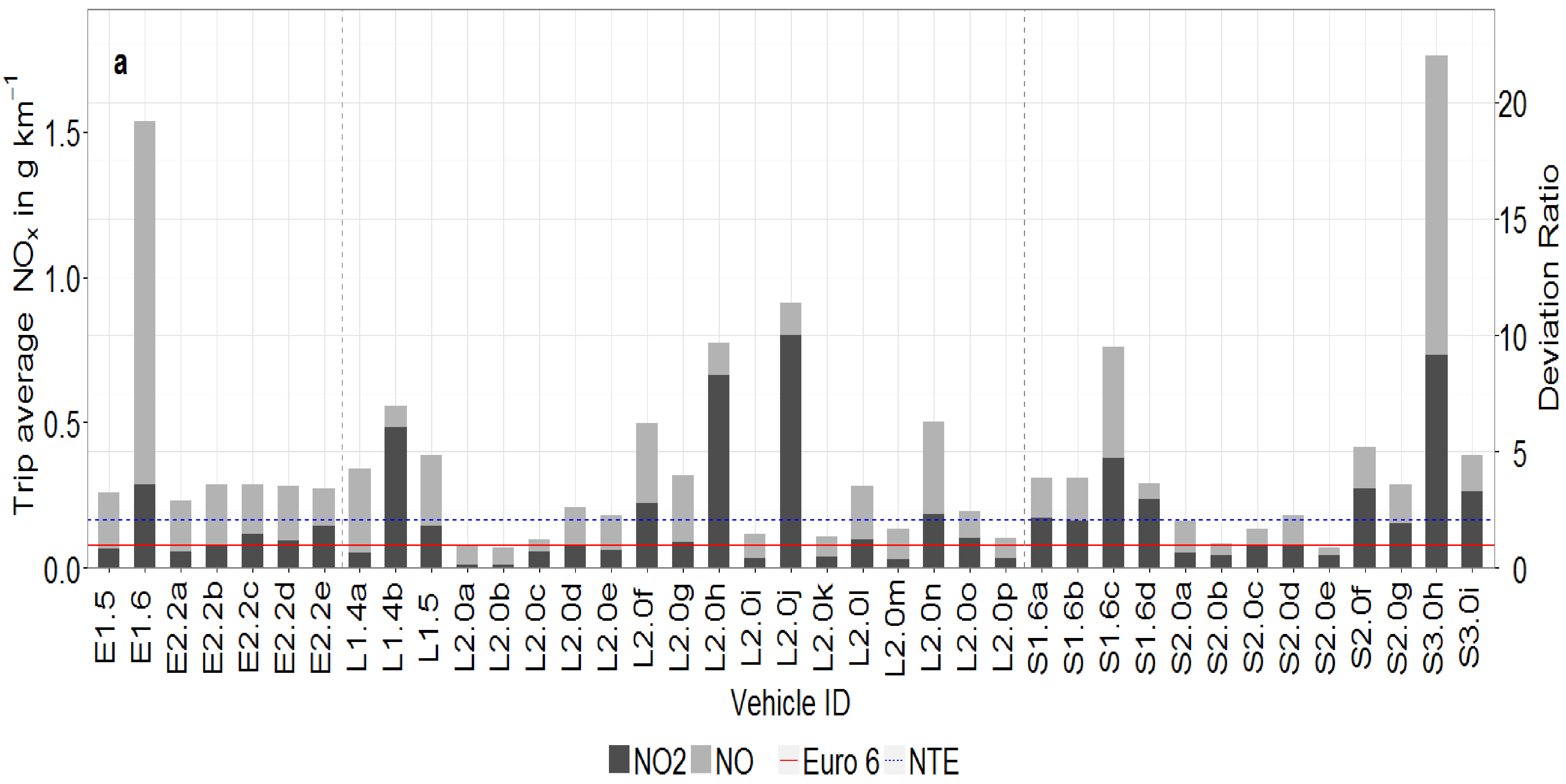


Test characteristics and consistency

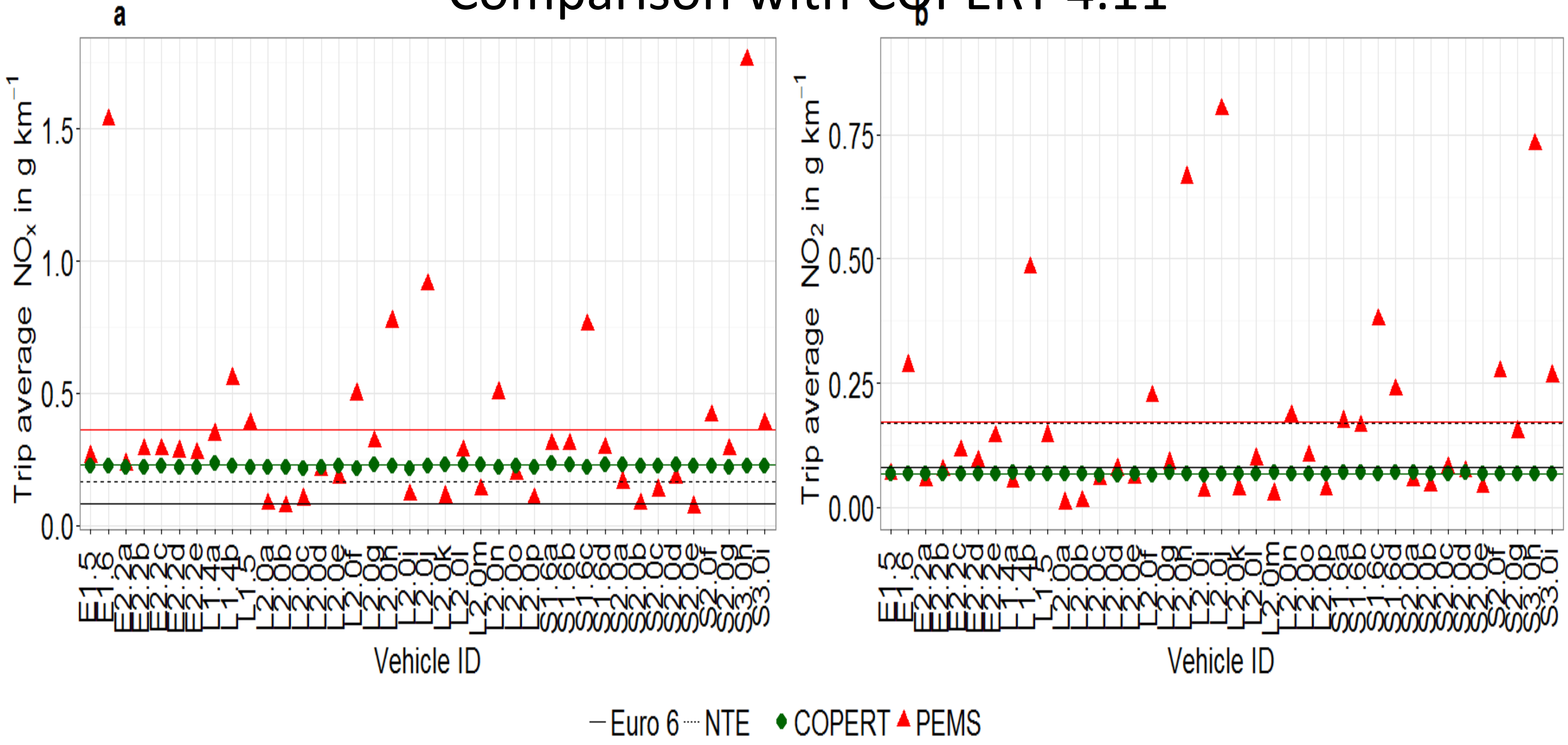


Speed distributions for entire route (a), urban and motorway speed distributions separated (b) and relative positive acceleration (c) Test cycle data from (Tutuianu et al., 2013).

Examples standard achievable by LNT and SCR; BUT some extremely high values (up to DR of 22)
Primary NO2 can also be very high, several times NOx standard on its own!



Comparison with COPERT 4.11



Ave PEMS NOx = O.36g/km equivalent to 1.6 times COPERT estimate of 0.23

Ave PEMS NO2 = 0.07 g/km equivalent to 2.5 times COPERT estimate

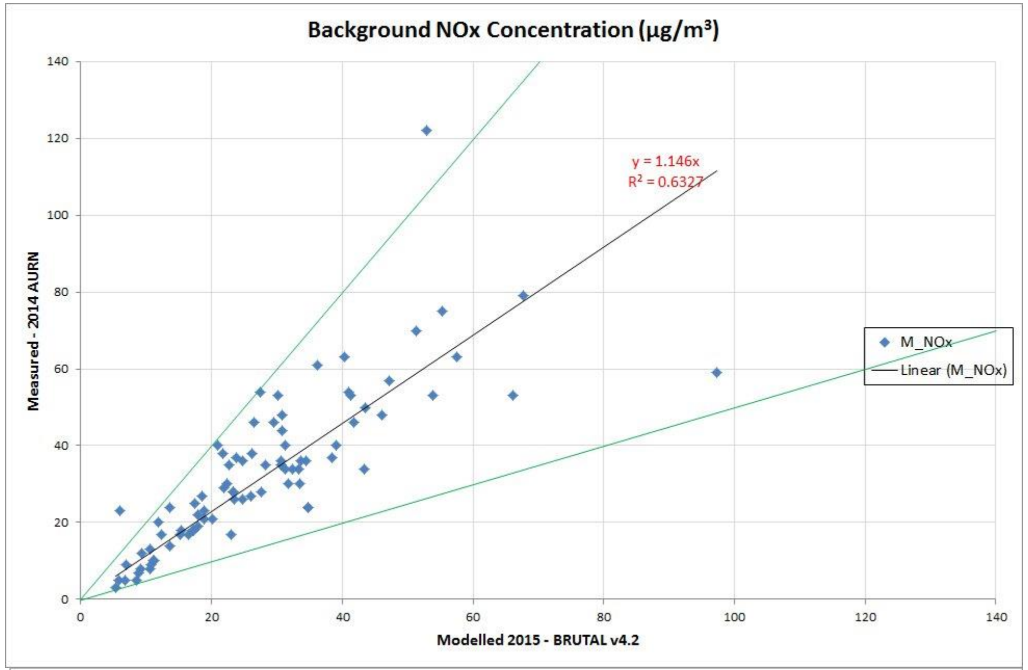
Urban sections EFs 1.7 times motorway EFs; (NB analysis of RPA-relative positive association)

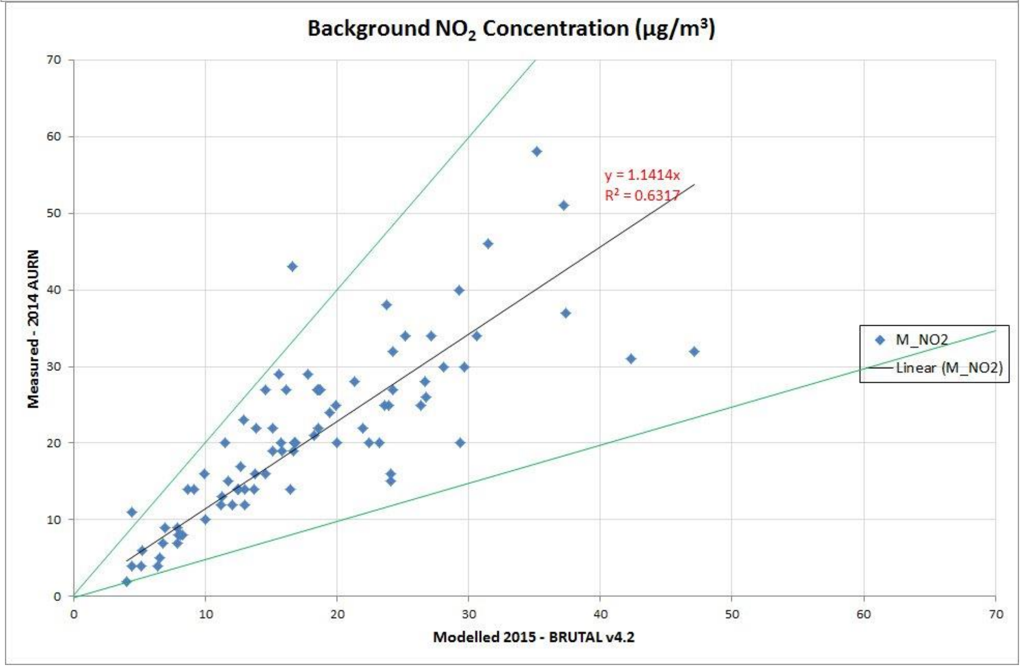
Urban =0.43 gNOx/km (DR= 5.4) and) 0.21 gNO2/km

NB Removing 5 worst vehicles reduced ave NOx to 0.25 g/km closer to COPERT

Table 3: Effect of assumed emission factor on emission contribution from Euro 6 diesel cars on UK NOx emissions in 2030

Origin	EF mg/km	NOx in kt
GAINS	71	23.97
Euro 6 standard	80	27.01
Euro 6c/RDE limit	168	56.72
NAEI	COPERT 4.11	58.7
PEMS study average	360	121.5
PEMS worst vehicles removed	250	84.40





Modelling of NO2 in UKIAM:

1x 1 km gridded concentrations of NOx; source apportionment ~90 categories of stationary sources Bottom-up modelling of road-transport from UK road network in BRUTAL sub-model

-> background NO2 concentrations and exposure and road-side increments

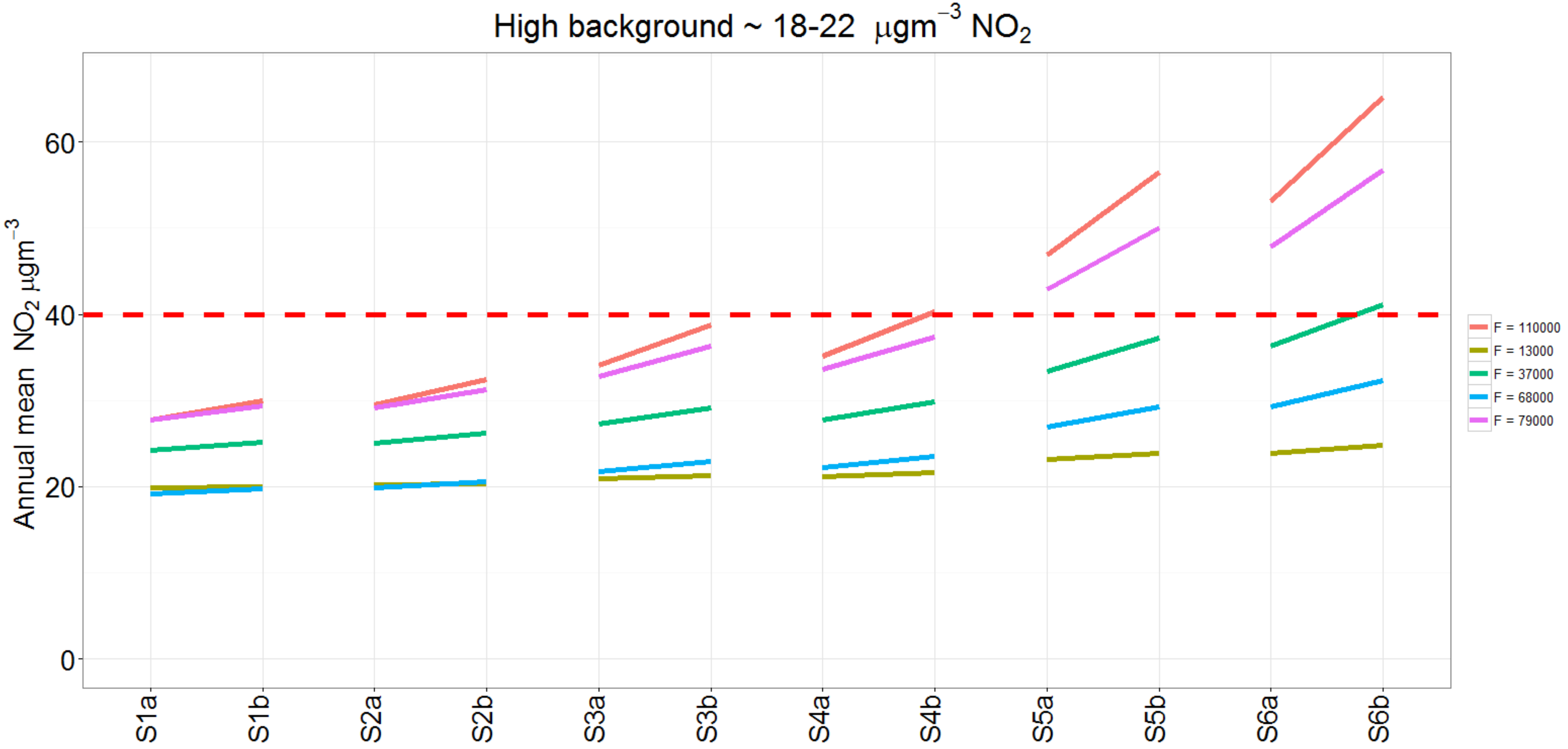
Validation studies of modelled NO2:

Comparison with measurements

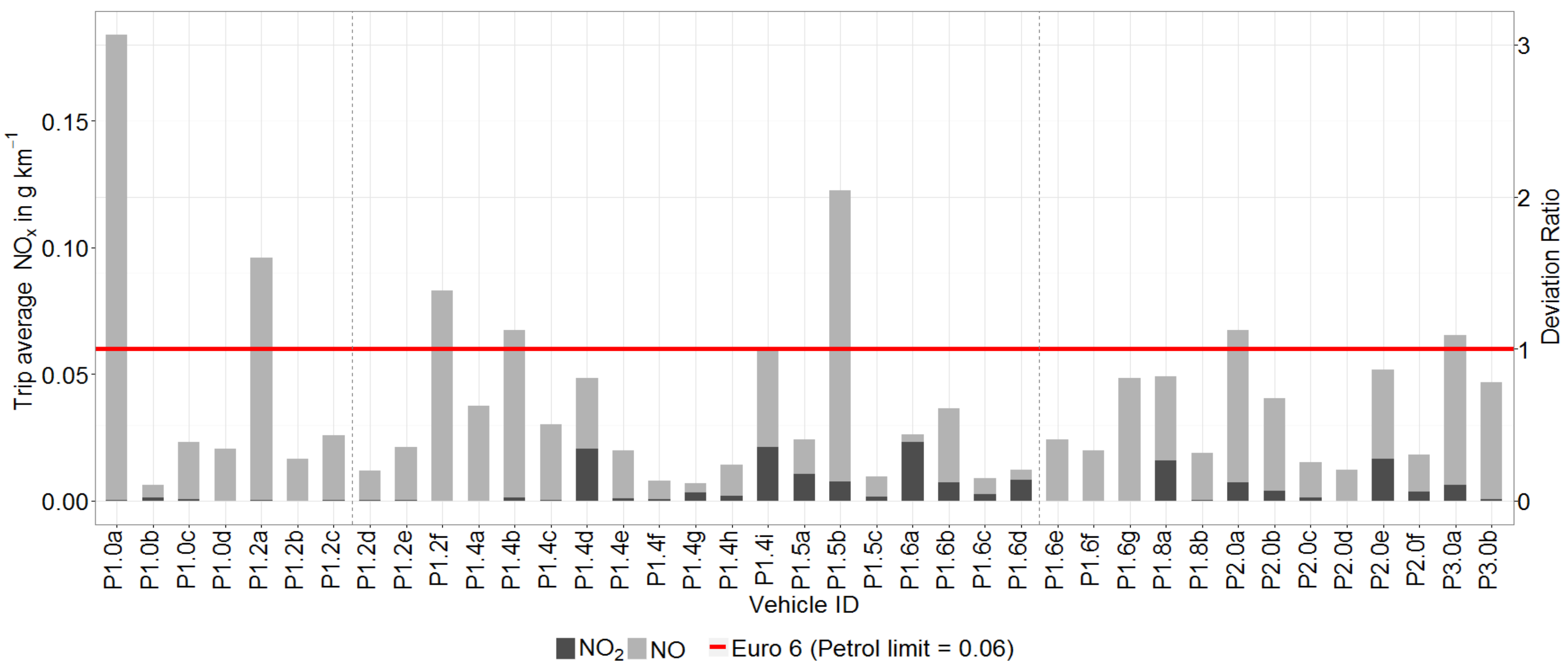
Example : UKIAM/BRUTAL modelling of NOx and NO2 compared with annual average measurements at background stations in London for 2015

Effect of primary NO2 from Euro 6 diesels on roadside concentrations : 30% in COPERT 4.11; 44% ave of PEMS data, for different CFs

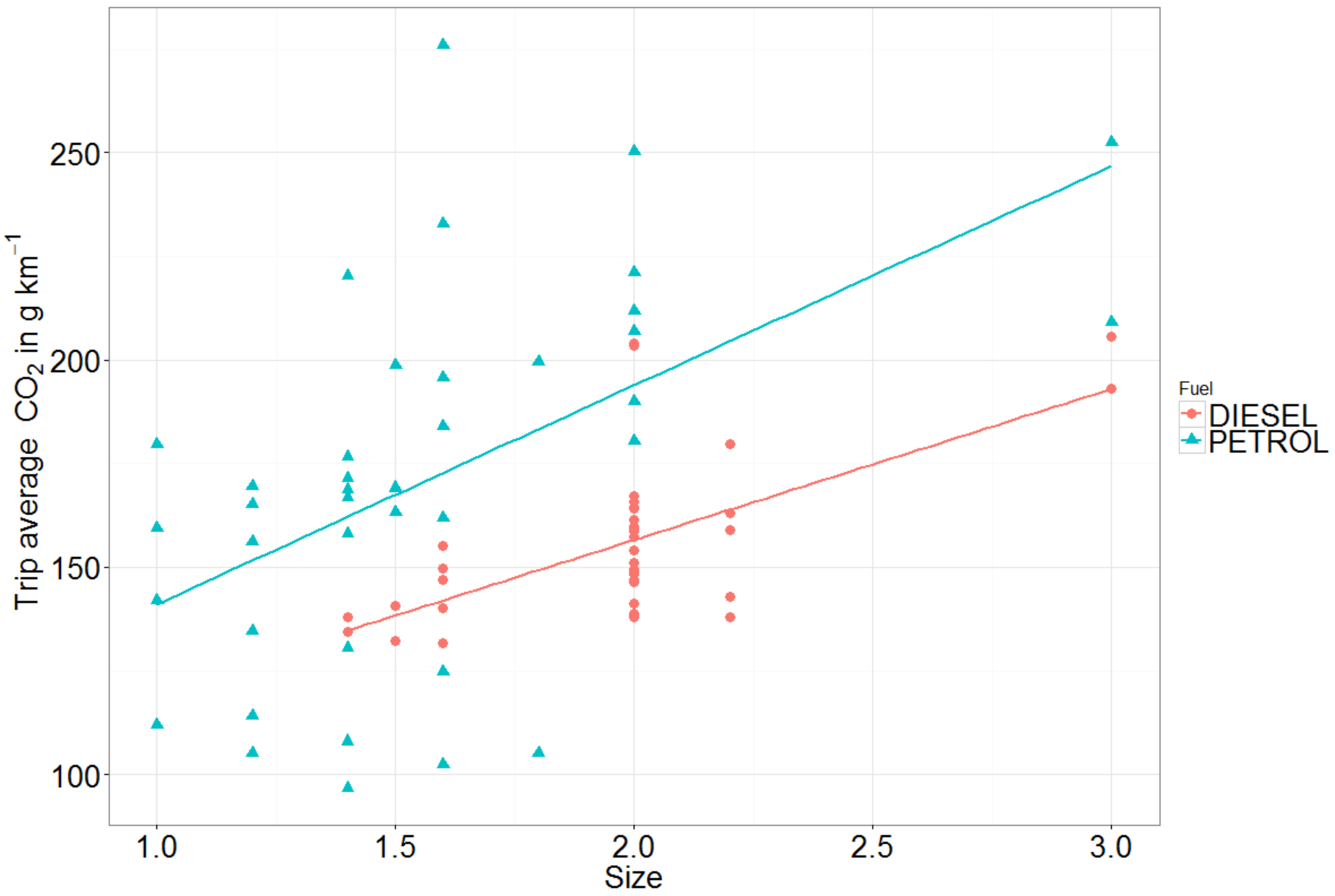
Roads with flows from 13000 to 110,000 v/day,
Vehicle mix for 2030 , ~44 % cars diesel, 90% Eu6



Conformity factors	
S1	1.0
S2	1.3
S3	2.1
S4	2.4
S5	4.3
S6 Mway	3.9
Urban	5.3



Similar analysis 39 petrol Euro 6: order left to right by size



Trip average CO_2 in g km^{-1}
250
200
150
100
1.0
1.5
2.0
2.5
3.0
Size
Fuel
DIESEL
PETROL

Emissions Analytics Accreditation Scheme for NOx emissions

see "EQUA Index" page in www. Emissionsanalytics.com

Rating	Lower bound (g/km, exclusive)	Upper bound (g/km, exclusive)	External reference point
A	0.00	0.08	Meets Euro 6 limit for diesels, and meets Euro 4 limit for petrols
B	0.08	0.12	Meets 1.5 Conformity Factor under Euro 6 Real Driving Emissions regulation
C	0.12	0.18	Meets Euro 5 limit for diesels (and similar to 2.1 Conformity Factor under Euro 6 Real Driving Emissions regulation)
D	0.18	0.25	Meets Euro 4 limit for diesels
E	0.25	0.50	Meets Euro 3 limit for diesels
F	0.50	0.75	No comparable Euro standard: roughly equal to 6-8 times Euro 6 limit
G	0.75	1.00	No comparable Euro standard: roughly equal to 8-12 times Euro 6 limit
H	1.00	None	No comparable Euro standard: roughly equal to 12+ times Euro 6 limit

Data for 244 Euro 5 and 130 Euro 6 cars

Mixture of petrol, diesel, hybrids already covering a high percentage of makes and models in use

Extract from data sheet for Euro 6 vehicles

Manufacturer	Model	Fuel Type	Mode	Engine si	Powe	Driven V	Transmission	Regulato	EQUA
Volkswagen	Golf	Petrol	2016	1.0	115	2	Manual	Euro 6	A
Volkswagen	Golf	Petrol Hybrid	2015	1.4	201	2	Automatic	Euro 6	A
Volkswagen	Golf SV	Diesel	2015	2.0	148	2	Automatic	Euro 6	A
Volkswagen	Passat	Diesel	2016	1.6	118	2	Manual	Euro 6	A
Volkswagen	Polo	Diesel	2015	1.4	89	2	Manual	Euro 6	F
Volkswagen	Polo	Petrol	2015	1.2	89	2	Manual	Euro 6	A
Volkswagen	Scirocco	Diesel	2015	2.0	148	2	Manual	Euro 6	A
Volkswagen	Touran	Diesel	2016	1.6	108	2	Manual	Euro 6	A
Volkswagen	Golf	Petrol	2013	2.0	218	2	Automatic	Euro 6	A
Volkswagen	CC	Diesel	2016	2.0	180	2	Automatic	Euro 6	C
Volkswagen	Beetle	Petrol	2016	1.4	148	2	Manual	Euro 6	A
Volvo	S60	Diesel	2016	2.0	148	2	Manual	Euro 6	B
Volvo	V40	Diesel	2015	2.0	187	2	Manual	Euro 6	E
Volvo	V40	Petrol	2015	2.0	242	2	Automatic	Euro 6	A
Volvo	XC60	Diesel	2016	2.4	217	4	Automatic	Euro 6	F
Volvo	XC90	Diesel	2016	2.0	222	4	Automatic	Euro 6	D
Volvo	S80	Diesel	2014	2.0	178	2	Manual	Euro 6	C
Volvo	S60	Diesel	2014	2.0	178	2	Automatic	Euro 6	F

Department for Transport have also published a report

https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/518437/vehicle-emissions-testing-programme.pdf

19 Euro5 diesels and 19 Euro 6 diesels

NEDC testing, track testing and on-road testing

Looked for detection of test cycle.

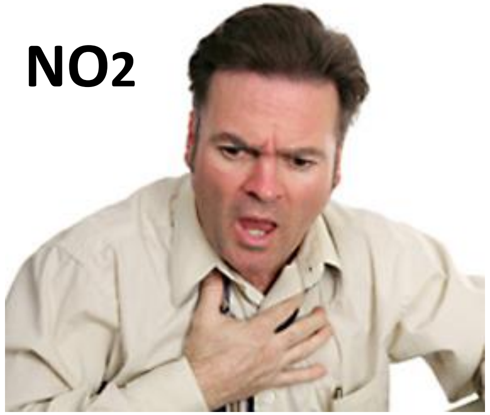
Dependence on ambient temperature NB optimised range for NOx technologies

Characteristics of real world test?

Found no cars that met the limit on RDE.

Response of Defra in the UK to new evidence on health impacts of NO_2

NO_2



Department
for Environment
Food & Rural Affairs

Valuing impacts on air quality:

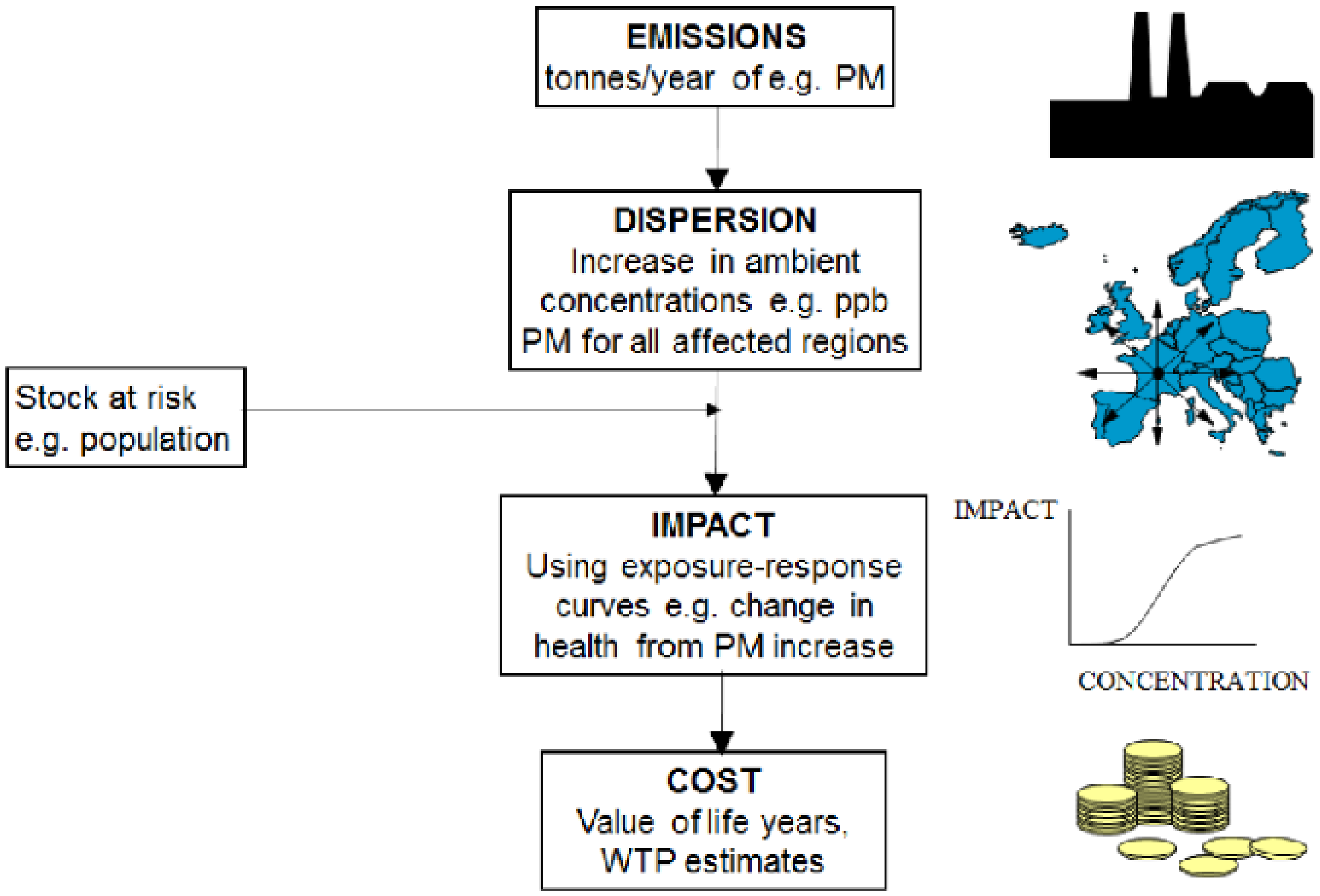
Updates in valuing changes in emissions of Oxides of Nitrogen (NO_X) and concentrations of Nitrogen Dioxide (NO_2)

September 2015

COMEAP have provided an interim steer to Defra on how the latest NO_2 evidence should be reflected in policy analysis. On 24 July 2015 a COMEAP working group on NO_2 wrote to Defra recommending that a coefficient of 1.025 per 10 μg/m^3 exposure to NO_2 (within the range 1.01 – 1.04)[4] should be used to assess the link between long term exposure to NO_2 and all-cause mortality.[5]

When the interim coefficient of 1.025 (1.01-1.04) is included in an assessment which also includes assessment of health impacts on the basis of particulate matter (PM), COMEAP recommend a reduction of the coefficient by up to 33% to take account of possible overestimation due to double counting of effects associated with PM.

Figure 1: Impact-pathway approach



Defra report used impact pathway approach adapted to NO2 and the PCM model of Ricardo- AEA to derive costs per ton of NOx emitted.

Also estimated current health impacts on UK population

Table 1: NO_X damage costs (per tonne, 2015 prices)

	Central	Low	High
Domestic	£14,646	£5,859	£23,434
Agriculture	£5,050	£2,020	£8,080
Waste	£10,858	£4,343	£17,373
Industry	£13,131	£5,253	£21,010
ESI	£1,263	£505	£2,020
Transport average	£25,252	£10,101	£40,404
Transport central London	£115,405	£46,162	£184,648
Transport inner London	£118,688	£47,475	£189,901
Transport outer London	£77,526	£31,010	£124,041
Transport inner conurbation	£61,365	£24,546	£98,184
Transport outer conurbation	£38,131	£15,253	£61,010
Transport urban big	£45,455	£18,182	£72,728
Transport urban large	£36,617	£14,647	£58,587
Transport urban medium	£28,788	£11,515	£46,061
Transport urban small	£18,182	£7,273	£29,091
Rural	£7,829	£3,131	£12,526

Damage costs per ton of NOx emitted

NB No allowance for possible double counting (33% reduction)

Table 4: Health Impact from NO_2 (2013)

	Central (2.5%)	Low (1%)	High (4%)
Annual equivalent attributable deaths	23,500	9,500	38,000
Annual Social Cost	£13.3bn	£5.3bn	£21.4bn

Possible overlap between the health impacts associated with ambient concentrations of particulate matter (PM) and NO_2 need to be borne in mind when considering the above estimate. It is likely that there will be some overlap. Further work is being undertaken to understand and quantify this overlap but the current recommendation is that between 0 and 33% of the effects associated with ambient concentrations of the two pollutants overlap. Table 5 below provides an indication of the combined effect associated with these pollutants assuming that the two are completely independent.

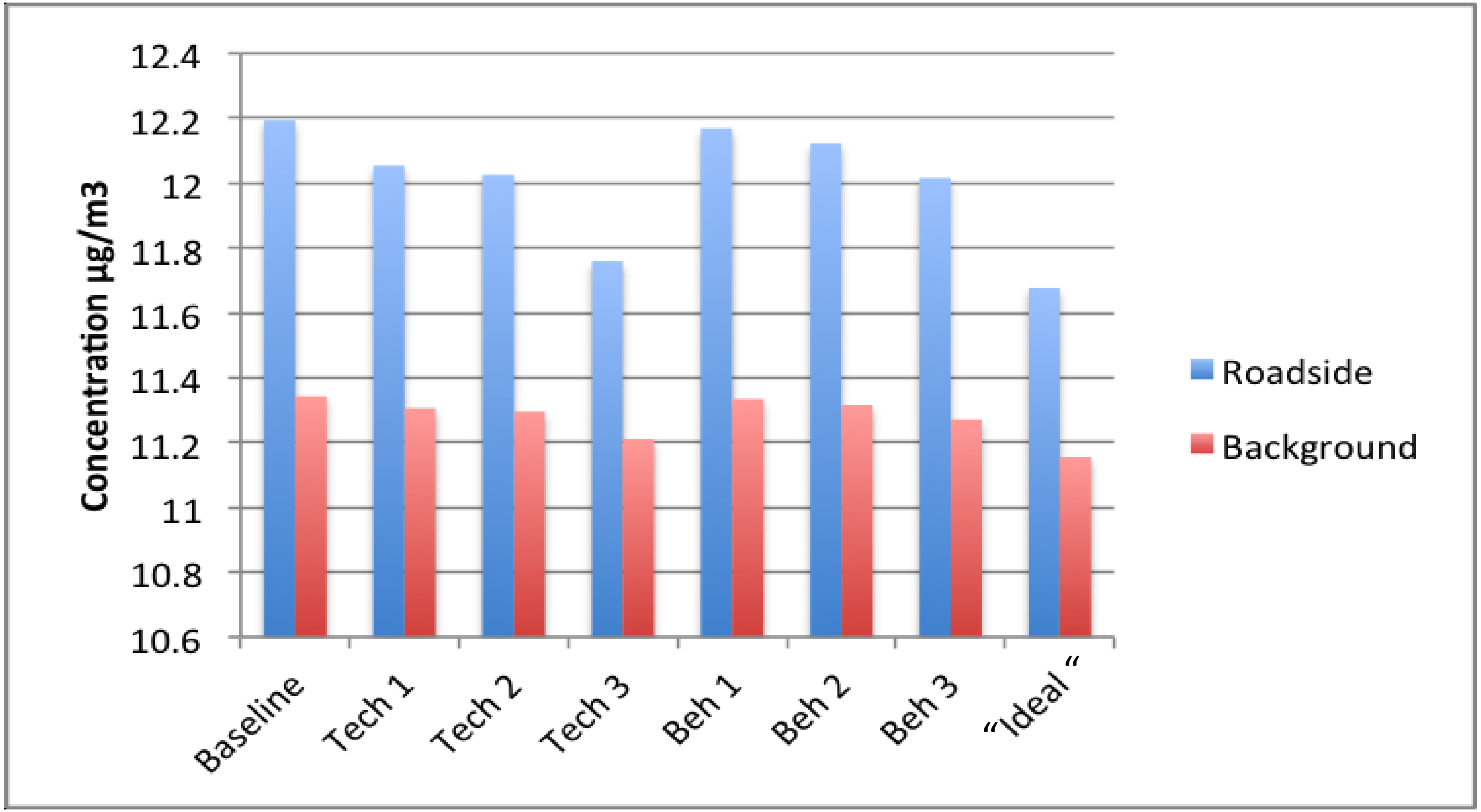
Table 5: Total health Impact from PM and NO_2

	Impact
Annual equivalent attributable deaths	44,750 - 52,500
Annual Social Cost	£25.3bn - £29.7bn

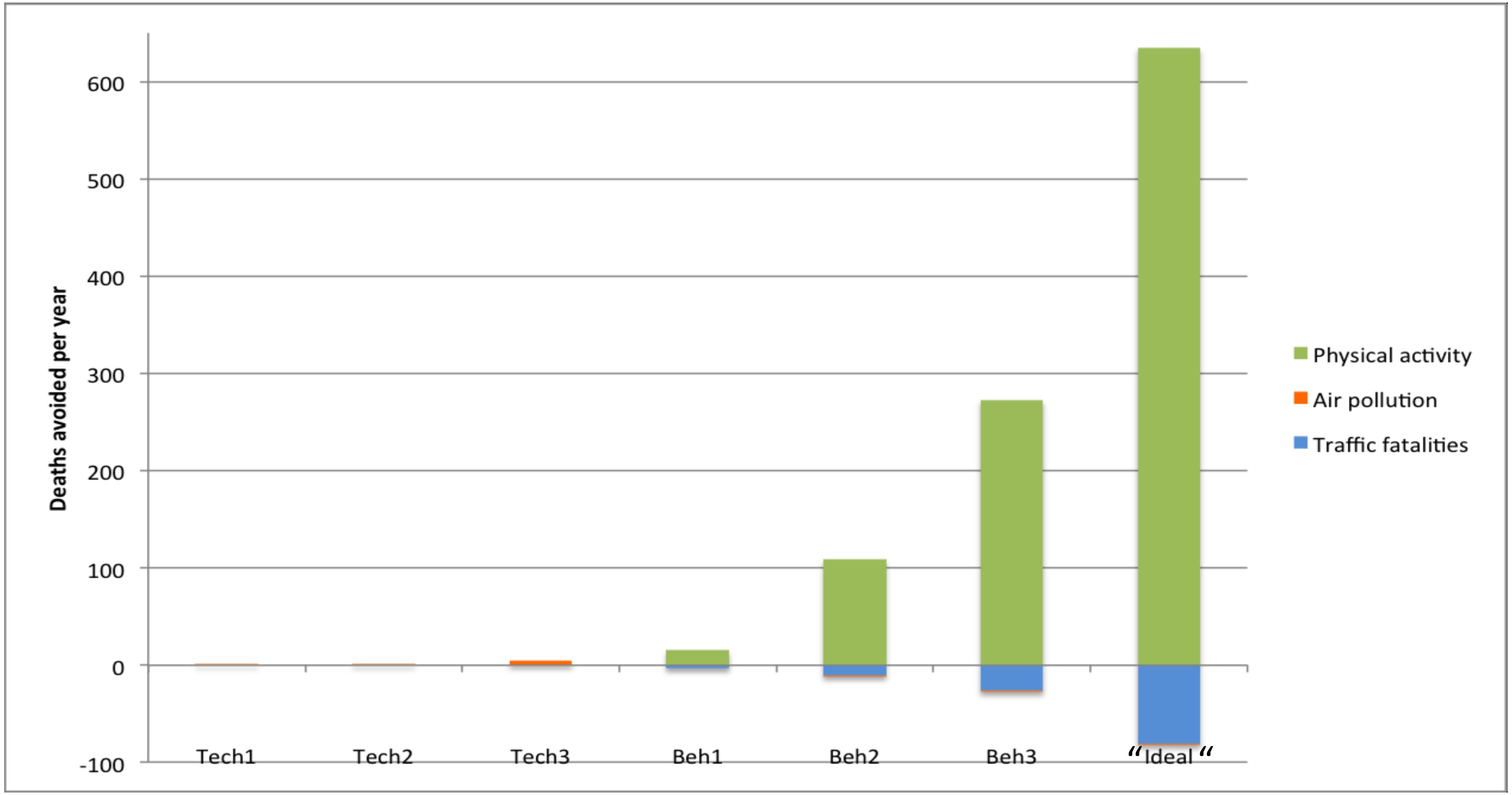
Now using same relationship between NO_2 exposure and damage costs in UKIAM

Has major implications for the relative cost-effectiveness of different abatement measures, previously dominated by health impacts of $PM_{2.5}$

Scenario	Technological and behavioural changes
Tech 1	All double-deck buses to hybrid; all single deck buses to zero emission; all taxis to Euro 6 (diesel black cabs)
Tech 2	Tech 1 + Ultra Low Emission Zone (ULEZ) implemented
Tech 3	Tech 2 + ban diesel cars completely from London
Behaviour 1	Cycle superhighway (all reduced car traffic to bicycles) – reduce traffic flow 10%
Behaviour 2	Increased active travel (5% car trips to cycling; 5% car trips to walking) and public transport (10% car trips to bus) = 20% of car trips replaced
Behaviour 3	Most increased active travel (25% car trips to cycling; 15% car trips to walking) and public transport (10% car trips to bus) = 50% of car trips replaced
Combined "ideal"	No private cars in London (30% car trips to bus, all of which are zero emission; 50% car trips to cycle; 20% car trips to walking) and all black cabs zero emission, including London wide ULEZ standards for remaining vehicles



PM2.5 concentrations resulting from baseline (current conditions) and policy scenarios



Health impacts, estimated as number of deaths avoided per year resulting from changes in air pollution, physical activity, and traffic fatalities, for the 7 policy scenarios (based on TAPAS)

CONCLUSIONS : health study

Need to take wider view of costs and benefits when considering behavioural change

This study based on PM2.5 where there is a large imported contribution less affected by local measures

Future work: repeat looking at NO_2 using new data on health risks and damage costs.

New London Mayor Sadiq Kahn -> consultation on proposals

extending ULEZ to N and S Circular Roads and bring forward before 2020

Implement extra charge on most polluting vehicles using Congestion charge system central London from 2017

Introducing ULEZ standards for heavy vehicles London wide from 2020

TfL to work on costs and challenges of diesel scrappage scheme as part of wider national scheme

For TfL : implementing clean bus corridors- cleaner buses on dirtiest routes

Expand ULEZ retrofit programme from 2000 to 3000 buses outside central zone

Purchasing only hybrid or zero-emission double-decker buses from 2018

Thanks for listening

Lots of uncertainties for the future of the transport sector and the diesel car!