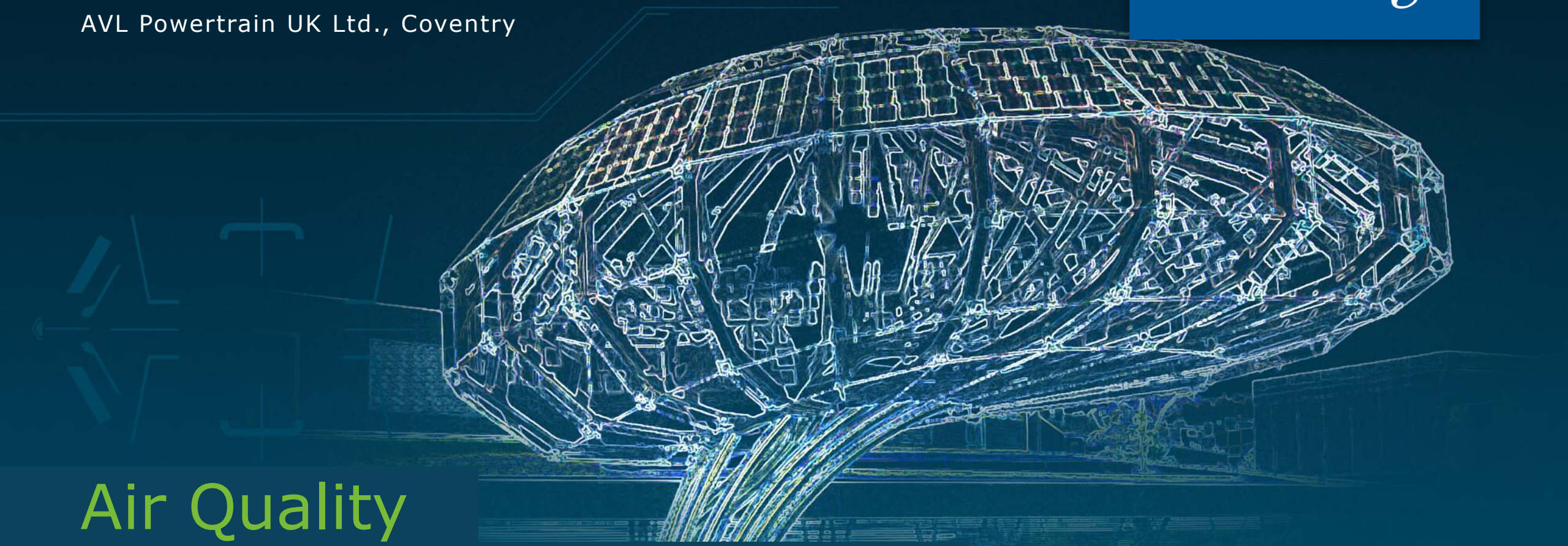
AVL Powertrain UK Ltd., Coventry



Air Quality

UK Product Development in Motion 2019

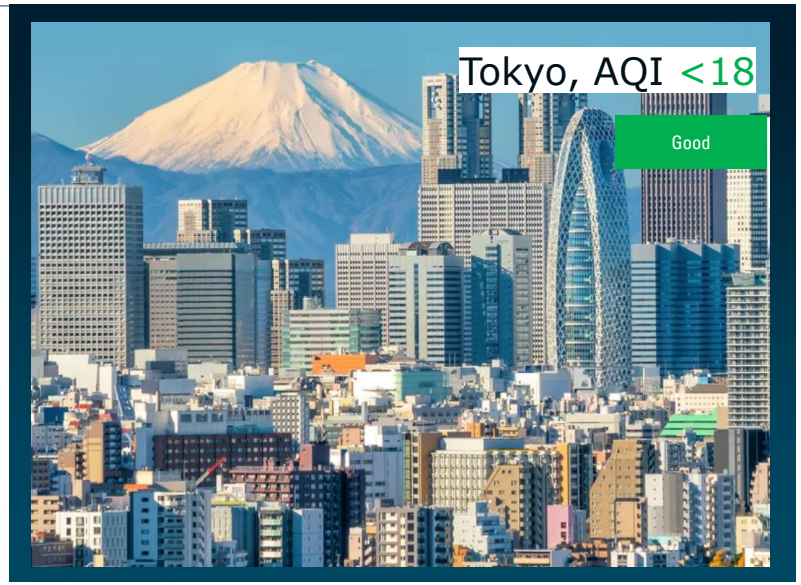
MTC Coventry, Ansty Park

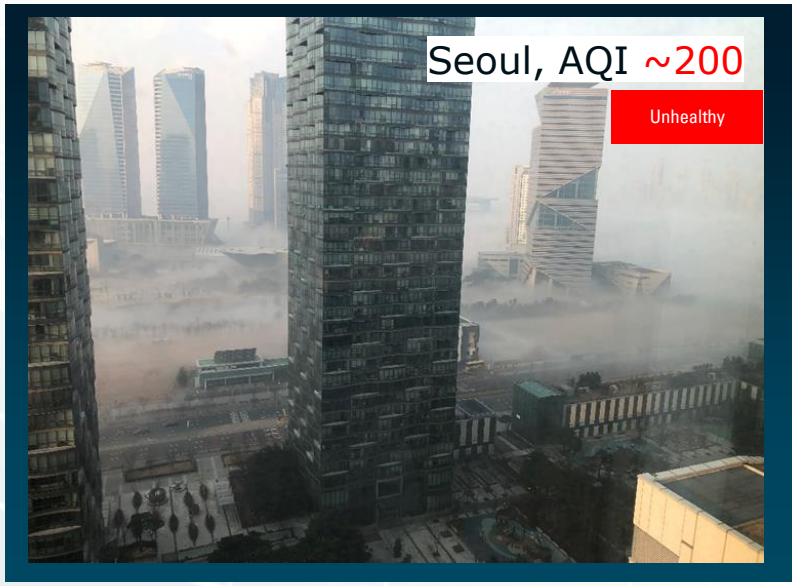
Gupta, Atul

Agenda

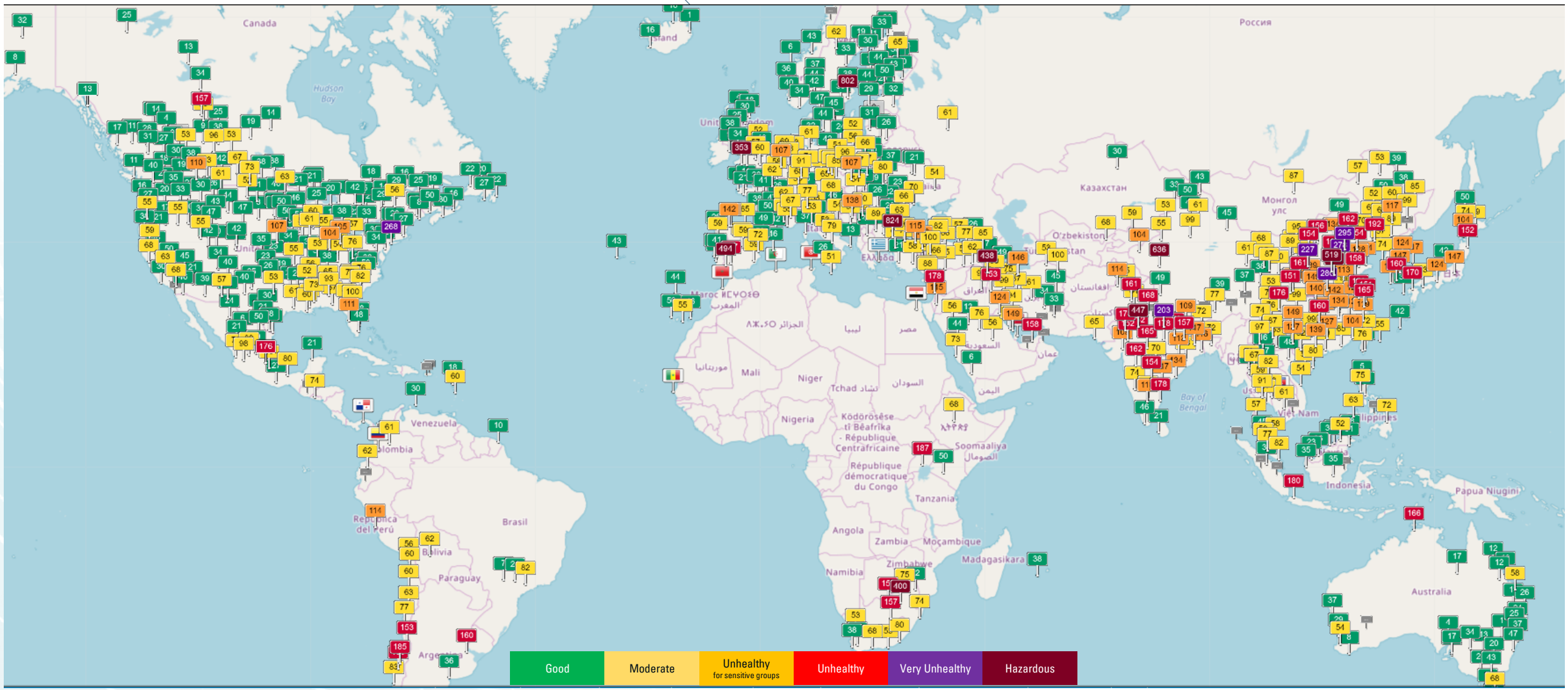
1. AIR QUALITY
   Where, What, How
2. UK EMISSION MAPS
3. ROAD MEASURMENTS
4. NEXT STEPS
5. EMISSION TRENDS
6. NON-EXHAUST EMISSIONS
7. AVIATION
8. SHIPPING
9. HOW DO YOU COMMUTE?

Air Quality (Where)





Air Quality Worldwide



Air Quality (Where, How)

Mexico	882	Slovenia	108	Peru	57
Turkey	814	Hong Kong	107	Ireland	57
Iran	500	Belgium	107	San Marino	57
India	488	Nepal	104	New Zealand	57
Thailand	327	Australia	104	Denmark	56
China	301	Austria	102	Armenia	56
United States	221	Slovakia	102	Moldova	56
Uganda	179	Viet Nam	100	Holy See	55
Mongolia	175	Bangladesh	99	Netherlands	54
Bulgaria	168	Saudi Arabia	95	Switzerland	53
Bahrain	166	Kuwait	95	Cyprus	52
Macedonia	165	Germany	93	Monaco	48
Norway	155	Macao	93	Sri Lanka	46
United Arab Emirates	153	Malta	90	Jordan	41
Poland	153	Lao People's Democratic Repub	90	Uzbekistan	38
France	151	Taiwan	89	Bolivia	30
Kosovo	149	South Korea	89	Palestine	30
Italy	136	Iraq	87	Estonia	30
Serbia	134	Hungary	87	Curaçao	30
Argentina	134	Kazakhstan	82	Brunei Darussalam	29
Spain	133	Greece	80	French Guiana	24
El Salvador	129	Israel	78	Lithuania	24
Indonesia	129	Malaysia	72	Martinique	22
Ukraine	128	Canada	72	Gibraltar	20
Chile	126	Réunion	66	Liechtenstein	17
Finland	122	Colombia	65	Andorra	14
Brazil	119	Ecuador	63	Guadeloupe	13
Russian Federation	118	Singapore	63	Iceland	12
Japan	112	Kyrgyzstan	63		
Sweden	111	Portugal	62		
Bosnia and Herzegovina	109	United Kingdom	62		
South Africa	109	Croatia	61		
Ethiopia	109	Romania	60		
		Luxembourg	59		

On 1st April 0900 BST.

The maximum of any city within that country is used for ranking.

AQI	Air Pollution Level	Health Implications	Cautionary Statement (for PM2.5)
0 - 50	Good	Air quality is **satisfactory**, little or no risk	None
51 -100	Moderate	Air quality is acceptable; moderate concern for **unusually sensitive people** to **some pollutants**	Active children and adults, and people with respiratory disease, should **limit prolonged outdoor** exertion.
101-150	Unhealthy for Sensitive Groups	The general public is not likely to be affected. **Members of sensitive groups** may experience health effects.	Active children and adults, and people with respiratory disease, should **limit prolonged outdoor** exertion.
151-200	Unhealthy	**Everyone** may begin to experience health effects; members of sensitive groups may experience more **serious health effects**	Active children and adults, and people with respiratory disease, should **avoid prolonged outdoor** exertion; everyone else, especially children, should limit prolonged outdoor exertion
201-300	Very Unhealthy	Health warnings of **emergency** conditions. The entire population is more likely to be affected.	Active children and adults, and people with respiratory disease, should **avoid all outdoor** exertion; everyone else, especially children, should limit outdoor exertion.
300+	Hazardous	**Health alert**: everyone may experience more serious health effects	Everyone should **avoid all outdoor exertion**

aqicn.org/

What Comprises Air Quality, Objectives and Health Effects

AQI Category (Range)	PM_{10} (24hr) µg/m³	$PM_{2.5}$ (24hr) µg/m³	NO_2 (24hr) µg/m³	O_3 (8hr) µg/m³	CO (8hr) ??	SO_2 (24hr) µg/m³	NH_3 (24hr) µg/m³	Pb (24hr) µg/m³
Good (0–50)	0–50	0–30	0–40	0–50	0–1.0	0–40	0–200	0–0.5
Satisfactory (51–100)	51–100	31–60	41–80	51–100	1.1–2.0	41–80	201–400	0.5–1.0
Moderately polluted (101–200)	101–250	61–90	81–180	101–168	2.1–10	81–380	401–800	1.1–2.0
Poor (201–300)	251–350	91–120	181–280	169–208	10–17	381–800	801–1200	2.1–3.0
Very poor (301–400)	351–430	121–250	281–400	209–748	17–34	801–1600	1200–1800	3.1–3.5
Severe (401–500)	430+	250+	400+	748+	34+	1600+	1800+	3.5+

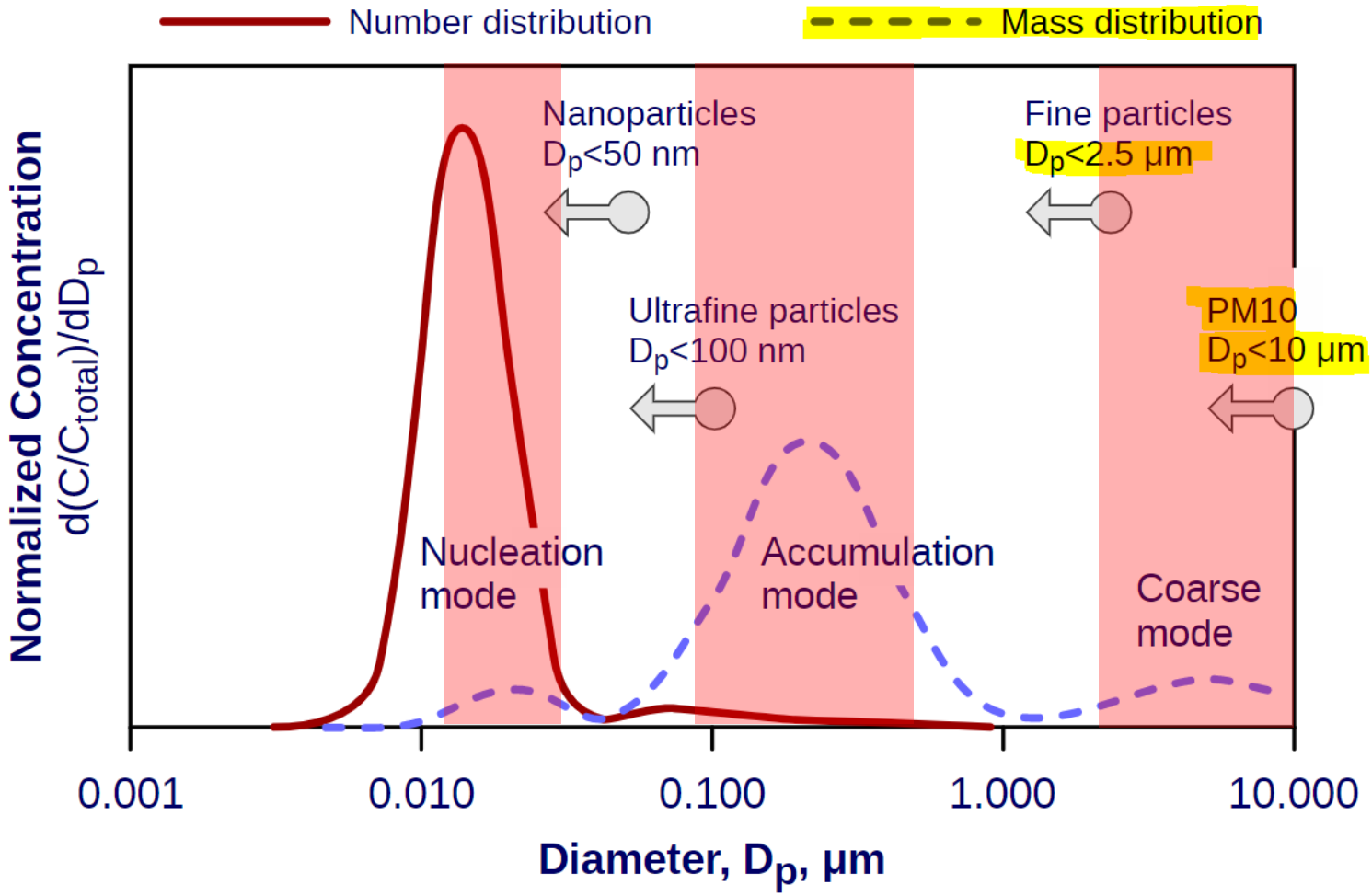
- Air pollution is a major environmental risk to health
- Reduced Life expectancy (9 months in EU, 14 years in LA, ~ 9 million deaths worldwide)
- Damage to the environment estimated at 330-940 billion EUR)

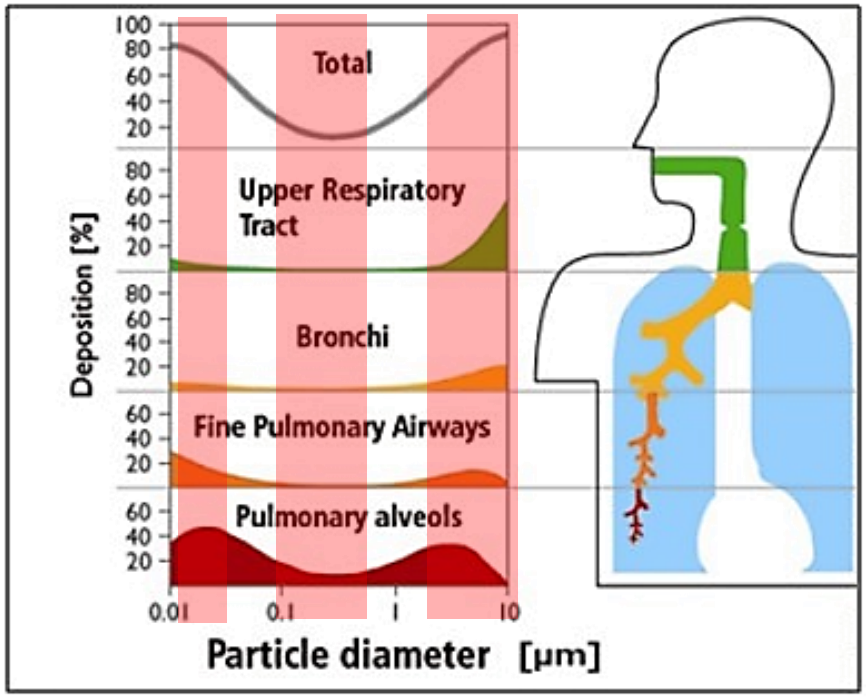
What Comprises Air Quality, Objectives and Health Effects

Pollutant	UK/ EU	Not to exceed	Measurement	Date	Health & Environmental Effects
PM_{10}	50 µg/m³ 40 µg/m³	35 times a year	24 hour mean Annual mean	>31 Dec 2004	**PM worst of all pollutants. Cardiopulmonary diseases (asthma, stroke, high blood pressure, inflammation in lungs- DPF) 2.5 micron particles are worse, aiding in cardiovascular cancer/ diseases, enter blood system.**
$PM_{2.5}$	25 µg/m³ Target 15% reduction in urban areas (EU 20%)		Annual mean	2020 2010-2020	
NO_x	200 µg/m³ 40 µg/m³	18 times a year	1 hour mean Annual Mean	31 Dec 2005	**Irritation of eyes, irritate airways, lung diseases, breathing problem, reduced lung function, bronchitis, Photo chemical smog formation; Forms H_2SO_4, catalysed by NO_x to form Acid Rain (destruction of plant life)**
Ground level Ozone	100 µg/m³ (EU 120 µg/m³)	10 times a year 25 times a year avg over 3 years	8 hour mean	31 Dec 2005	
SO_x	266 µg/m³ 350 µg/m³ 125 µg/m³	35 times a year 24 times a year 3 times a year	15 min mean 1 hour mean 24 hour mean	31 Dec 2005 31 Dec 2004 31 Dec 2004	
CO	10 mg/m³		maximum daily running 8 hour mean	31 Dec 2003	**Toxic- reduced O_2 in blood, heart diseases, Smog Formation, Lung diseases. (~50% CO is from transportation)**
Lead	0.5 µg/m³			31 Dec 2004	**Reduced lung capacity, accumulation in bones, affects nervous system, kidney, immune and reproductive system, brain damage**

- Air pollution is a major environmental risk to health
- Reduced Life expectancy (9 months in EU, 14 years in LA, ~ 9 million deaths worldwide)
- Damage to the environment estimated at 330-940 billion EUR)

PM Distribution from Diesel Exhaust

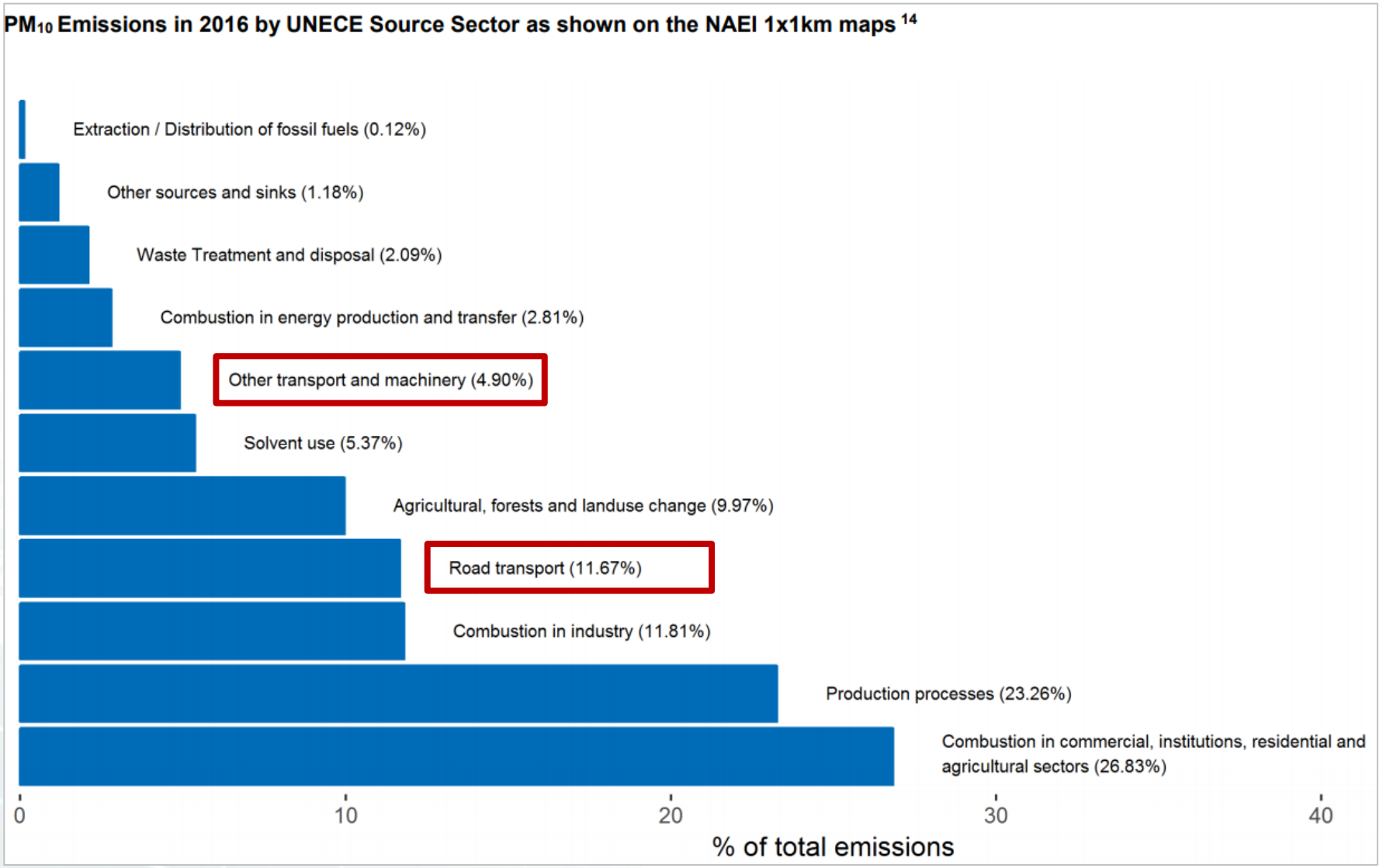




Recent measurements of nanoparticle emissions from engines, D.B. Kittelson
dieselnet.com/tech/dpm_size.php

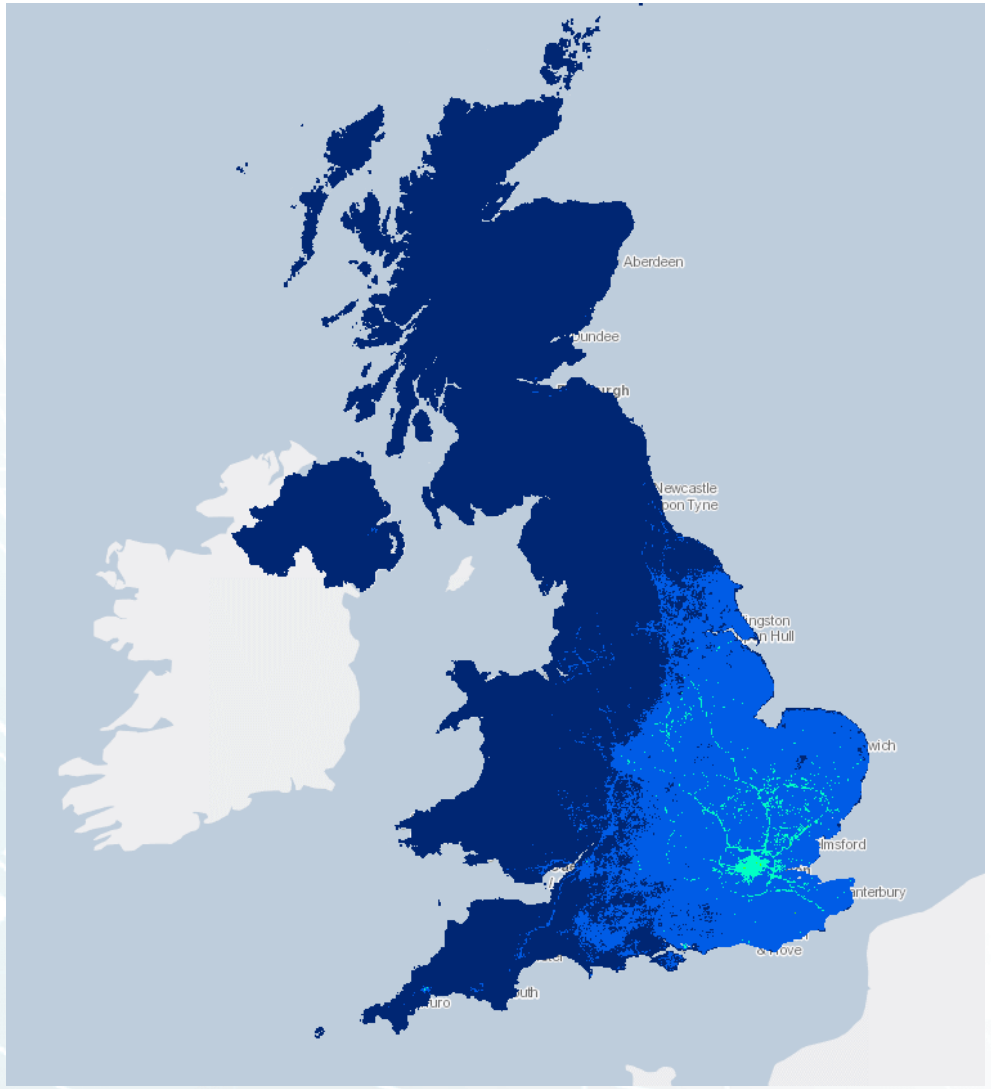
Sources of Pollution

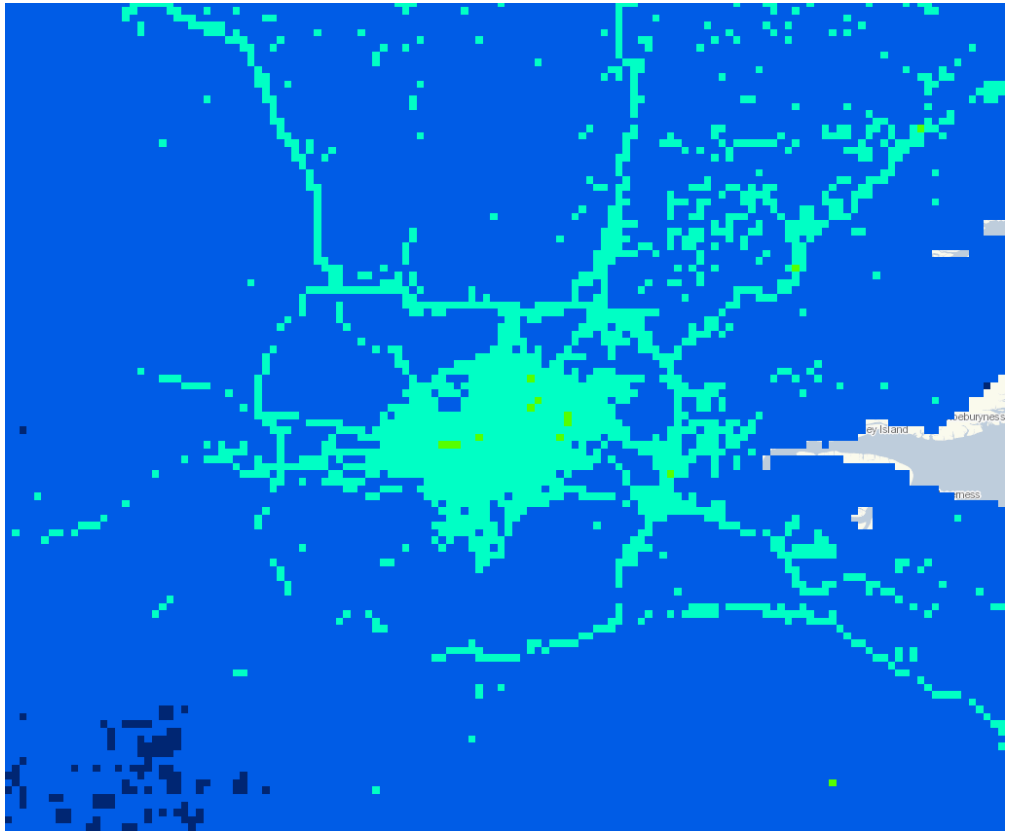
UK PM_{10} Sources of Pollution 2016



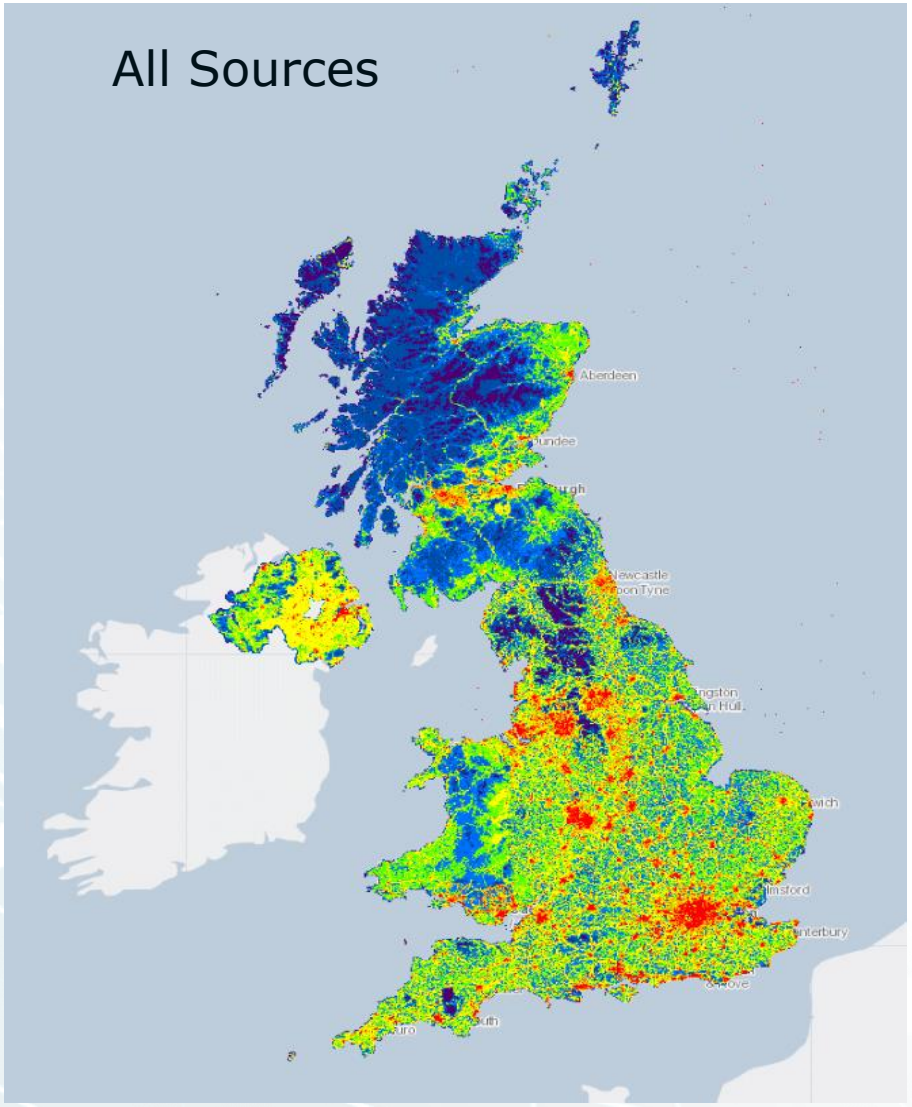
uk-air.defra.gov.uk/

PM_{10} Annual Mean ($\mu g/m^3$)





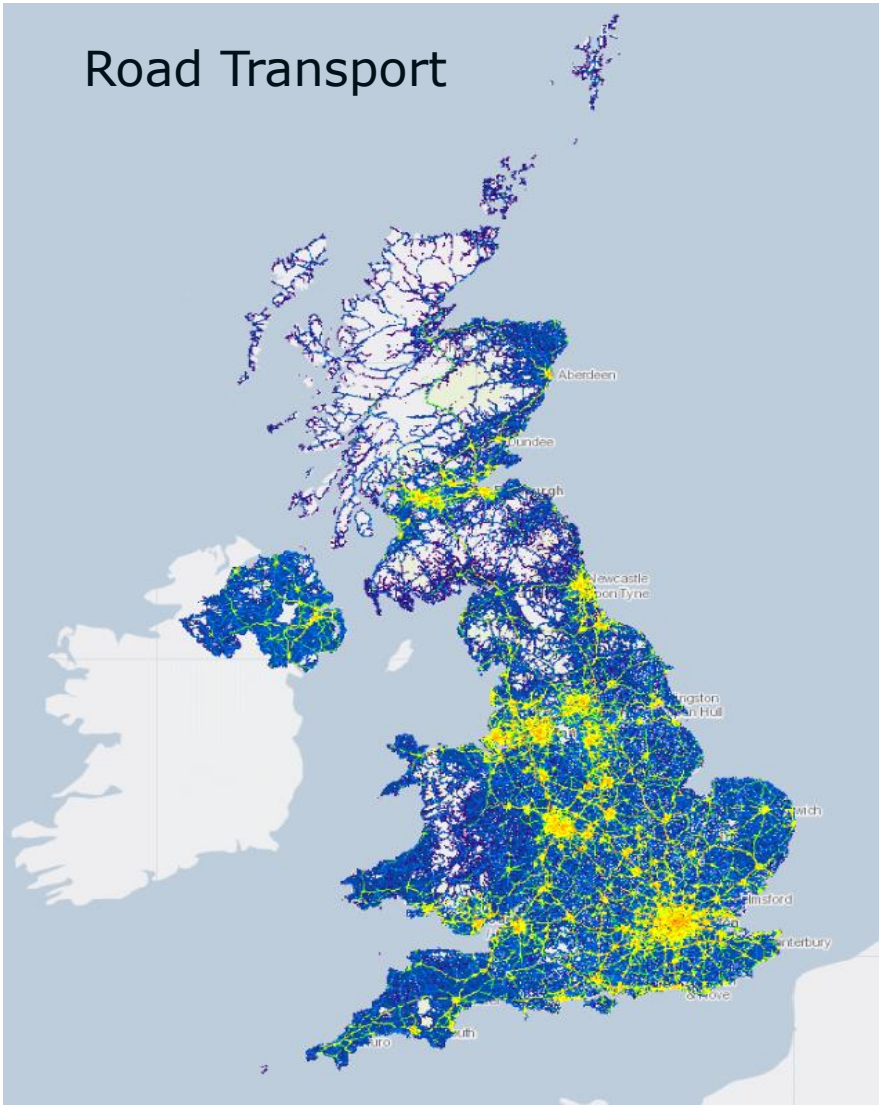
PM_{10} Surface Concentration



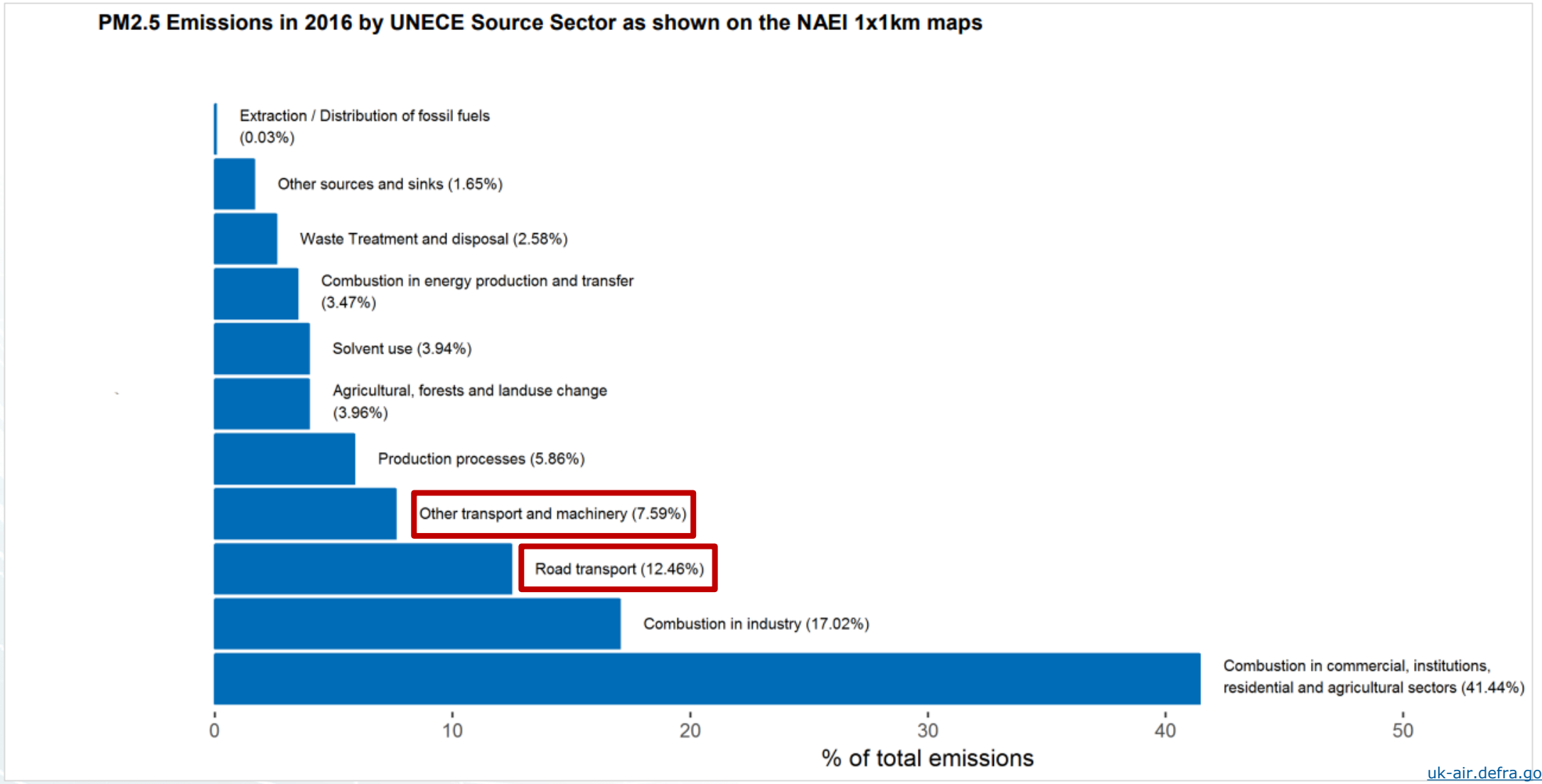
PM_{10} (Particulate Matter < 10µm)

Units t/1x1km

- < 0.003
- 0.003-0.03
- 0.03-0.1
- 0.1-0.2
- 0.2-1
- 1-4
- > 4

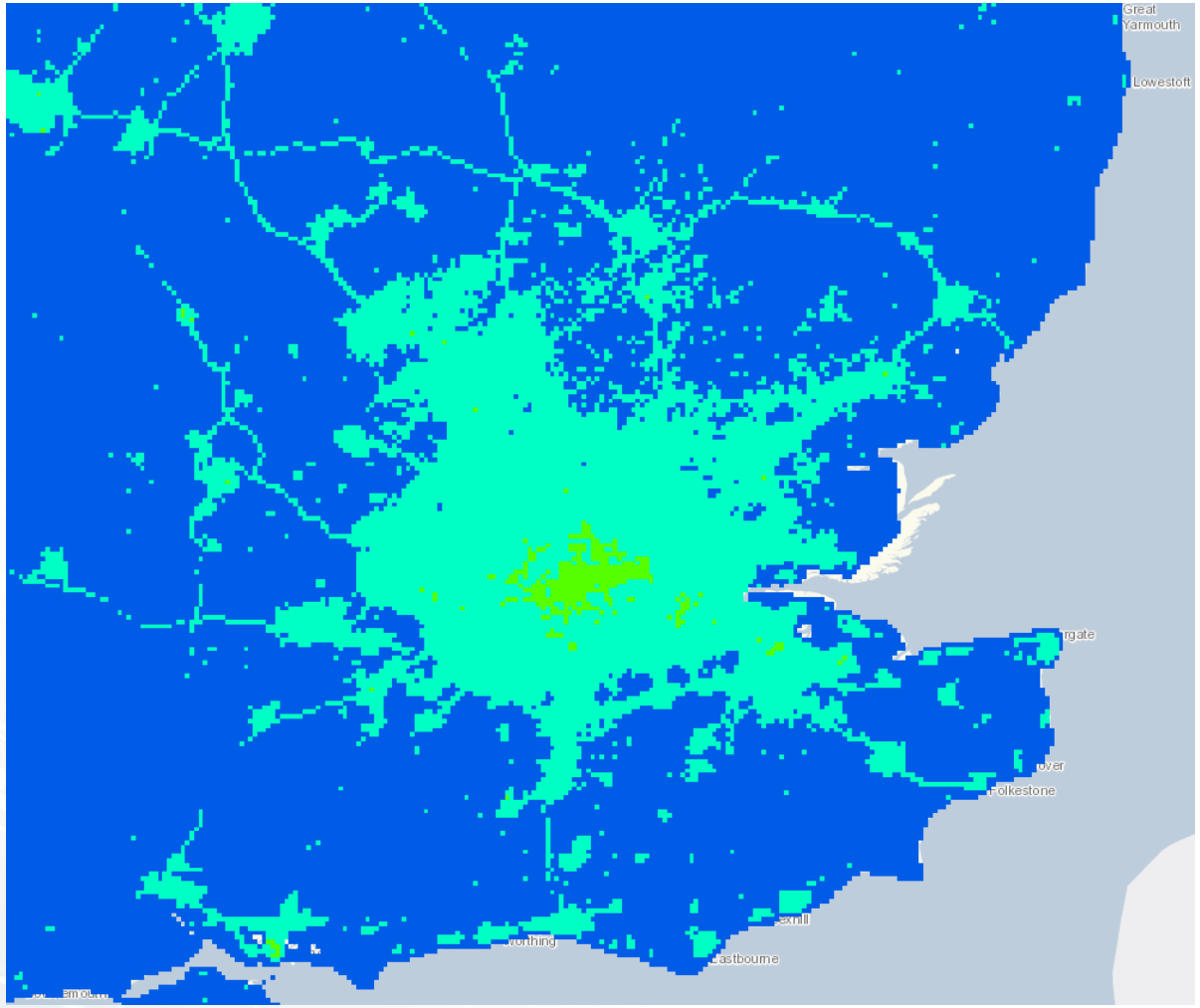


UK $PM_{2.5}$ Sources of Pollution 2016

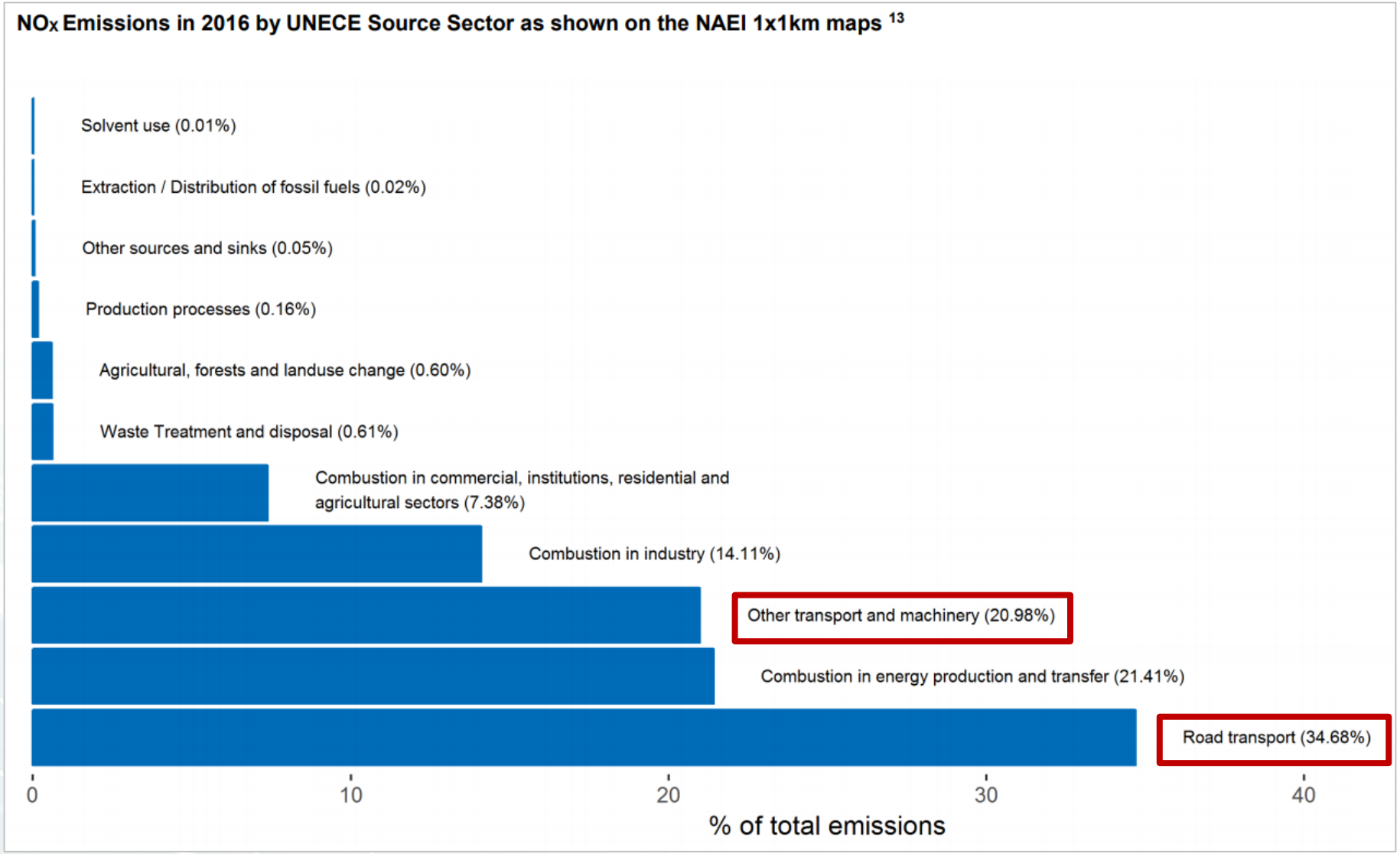


uk-air.defra.gov.uk/

$PM_{2.5}$ Annual Mean ($\mu g/m^3$)

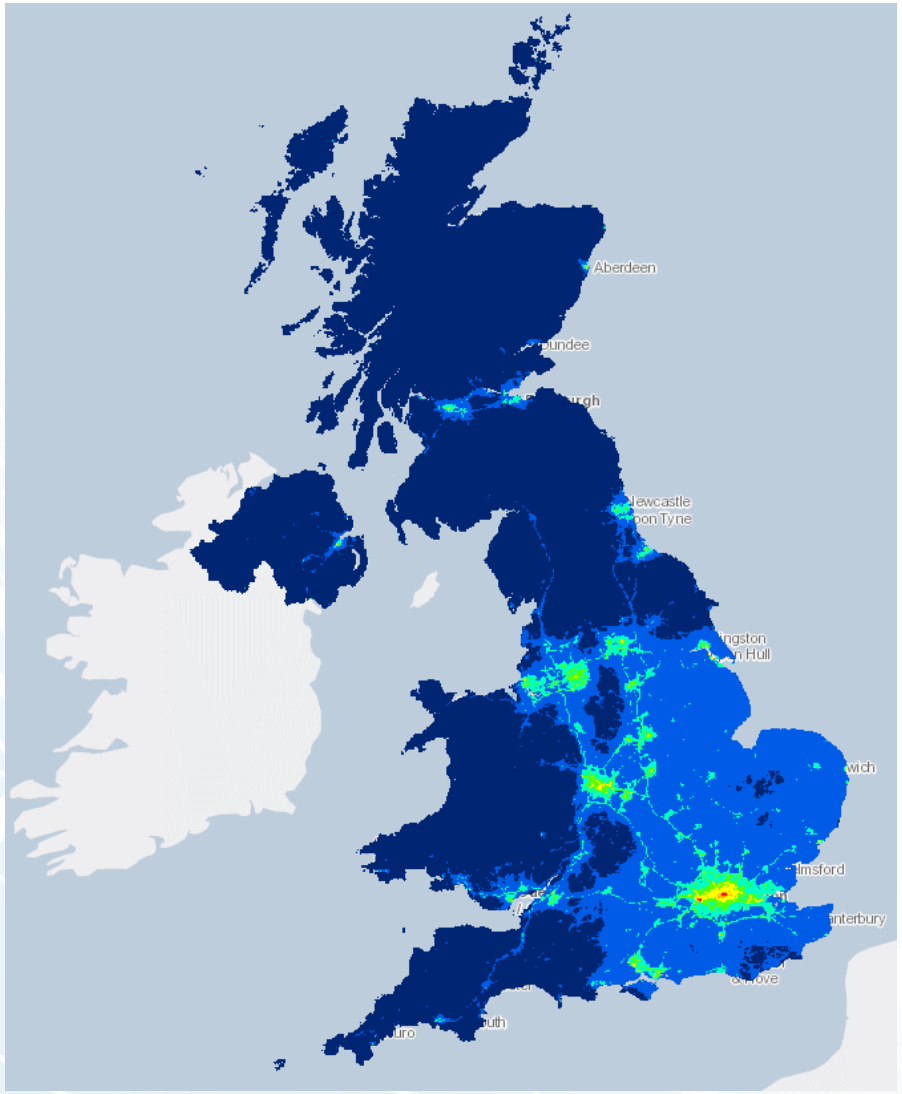


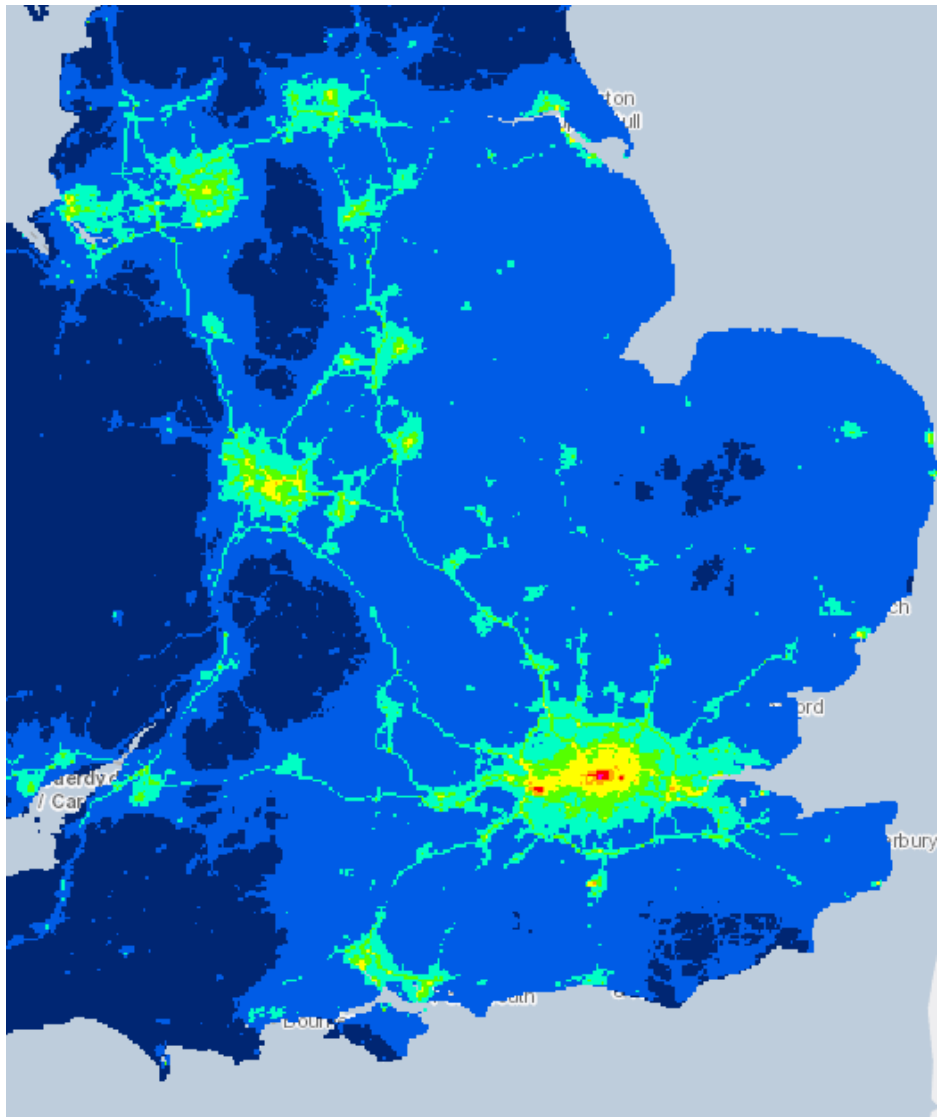
UK NO_x Sources of Pollution 2016



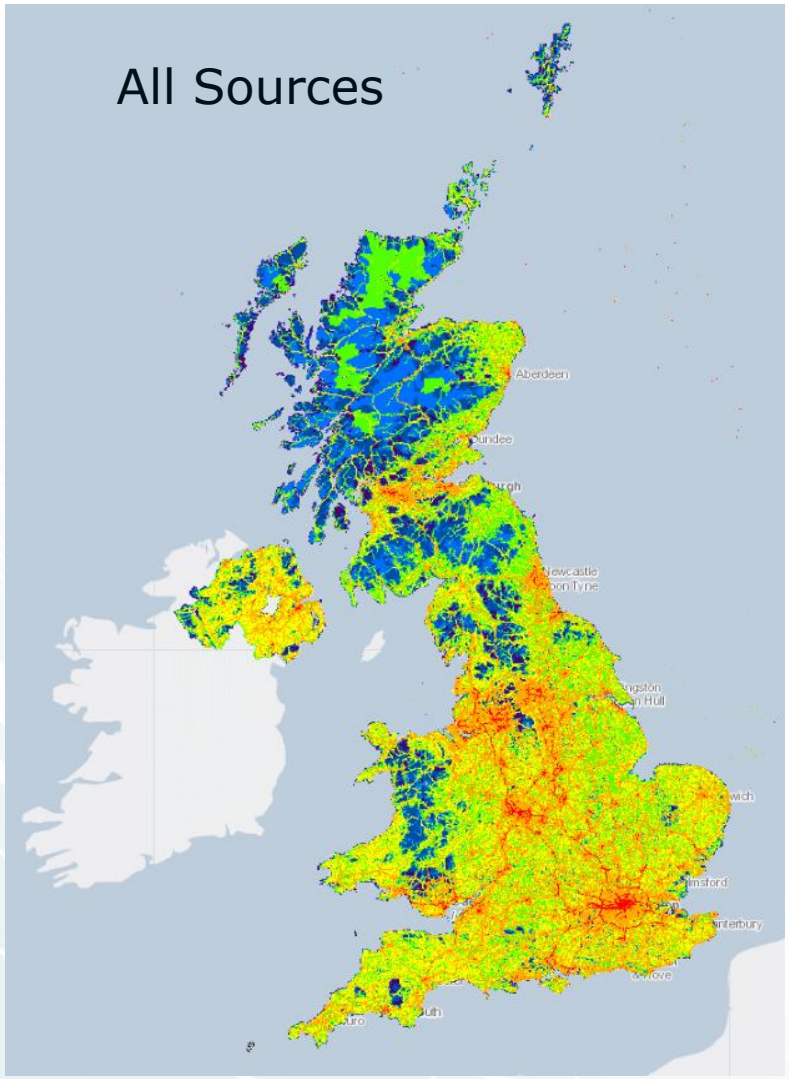
uk-air.defra.gov.uk

NO_x Annual Mean ($\mu g/m^3$)





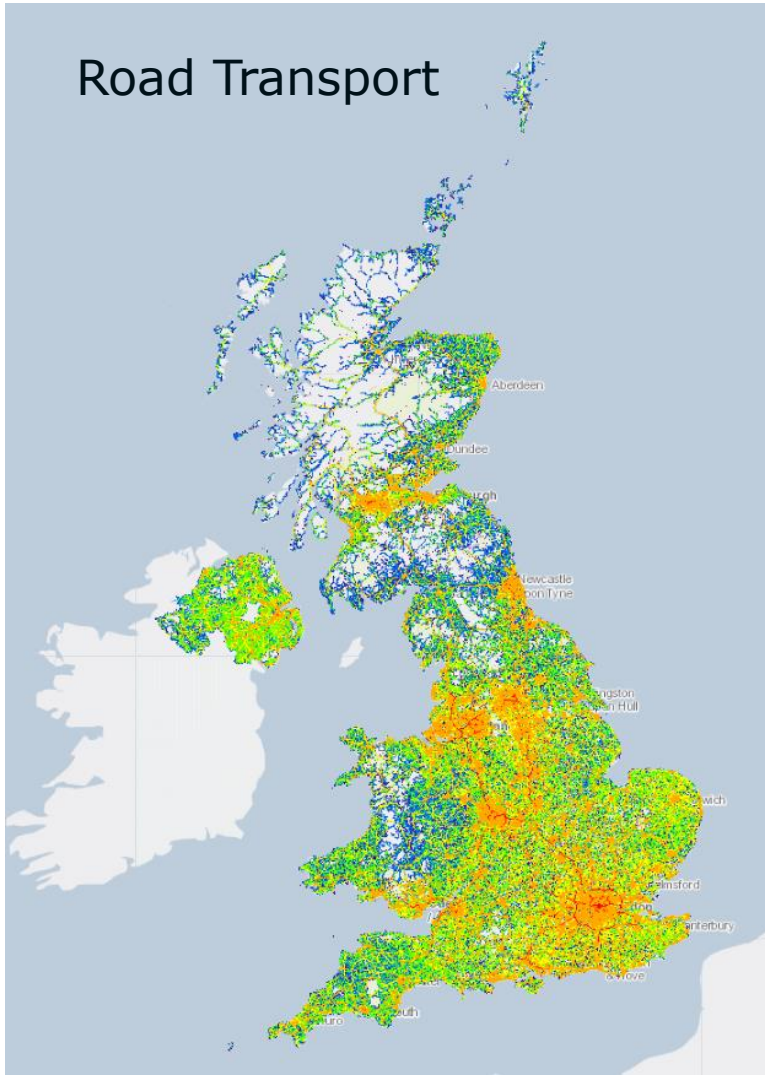
NO_x Surface Concentration



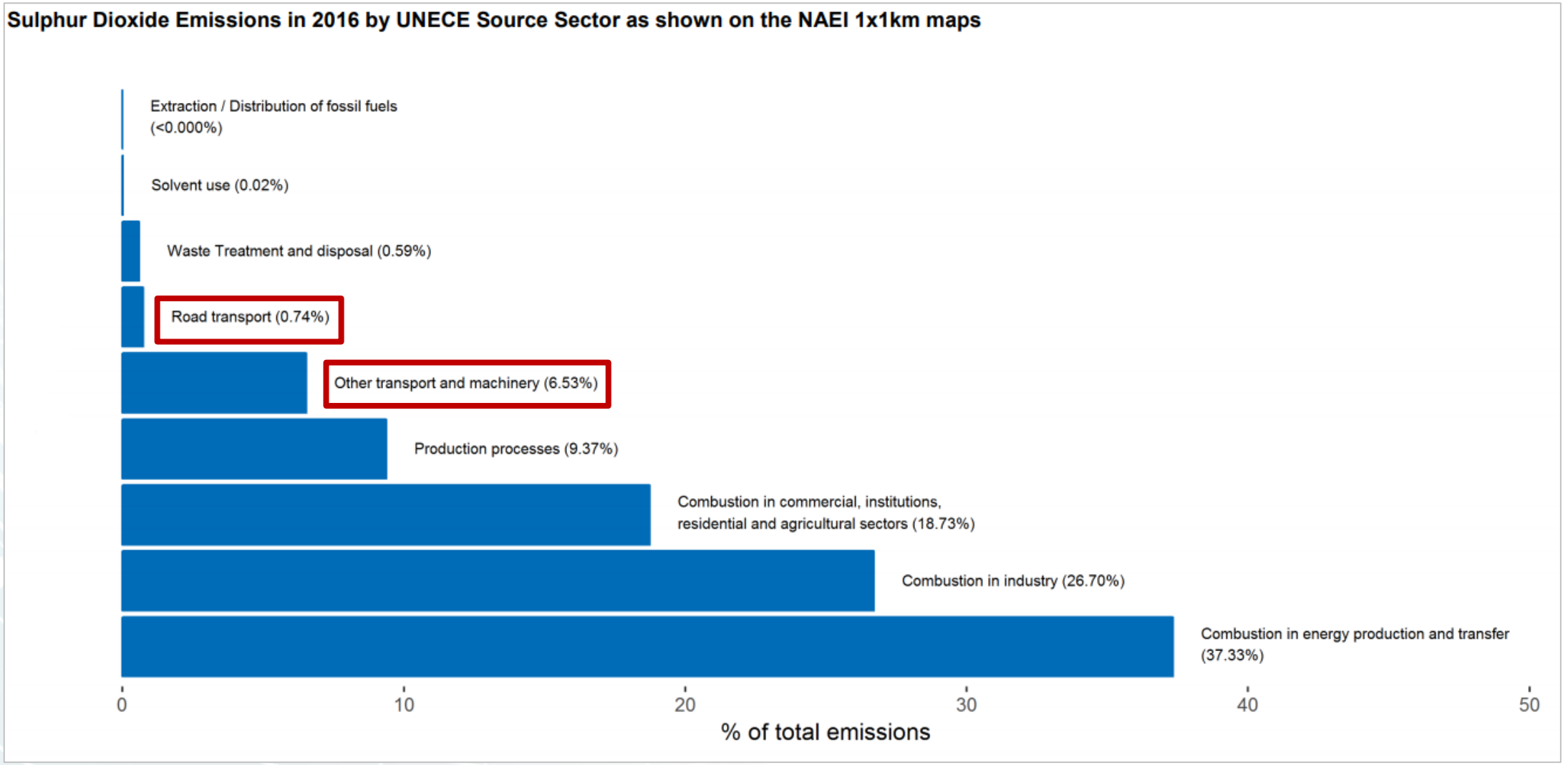
Nitrogen Oxides as NO_2

Units t/1x1km

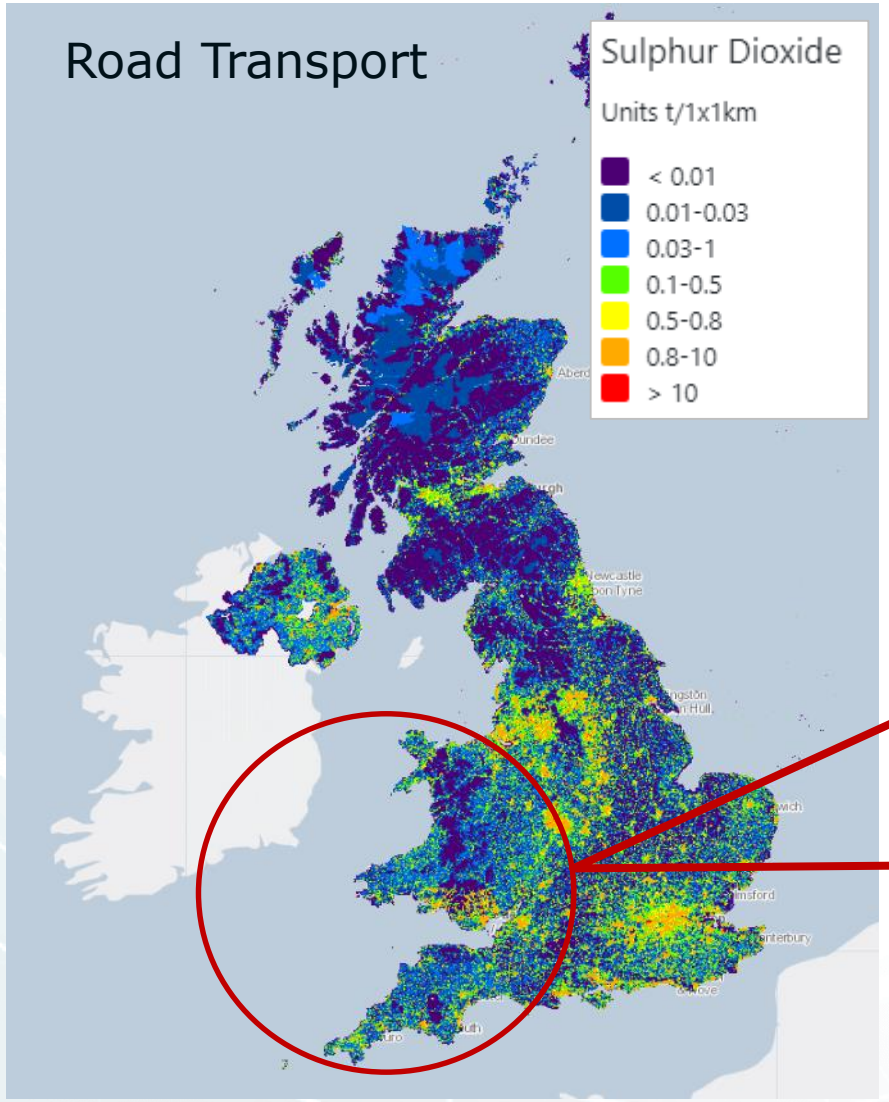
- < 0.01
- 0.01-0.03
- 0.03-0.1
- 0.1-0.3
- 0.3-1
- 1-25
- > 25



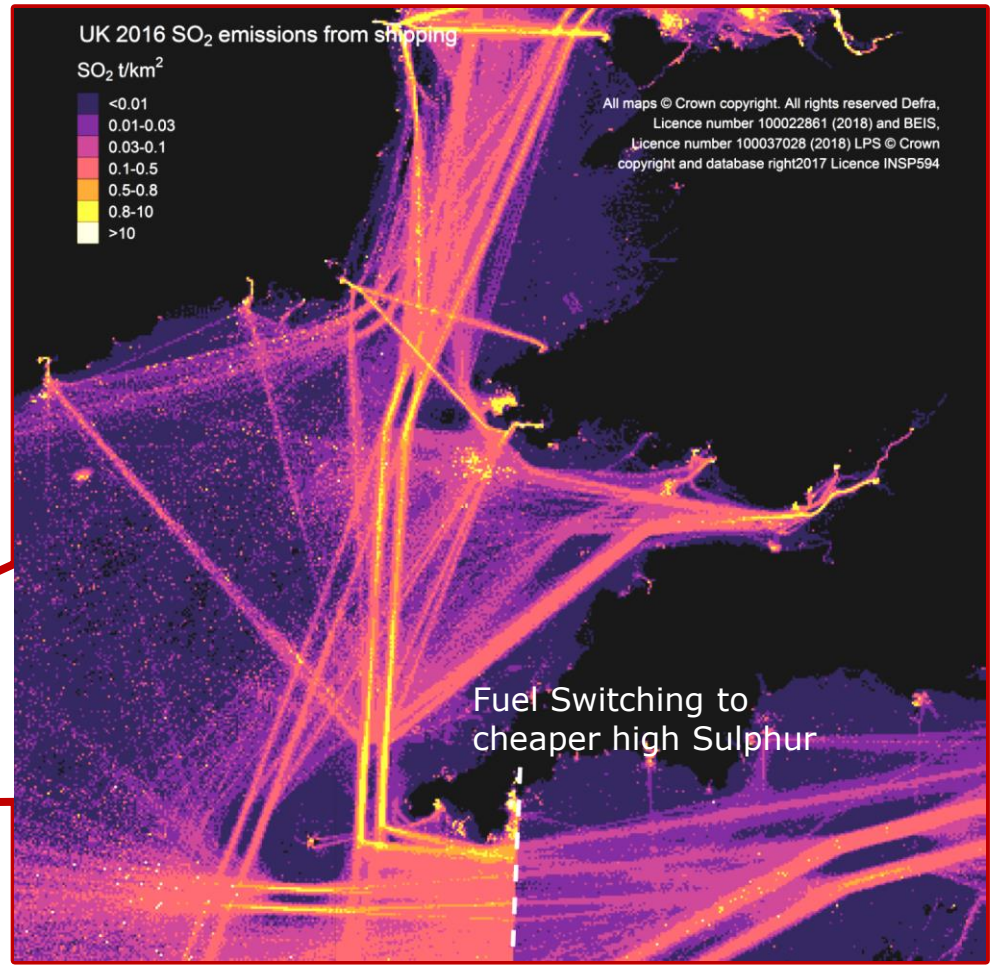
UK SO_x Sources of Pollution 2016



SO_x Surface Concentration



Shipping



Press

European car industry defends emissions standards amid TRUE Initiative media storm

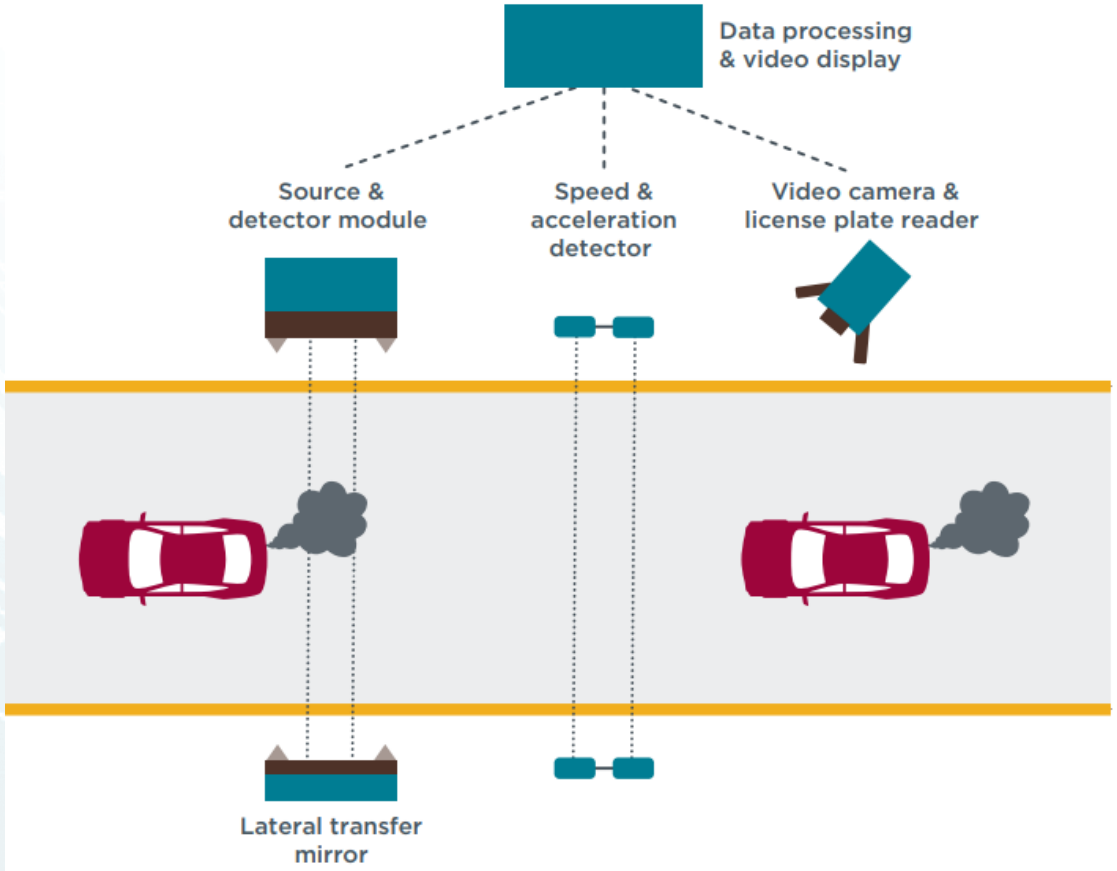
BASICS OF REMOTE SENSING

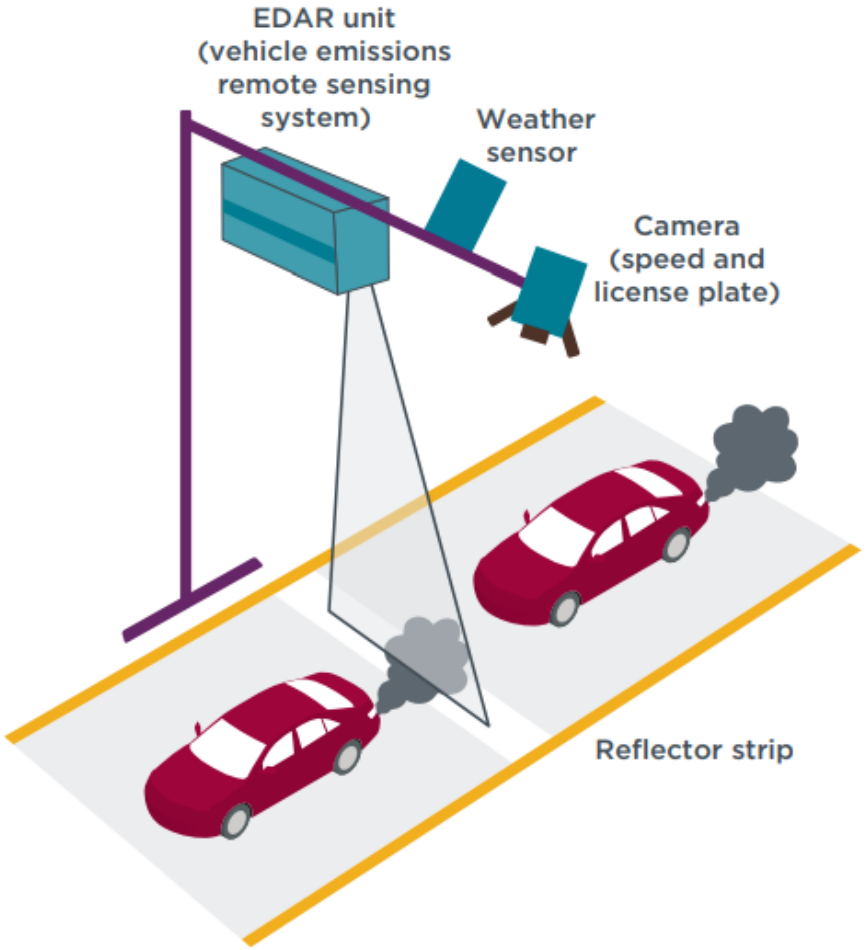
- Remote sensing is a non-intrusive technique that uses spectroscopy to capture a snapshot of a vehicle's emissions—typically, about one second's worth—as it drives by a sampling location.
- When many samples have been collected, from vehicles in many different operating states, at different speeds and engine loads, in different locations (urban, rural) and varying ambient conditions, statistical methods can be used to calculate an accurate picture of the average emissions of a given vehicle model.

Remote sensing of motor vehicle emissions in London

trueinitiative.org/data

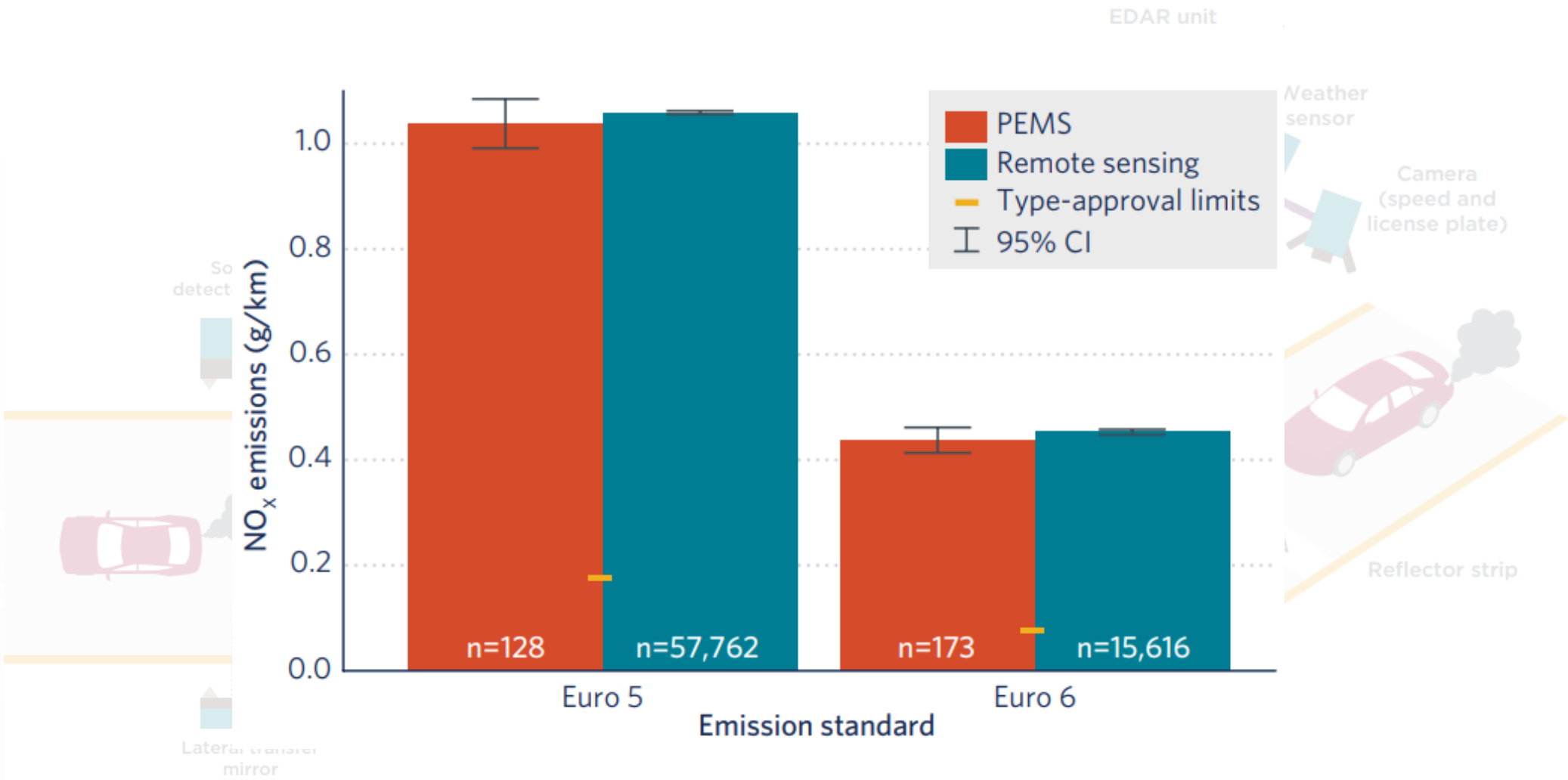
Remote Sensing





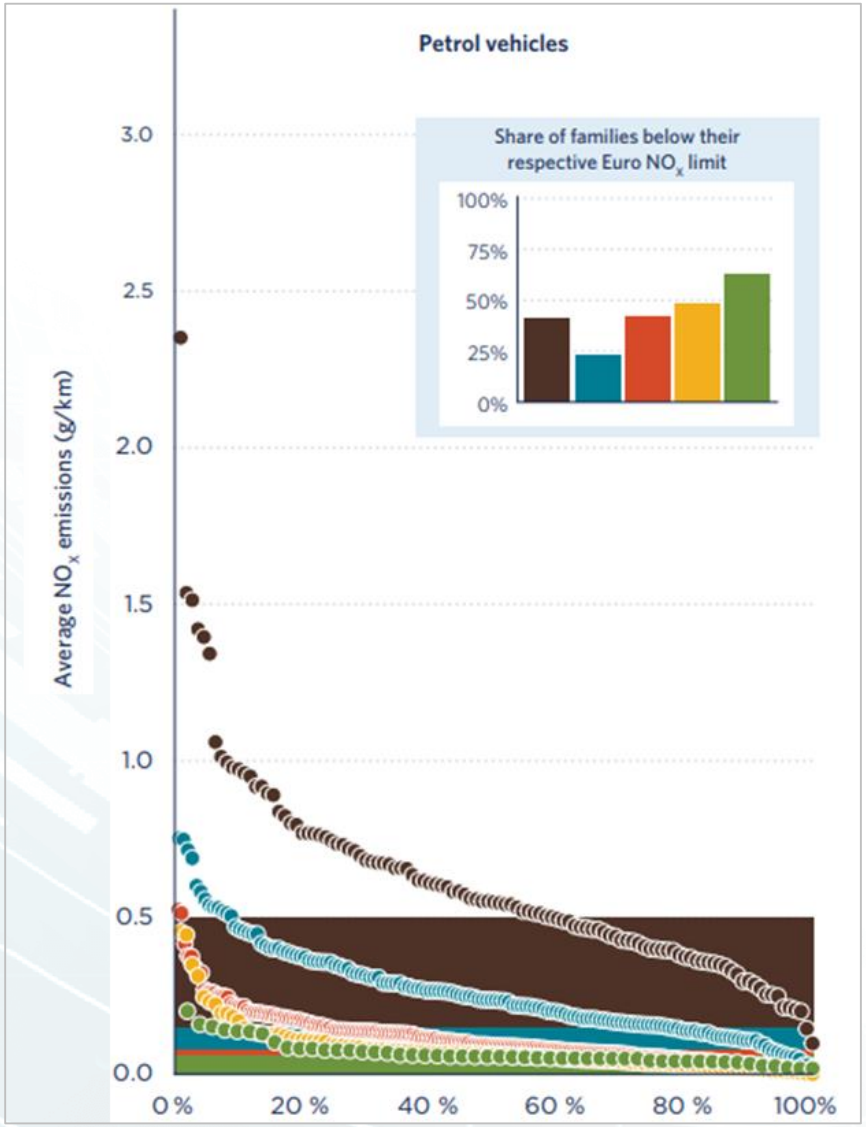
trueinitiative.org/data

Remote Sensing

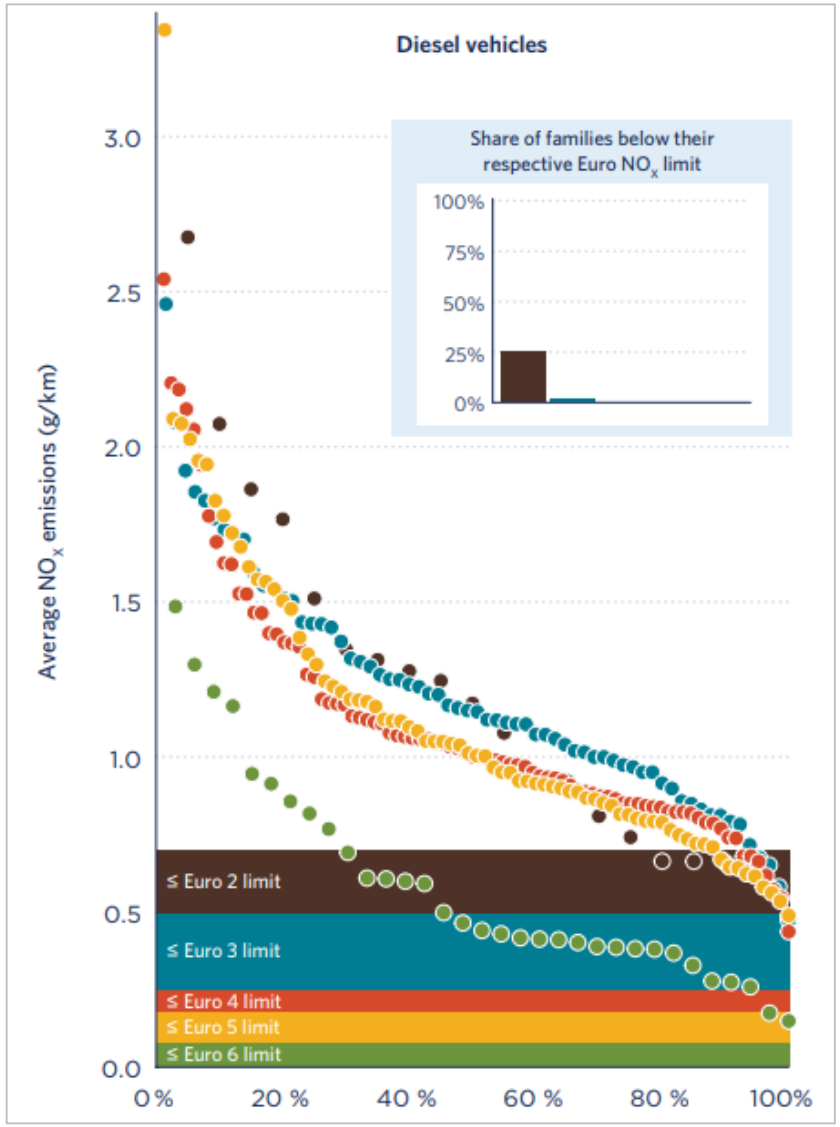


trueinitiative.org/data

Results: Avg NO_x Emissions

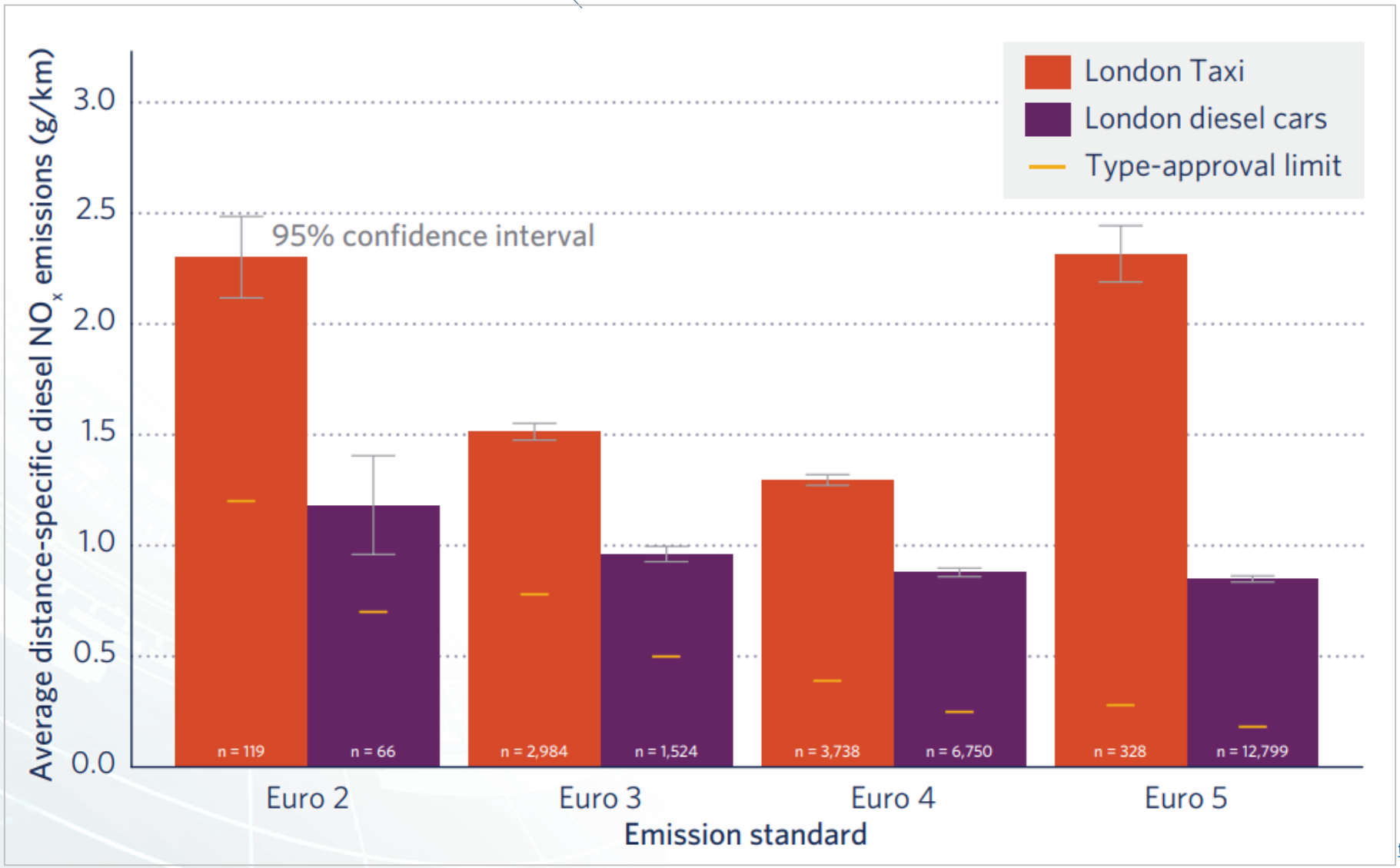


Euro 2
Euro 3
Euro 4
Euro 5
Euro 6



trueinitiative.org/data

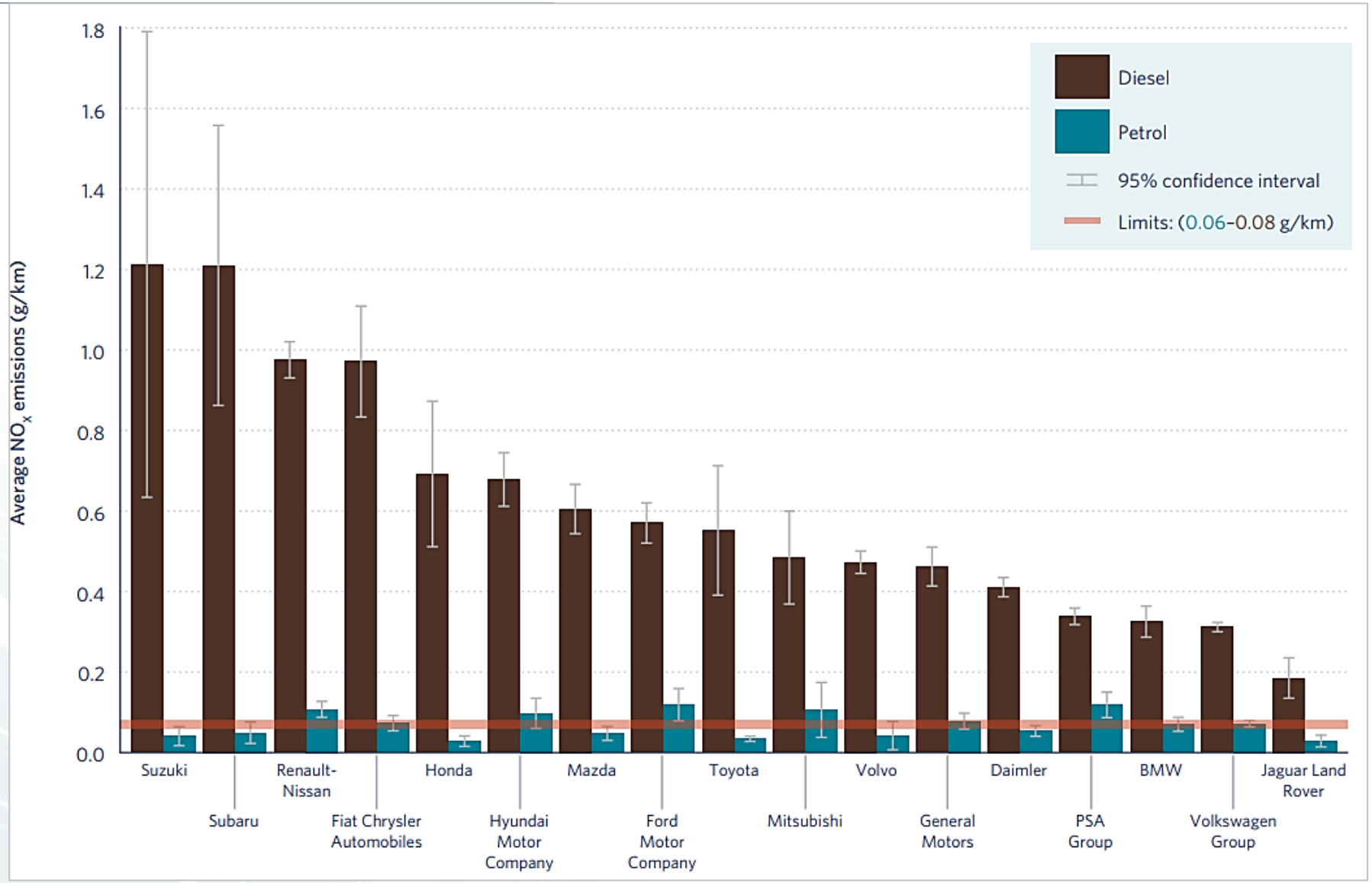
Results: Worst Offenders



trueinitiative.org/data

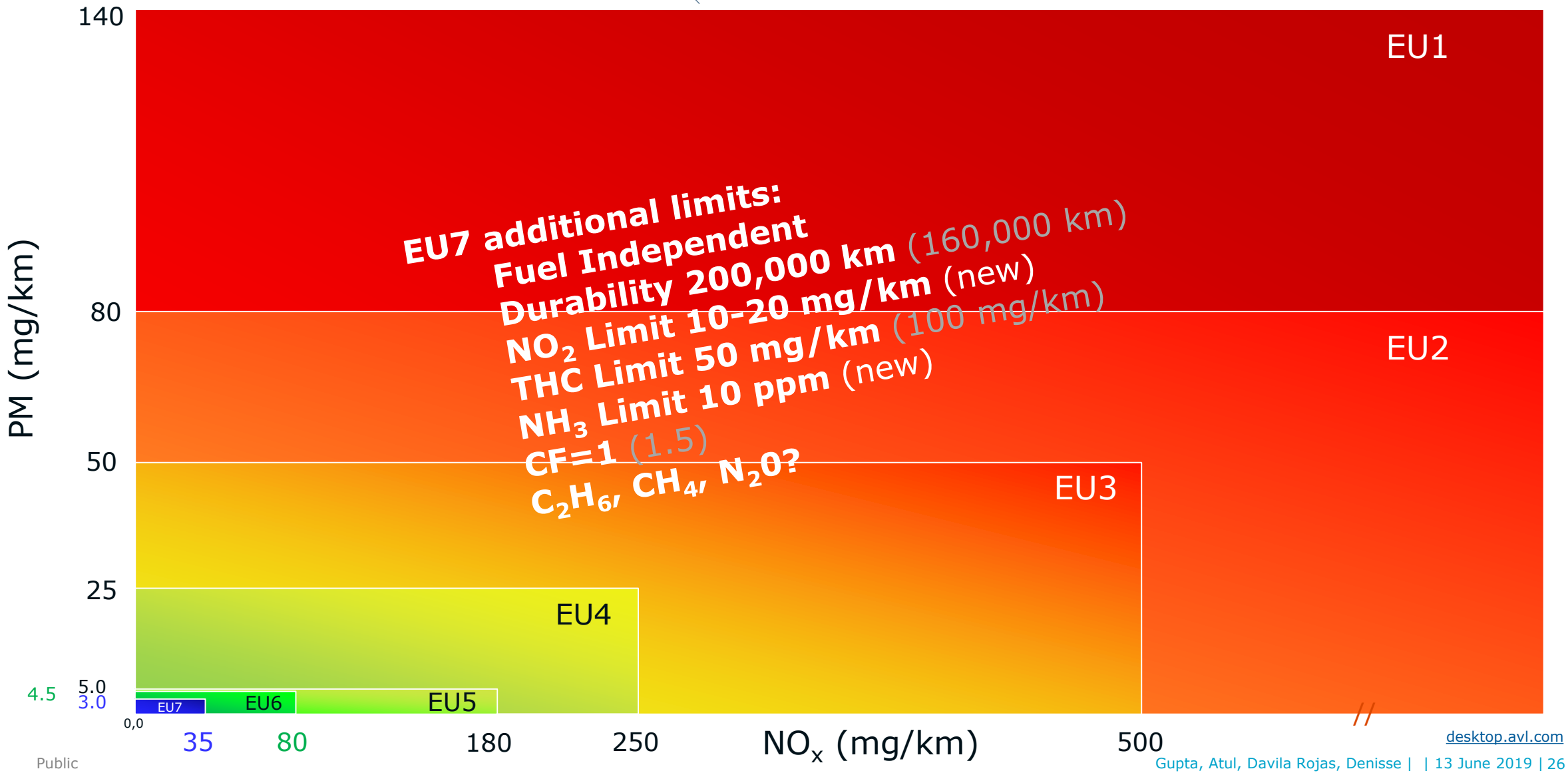
Results: Manufacturer Comparison (NO_x)

London
2017-18
Data



trueinitiative.org/data

Next Steps: Euro Emission Standards (Diesel)



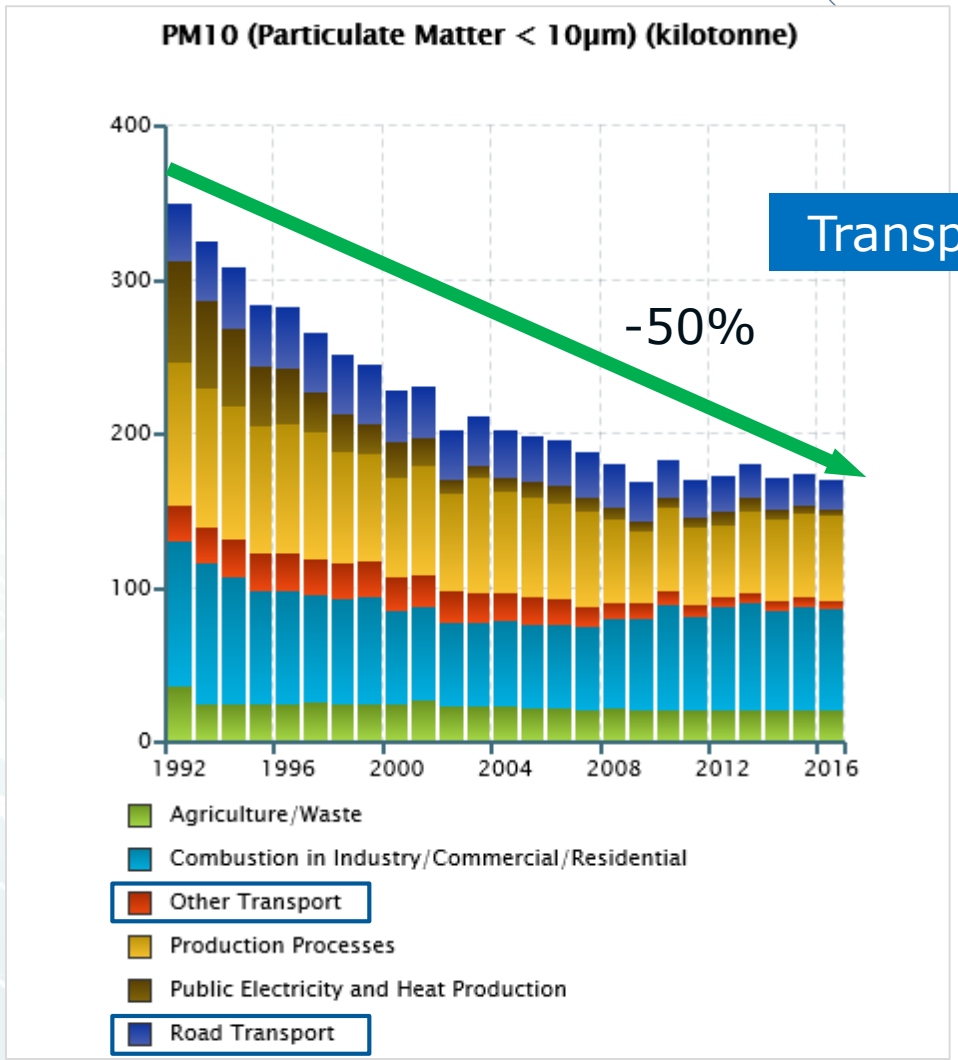
Next Steps in Improving Air Quality

20 June 2019

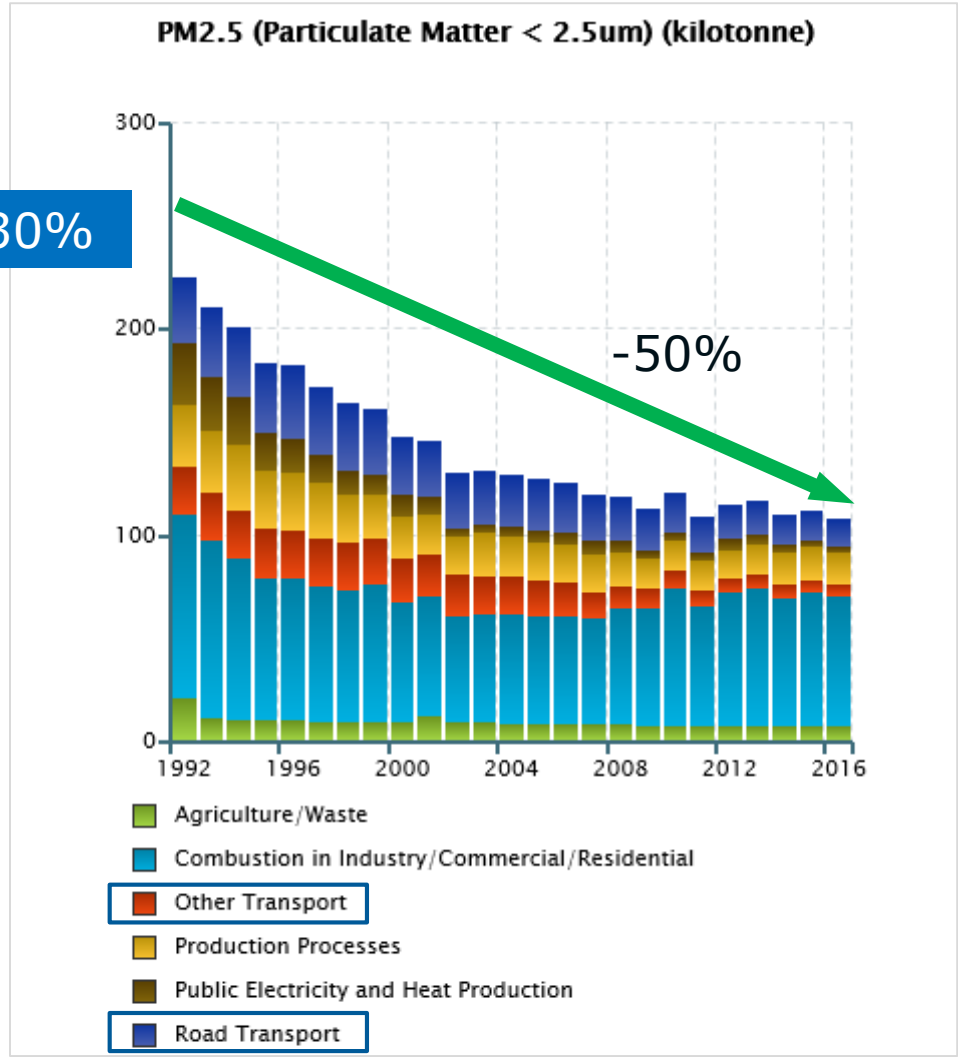
CleanAirDay

Emission Trends

UK PM Air Pollution Trends



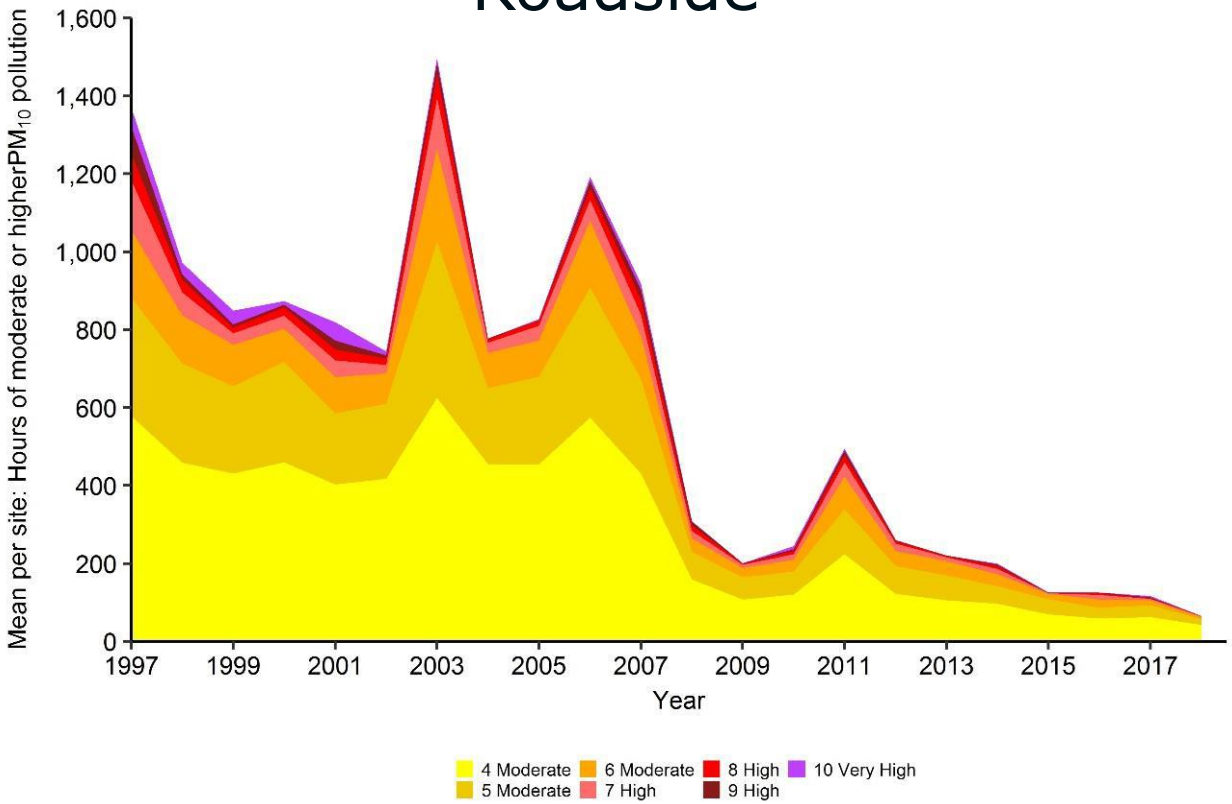
Transport -30%



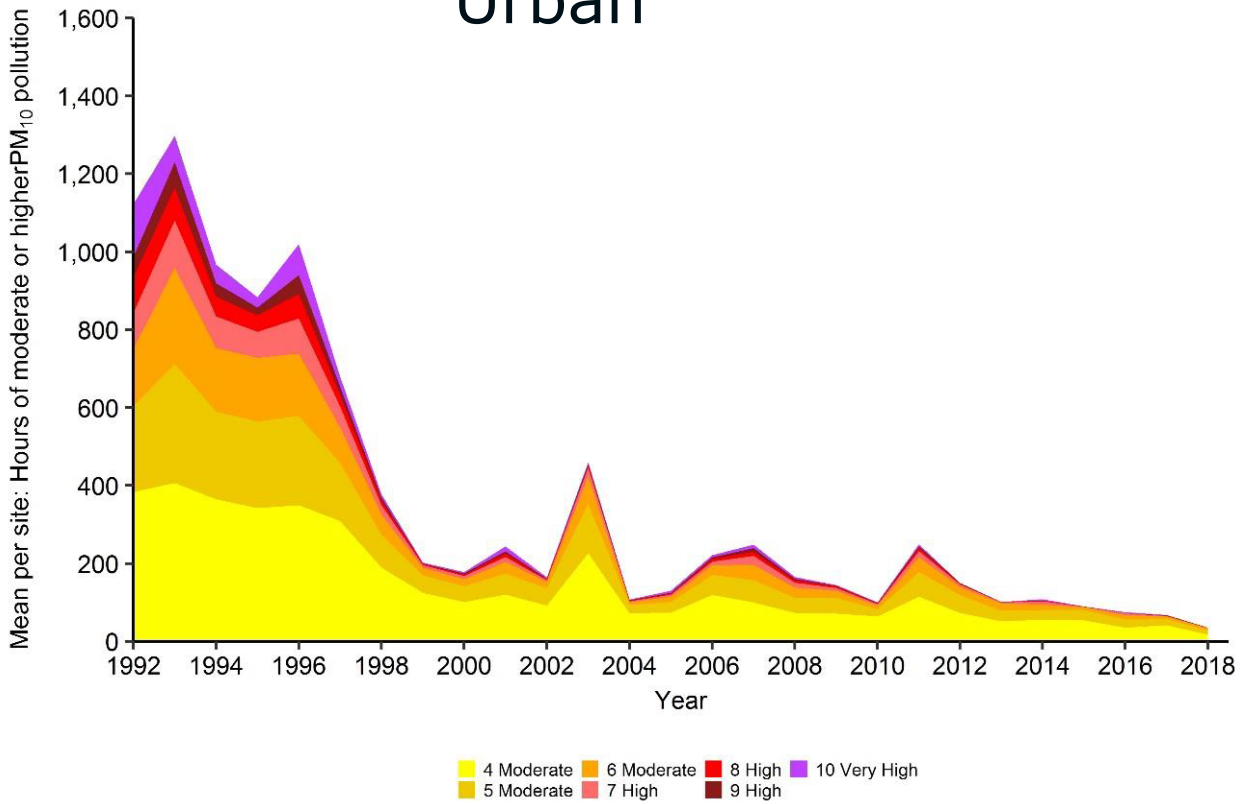
Air Pollution in the UK 2017, DEFRA

PM_{10} Annual Mean Hours Exceedance

Roadside



Urban

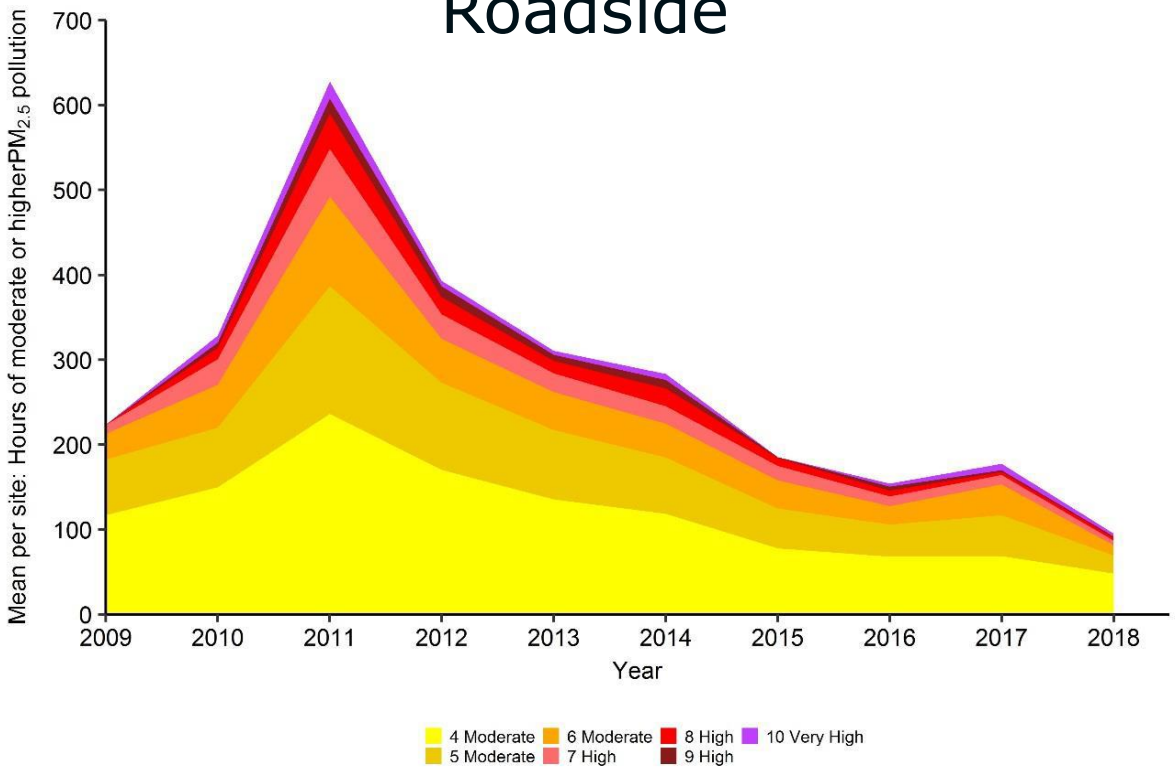


Exceedance 50 µg/m^3 / 24hrs running mean

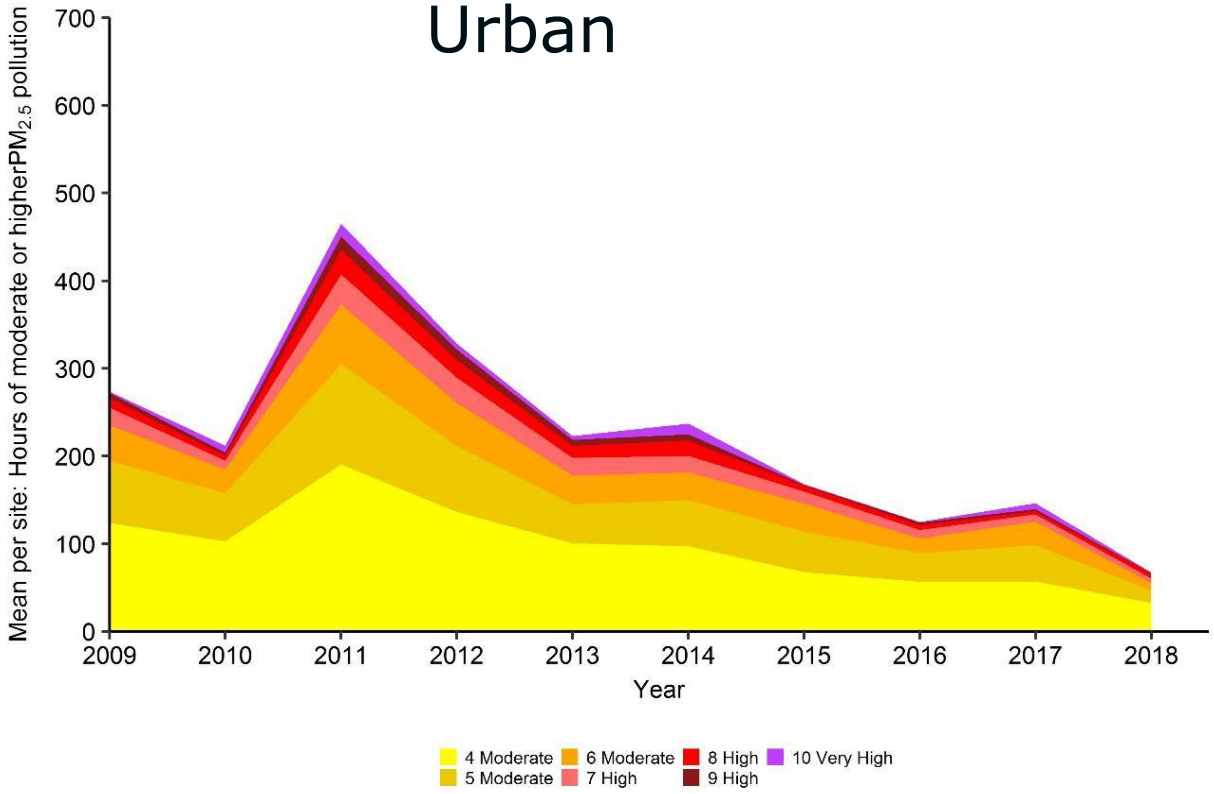
Defra National Statistics Release: Air quality statistics in the UK 1987 to 2018

$PM_{2.5}$ Annual Mean Hours Exceedance

Roadside



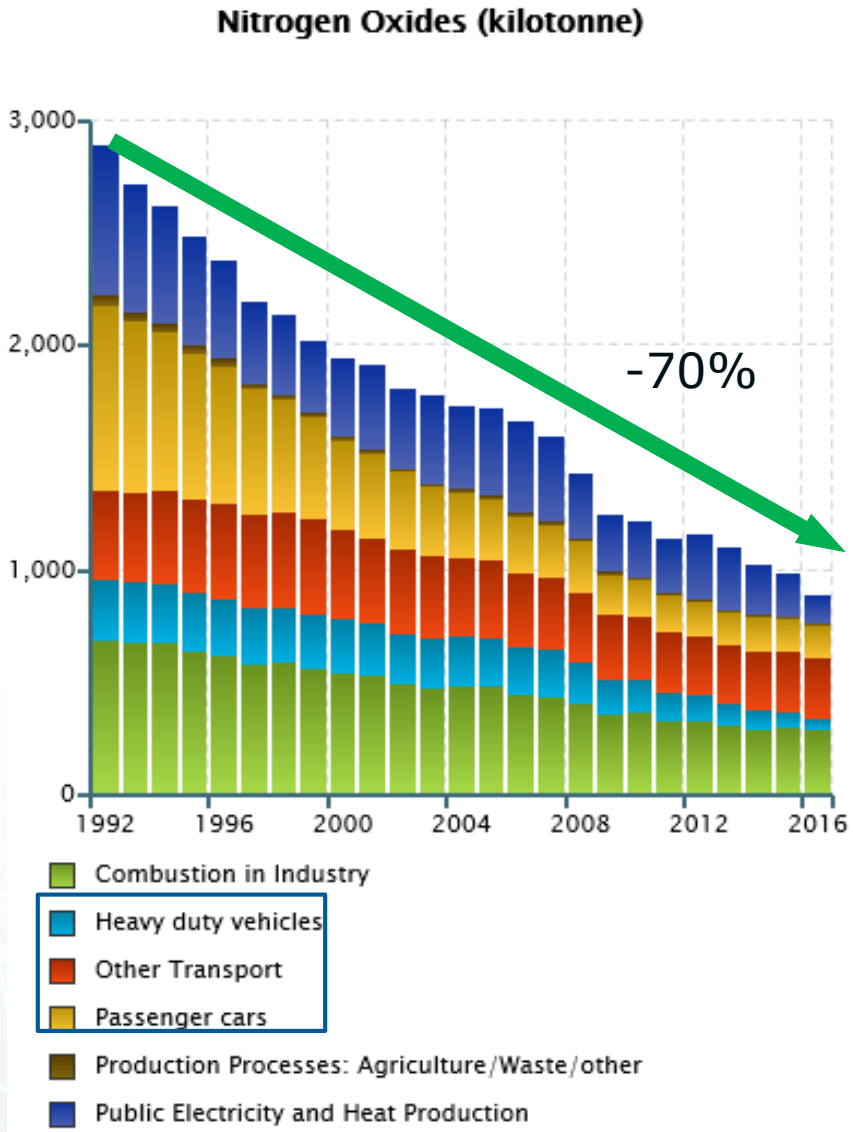
Urban



Exceedance 35 µg/m^3 / 24hrs running mean

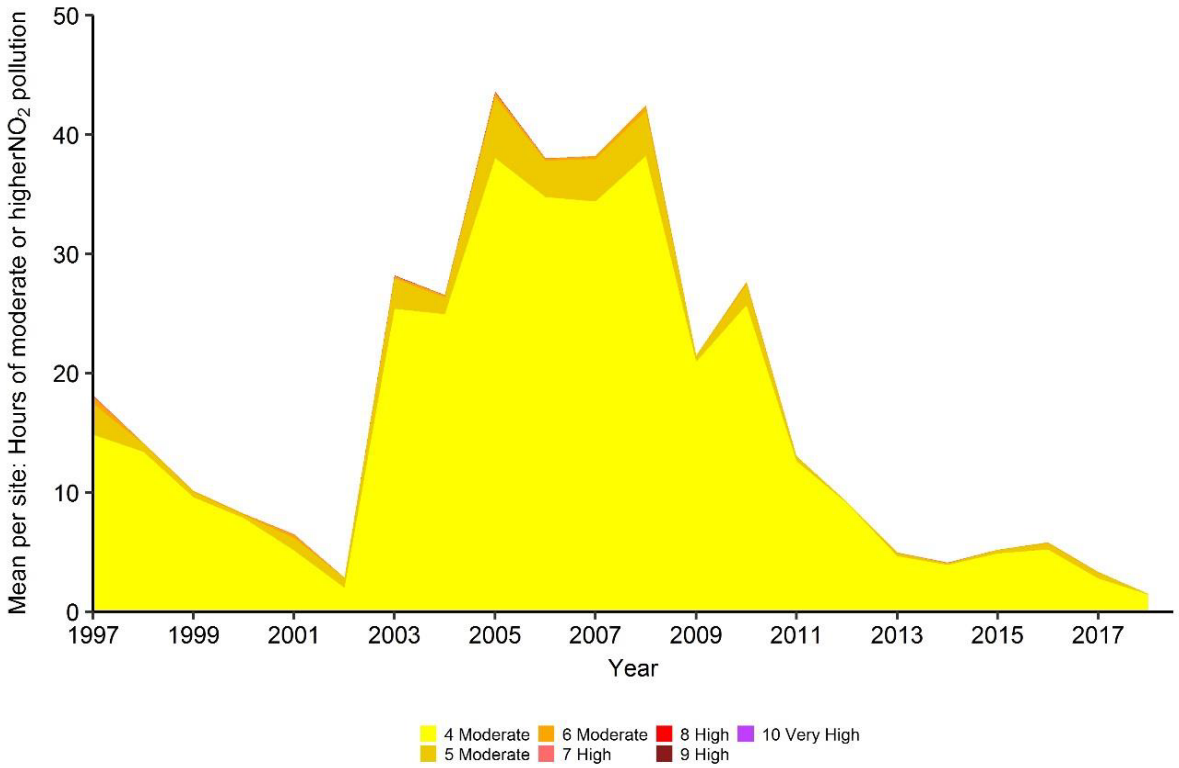
Defra National Statistics Release: Air quality statistics in the UK 1987 to 2018

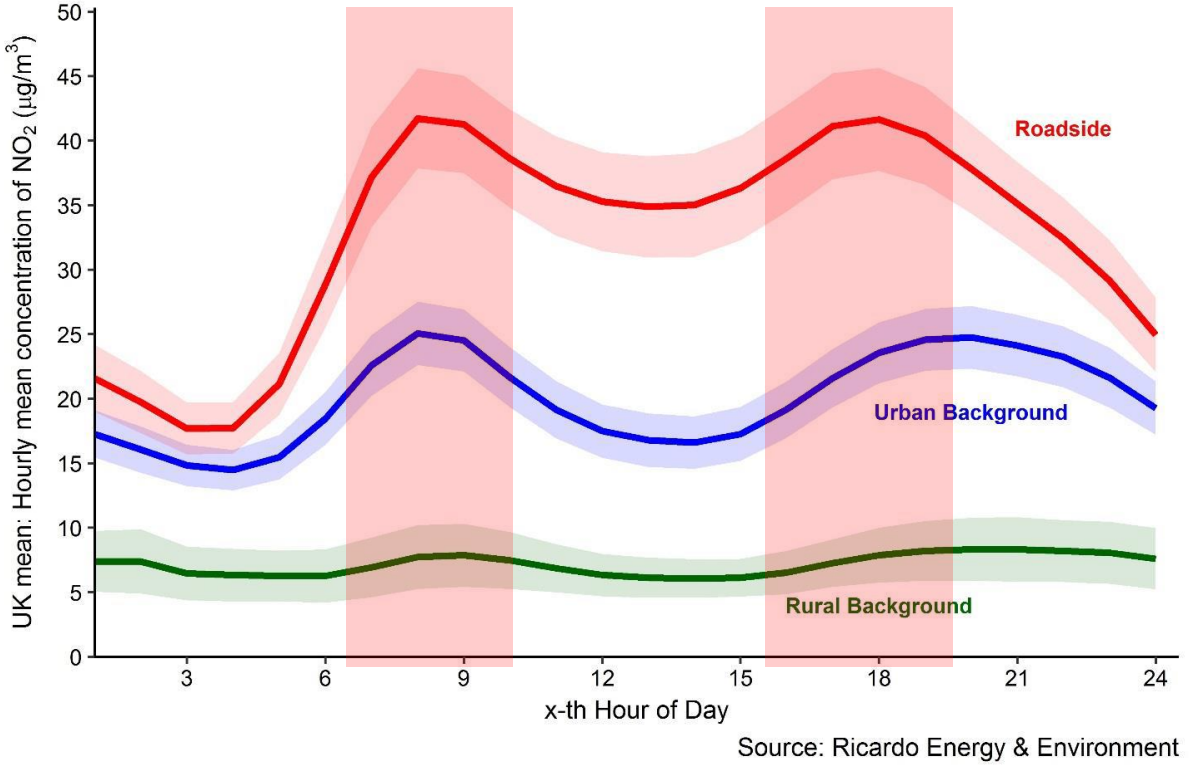
UK NO_x Air Pollution Trends



Air Pollution in the UK 2017, DEFRA

NO_2 Annual Mean Hours Exceedance

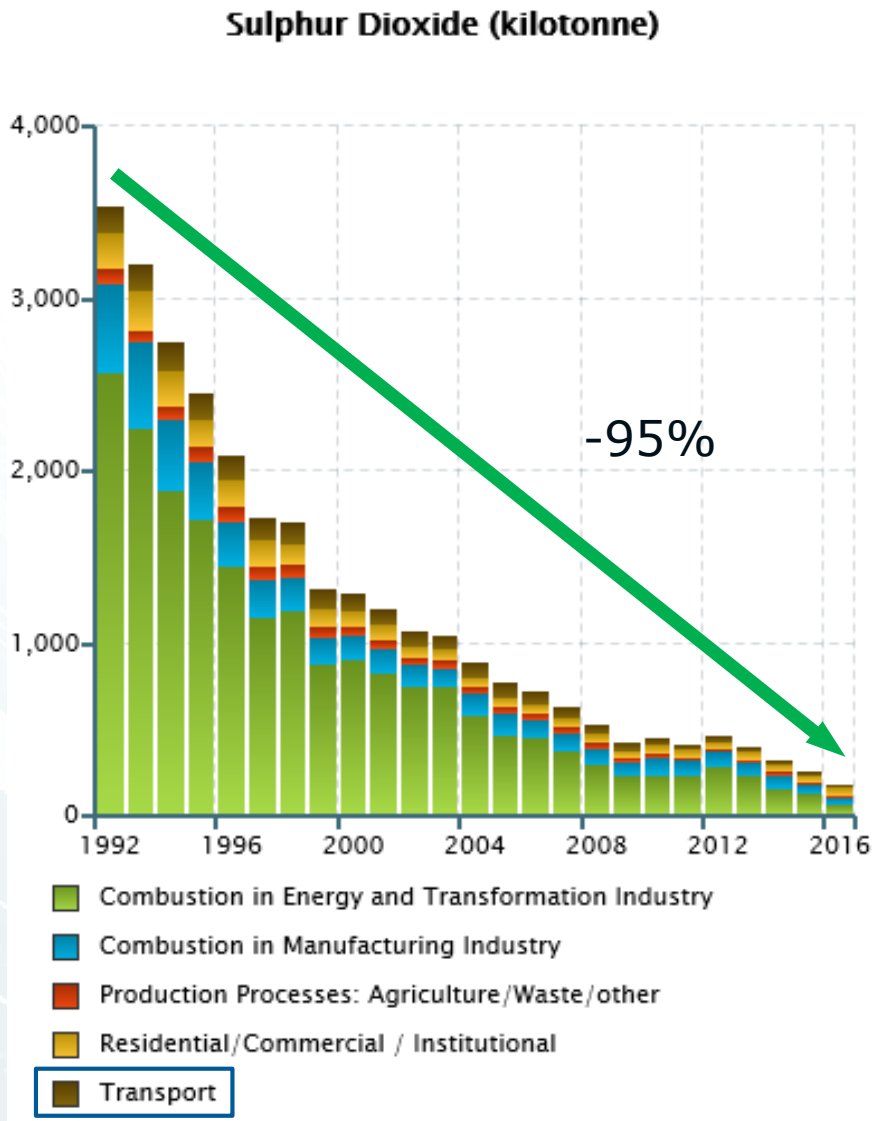


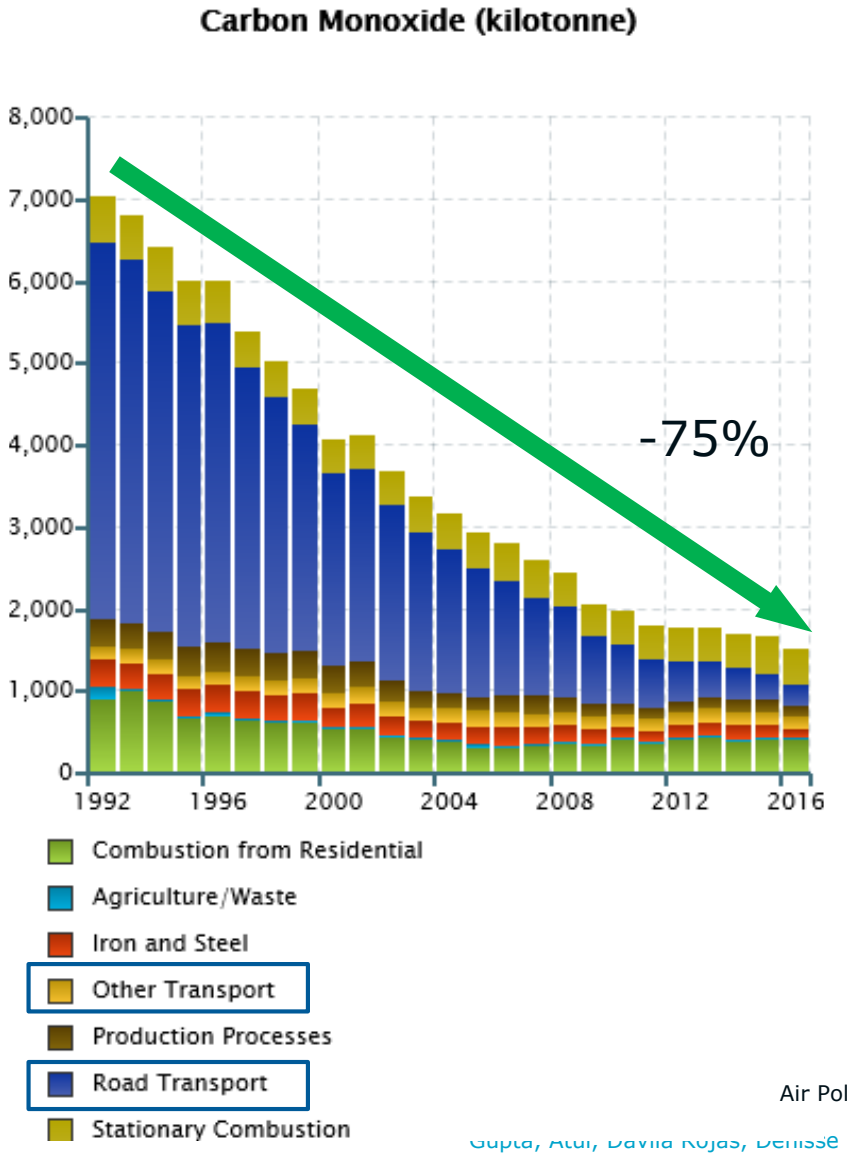


Exceedance: 200 µg/m^3 hourly mean

Defra National Statistics Release: Air quality statistics in the UK 1987 to 2018

UK Air Pollution Trends

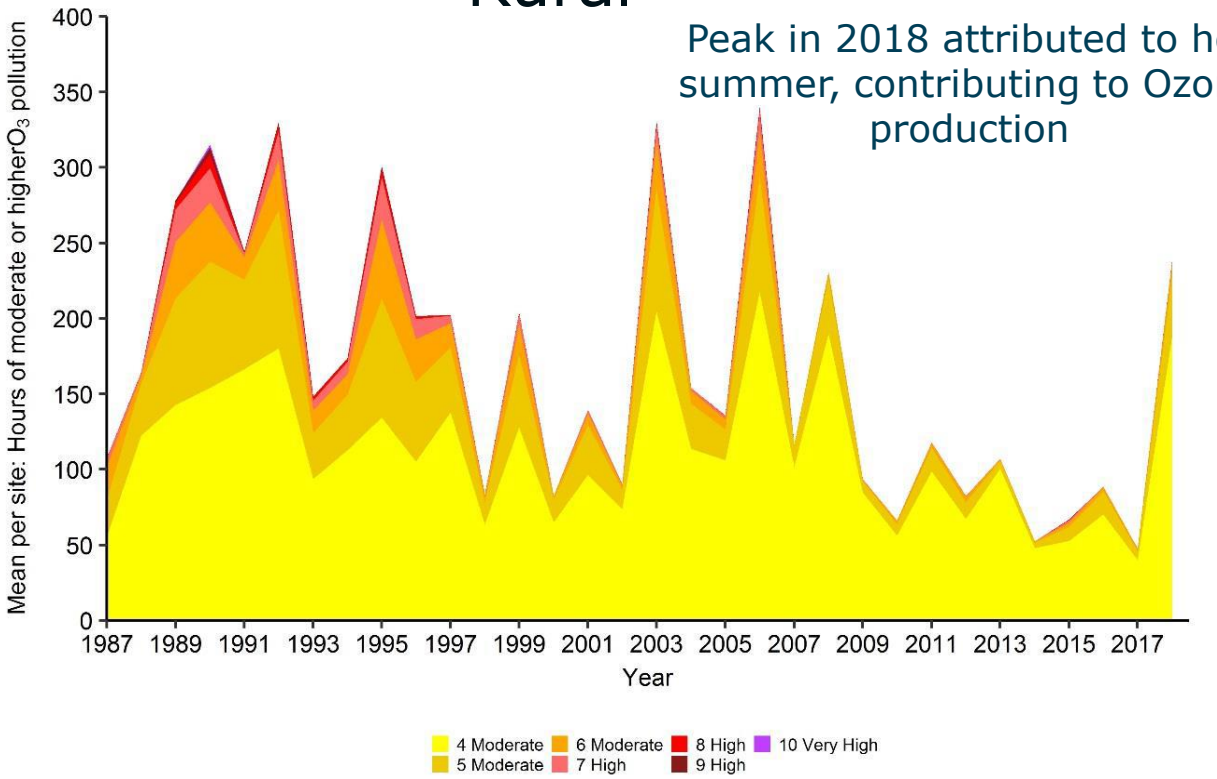




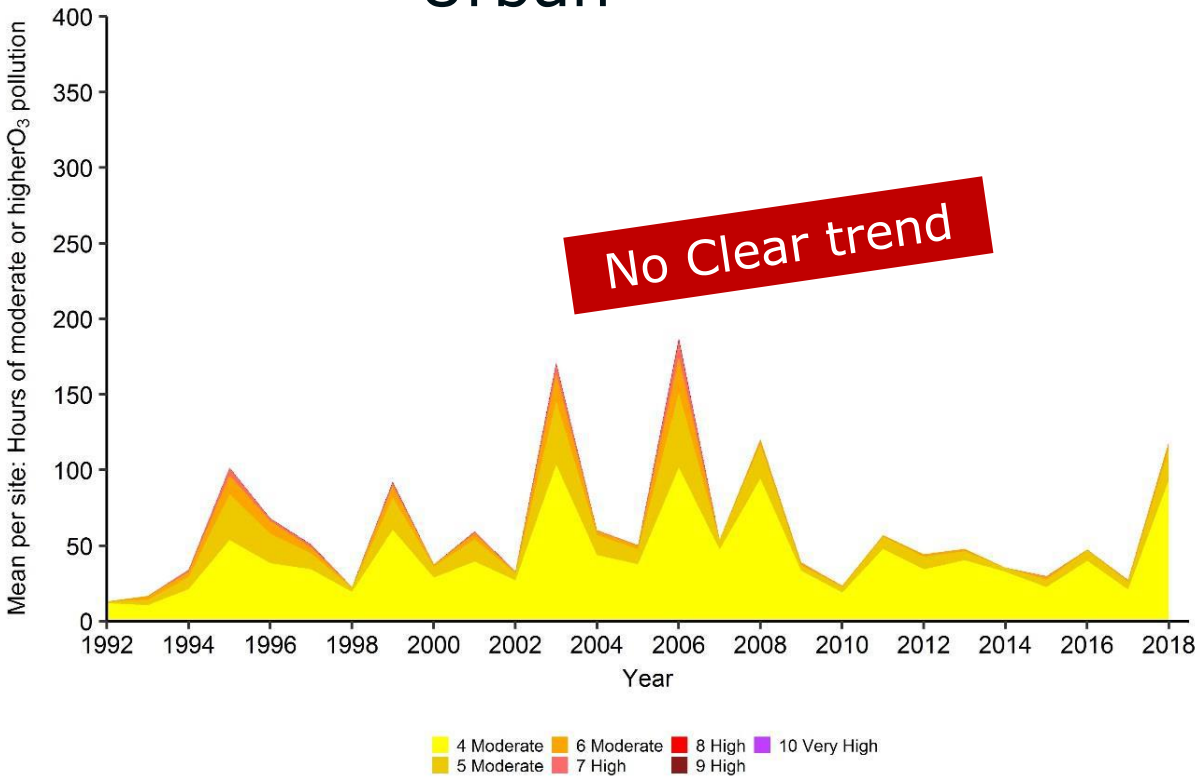
Air Pollution in the UK 2017, DEFRA

Ozone Annual Mean Hours Exceedance

Rural



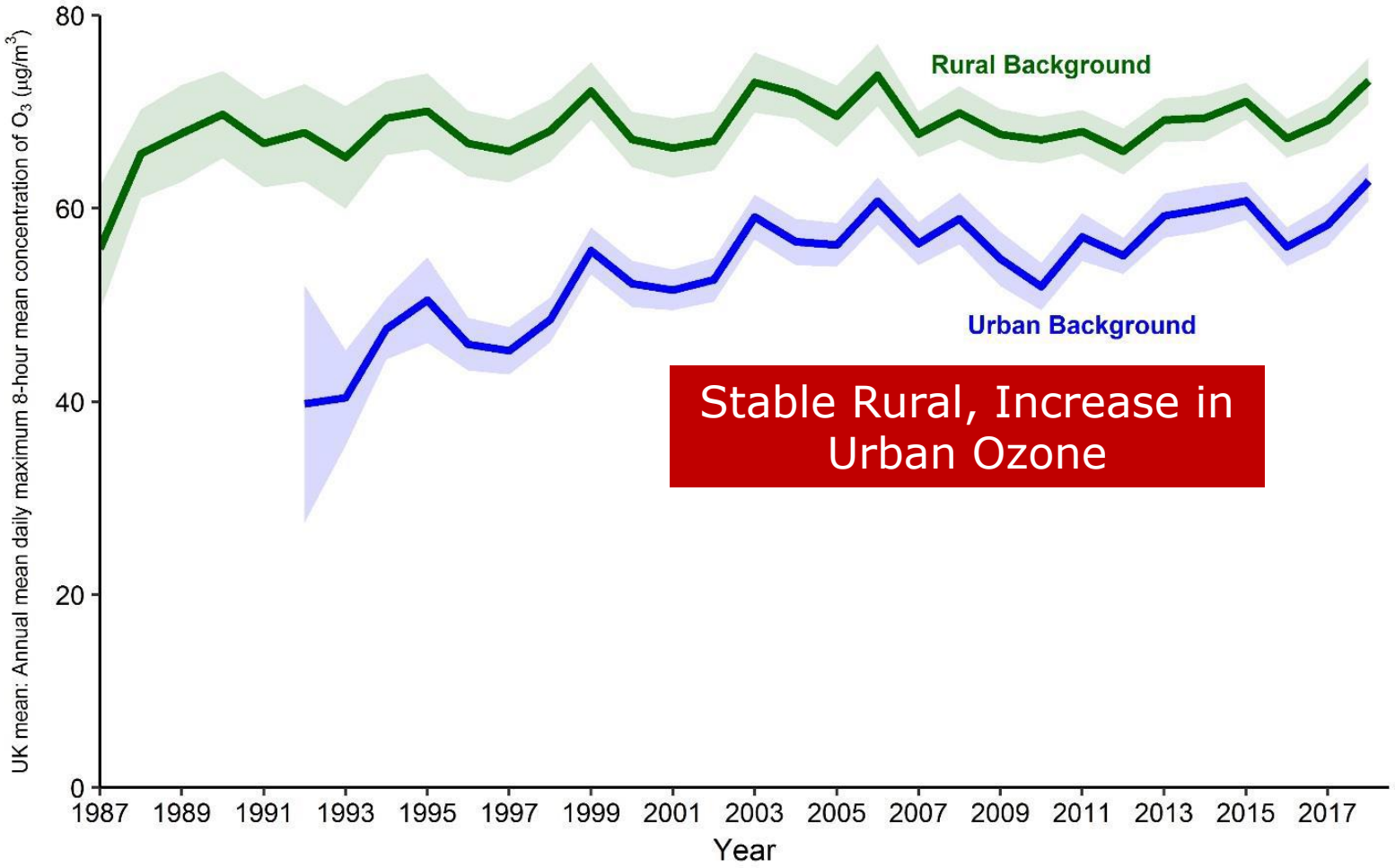
Urban



Exceedance 100 µg/m^3 /8 hrs running mean

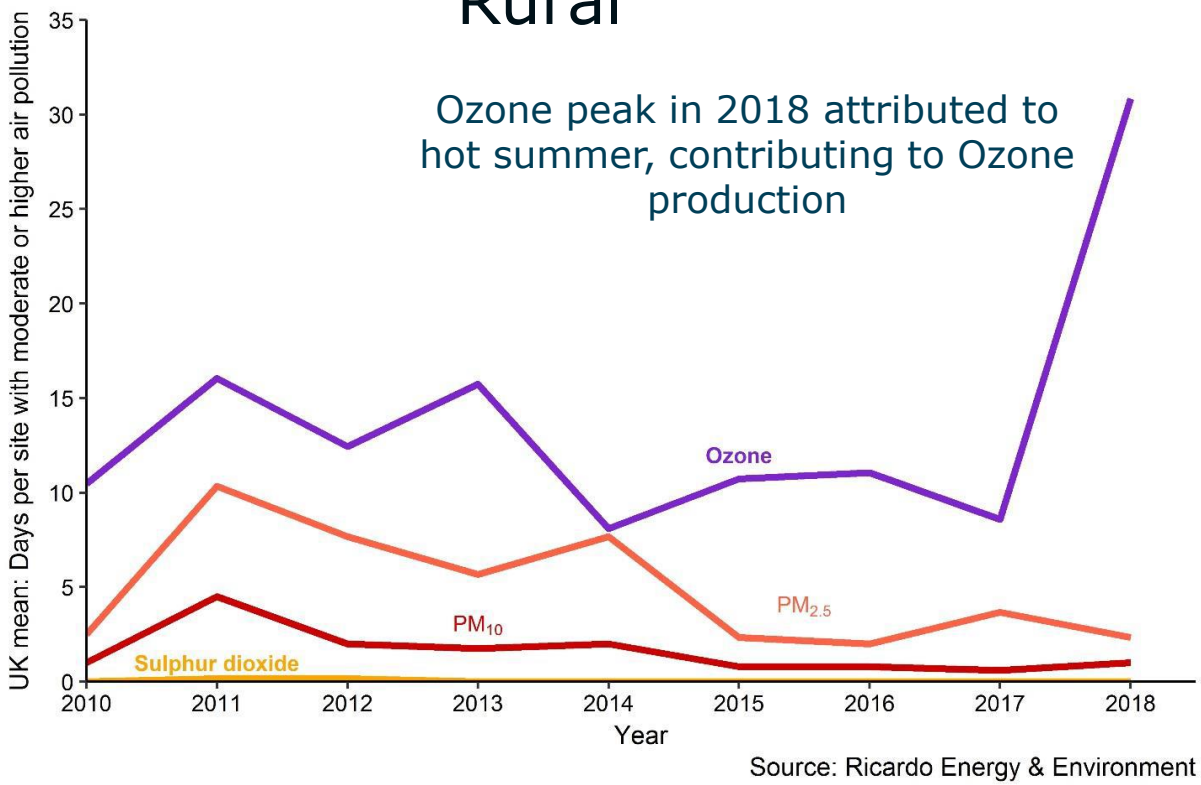
Defra National Statistics Release: Air quality statistics in the UK 1987 to 2018

Ozone


Rural Background
Urban Background
Stable Rural, Increase in Urban Ozone
UK mean: Annual mean daily maximum 8-hour mean concentration of O_3 (µg/m^3)
80
60
40
20
0
1987 1989 1991 1993 1995 1997 1999 2001 2003 2005 2007 2009 2011 2013 2015 2017
Year
Source: Ricardo Energy & Environment

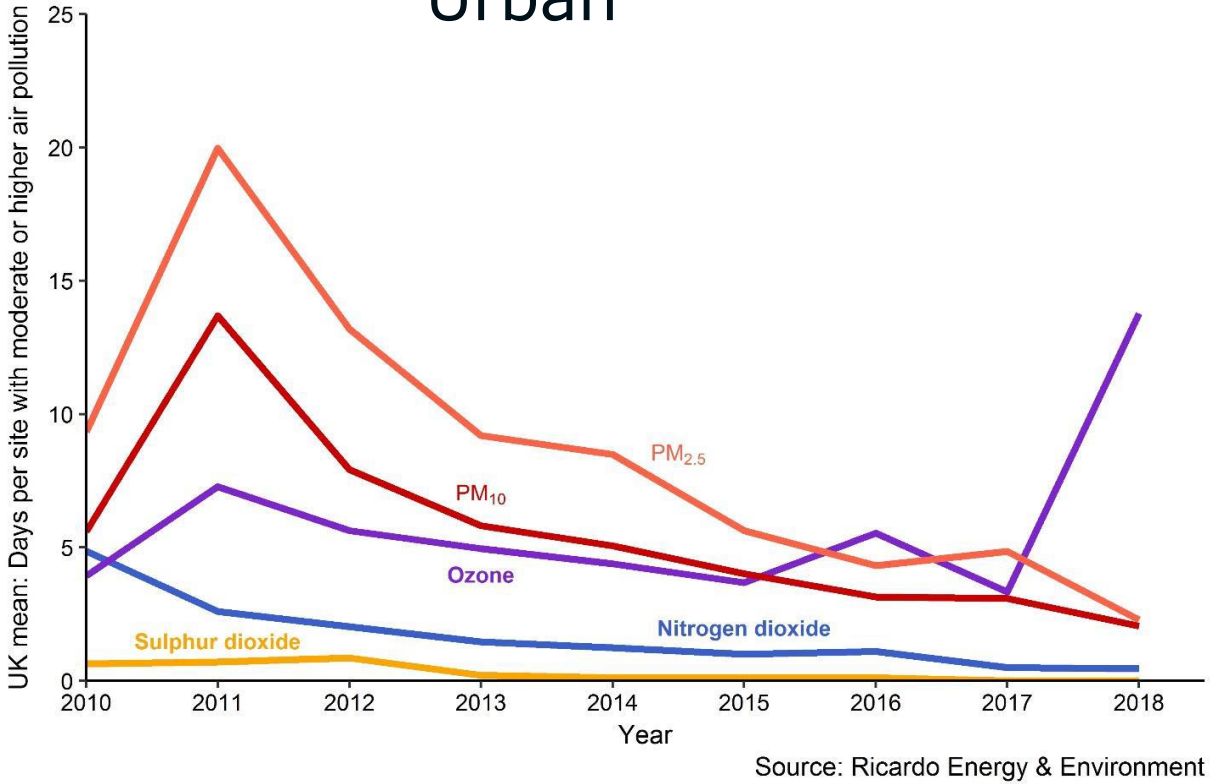
Overall Emissions Exceedance

Rural



Source: Ricardo Energy & Environment

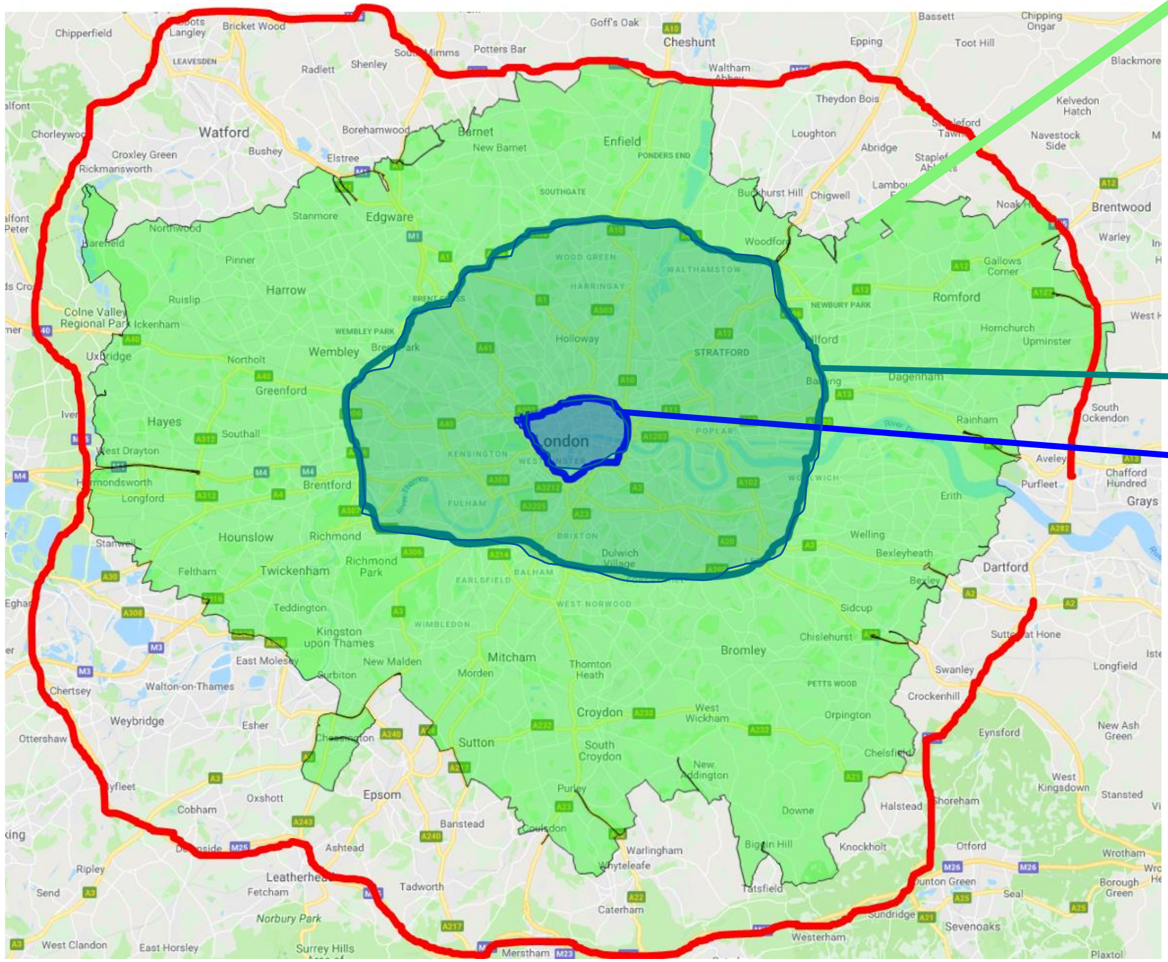
Urban



Source: Ricardo Energy & Environment

Low Emission Zones

London LEZ, ULEZ



London LEZ

Existing	
Larger vans and minibuses**	Euro 3 (Particulate Matter)
Buses, coaches, lorries and specialist heavy vehicles**	Euro IV (Particulate Matter)

>26 Oct 2020	
Larger vans and minibuses**	Euro 3 (Particulate Matter)
Buses and coaches over 5T; lorries and specialist heavy vehicles over 3.5T***	Euro VI

London ULEZ

Existing (T-Charge)	
Motor tricycles and quadricycles*	Euro 3
Cars and small vans	Euro 4
Larger vans and minibuses**	Euro 4
Buses, coaches and lorries and specialist heavy vehicles***	Euro IV

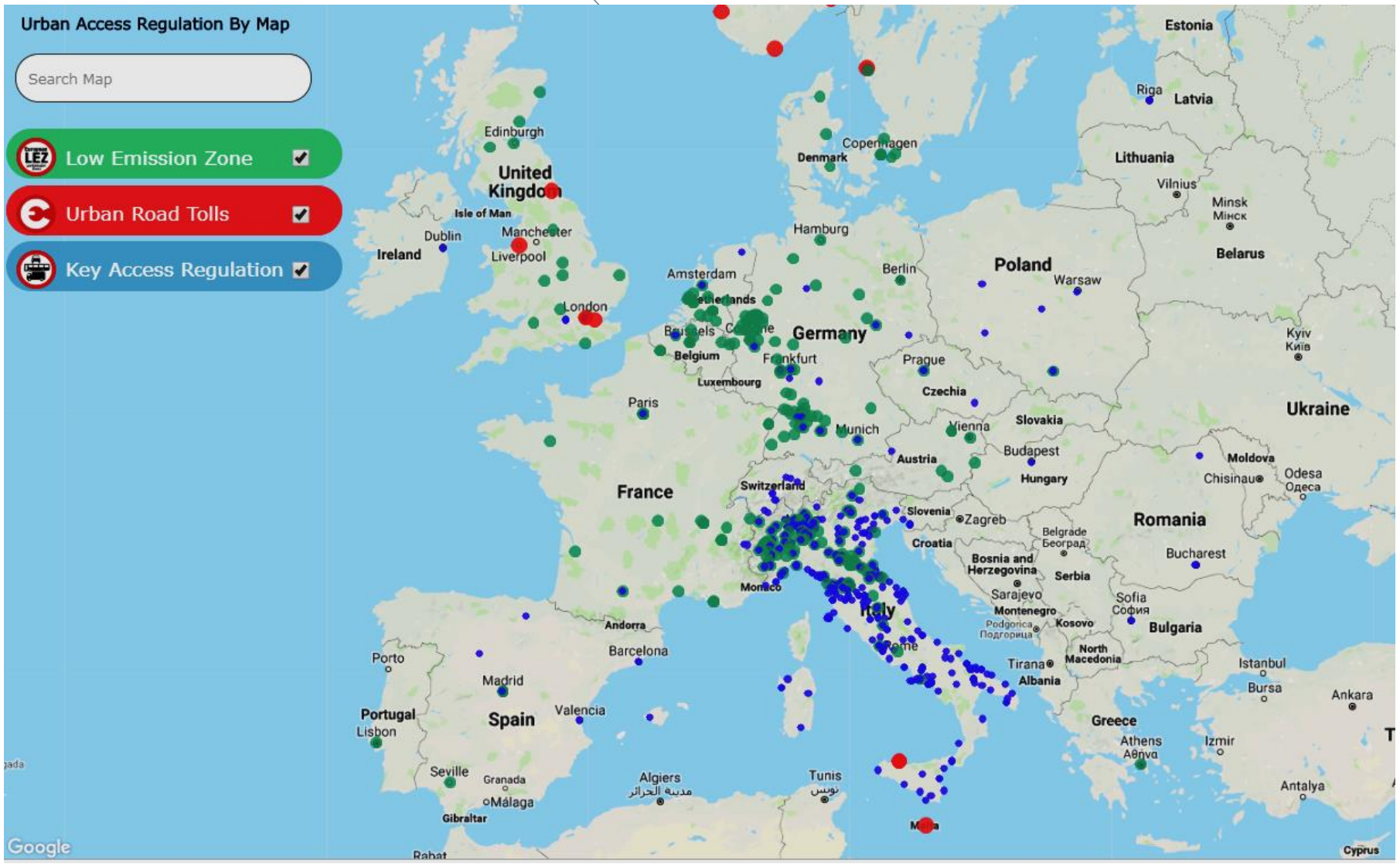
>8 Apr 2019 (ULEZ)	
Motorcycles, Motor tricycles and quadricycles	Euro 3
Cars, private hire vehicles and small vans	Euro 4 Petrol Euro 6 Diesel
Larger vans and minibuses**	Euro 4 Petrol Euro 6 Diesel
Buses and coaches over 5T; lorries and specialist heavy vehicles over 3.5T***	Euro VI

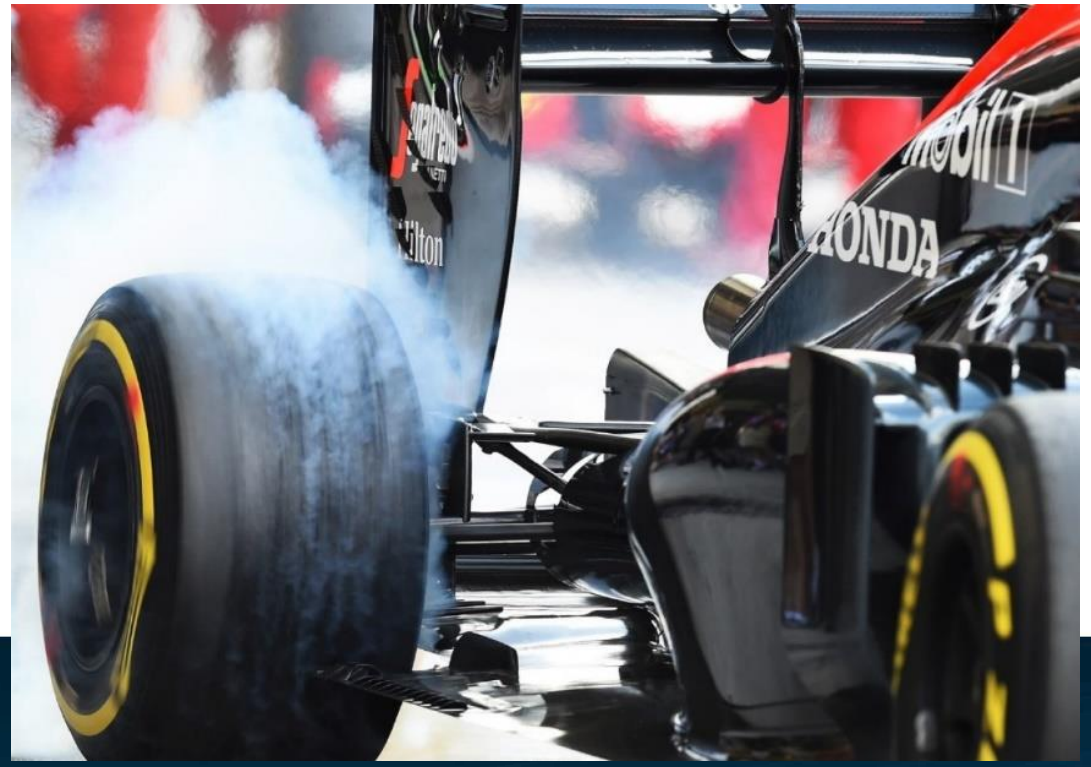
>26 Oct 2021 Boundary Expansion

UK LEZ

LEZ	Standard		Vehicles	Date
Aberdeen	Diesel EU6		HGV's, buses	?
Bath	Diesel EU6	Petrol EU4	HGV's, buses, taxis and vans	? late 2020
Birmingham	Diesel EU6	Petrol EU4	All except 2 wheelers	1 Jan 2020
Brighton	Buses EU5		Buses	1 Jan 2015
Dundee	Diesel EU6	Petrol EU4		?
Edinburgh	Diesel EU6	Petrol EU4		?
Glasgow	Diesel EU6 Diesel EU6 Petrol EU4 Petrol EU3		Local buses All vehicles All vehicles except 2 wheelers 2 wheelers	31 Dec 2018 31 Dec 2022 31 Dec 2022 31 Dec 2022
Leeds	Diesel EU6		Buses, Coaches, HGV, Taxi	6 Jan 2020
Leicester	Diesel EU6		Buses	? End 2020
London			Covered by previous slide	
Manchester	Diesel EU6		HGV's, buses, taxis and vans	? 2021-2023
Norwich	Diesel EU3		Buses	1 Apr 2008
Nottingham	Diesel EU3		Buses	
Oxford	Diesel EU5		Buses	1 Jan 2014
Sheffield	Diesel EU6	Petrol EU4	HGV's, buses, taxis and vans	? 2020-2021
York	Diesel EU6			? 2020

EU LEZ


Urban Access Regulation By Map
Search Map
Low Emission Zone
Urban Road Tolls
Key Access Regulation
Edinburgh
United Kingdom
Isle of Man
Dublin
Ireland
Manchester
Liverpool
London
Amsterdam
Netherlands
Brussels
Belgium
Luxembourg
Frankfurt
Germany
Hamburg
Berlin
Copenhagen
Denmark
Poland
Warsaw
Prague
Czechia
Paris
France
Munich
Vienna
Slovakia
Austria
Budapest
Hungary
Switzerland
Slovenia
Zagreb
Croatia
Belgrade
Beograd
Bosnia and Herzegovina
Sarajevo
Serbia
Monaco
Italy
Andorra
Barcelona
Porto
Madrid
Portugal
Lisbon
Spain
Valencia
Seville
Granada
Málaga
Gibraltar
Algiers
Tunis
Rabat
Estonia
Riga
Latvia
Lithuania
Vilnius
Minsk
Belarus
Kyiv
Ukraine
Moldova
Chisinau
Odesa
Romania
Bucharest
Sofia
Bulgaria
Montenegro
Podgorica
Kosovo
North Macedonia
Tirana
Albania
Greece
Athens
Izmir
Istanbul
Bursa
Ankara
Antalya
Cyprus
Google



Non-Exhaust Emissions

Non-Exhaust Emissions

BRAKE WEAR

- Brake materials
- Driving conditions and history
- Brake pad temperatures
- Vehicle load

TIRE/ROAD WEAR

- Tire materials
- Driving behavior
- Road condition

ROAD-DUST RESUSPENSION

- Urban vs rural area
- Season
- Proximity to crustal materials
- Driving speed

- Accounts for ~50% of overall PM from light duty vehicle
- ~50% PM_{10} gets airborne
- Ceramic dust, toxic organic compounds, heavy metal dust, etc

https://ww2.arb.ca.gov/resources/documents/brake-tire-wear-emissions
http://publications.jrc.ec.europa.eu/repository/bitstream/JRC89231/jrc89231-online%20final%20version%202.pdf

Tyre Wear fun fact

~40 million tyres sold in UK every year

Assuming 205/55R16 tyre size, initial tread depth 8 mm, replacement at 1.6 mm

Wear from 612 mm to ~600 mm diameter

Volume lost/ tyre = 0.091 m^3

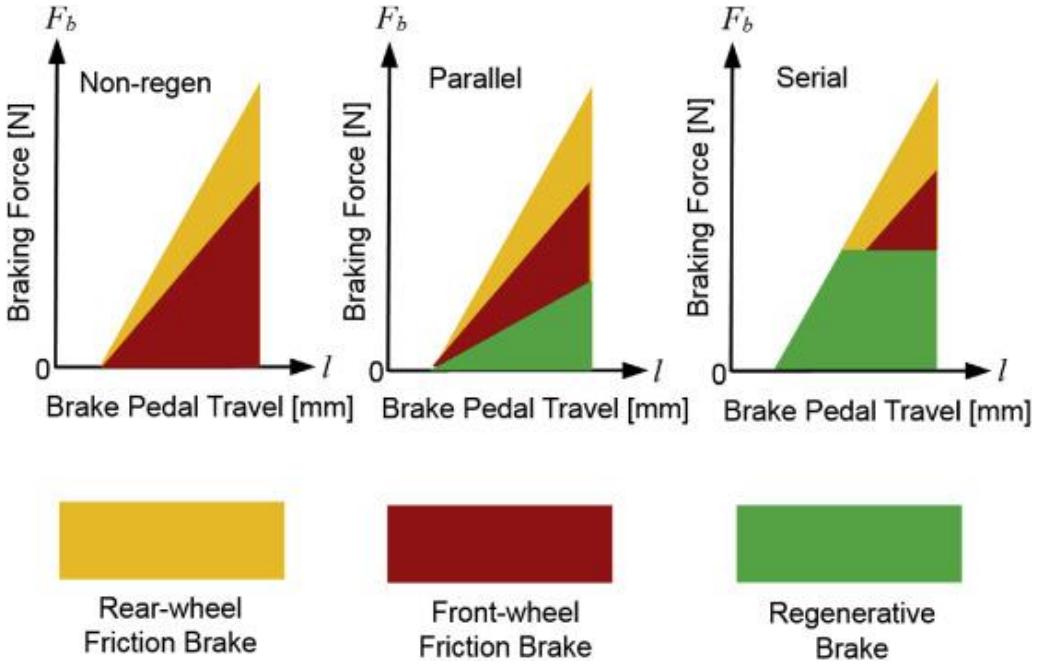
Volume lost/ 40 million tyres = 365,530 m^3 = ~150 Olympic swimming pools

Density of tires = 500 kg/m^3

Total mass of 40 million tyres = ~183,000,000 kg = ~365 Airbus A380 aircrafts

Number of tyres sold in US = 280 million! (7 times)

Reducing Brake Dust



Regenerative braking:

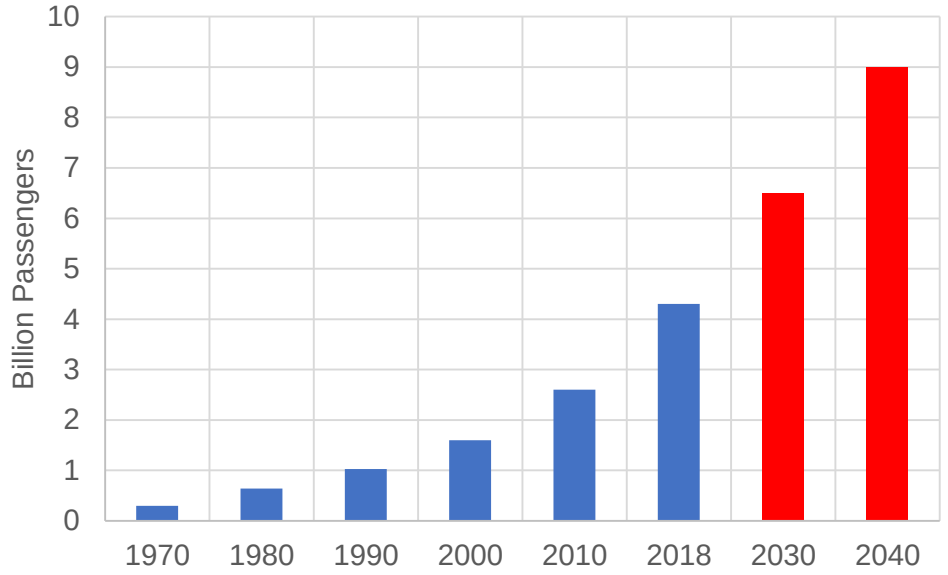
1. Certainly improves efficiency and reduces brake dust PM.
2. 60-70% braking energy returned to acceleration.
3. Overall ~20-30% increase in range in real driving.
4. However, EV's are also heavier with larger wheels, so realisation of brake/ tyre dust is offset.

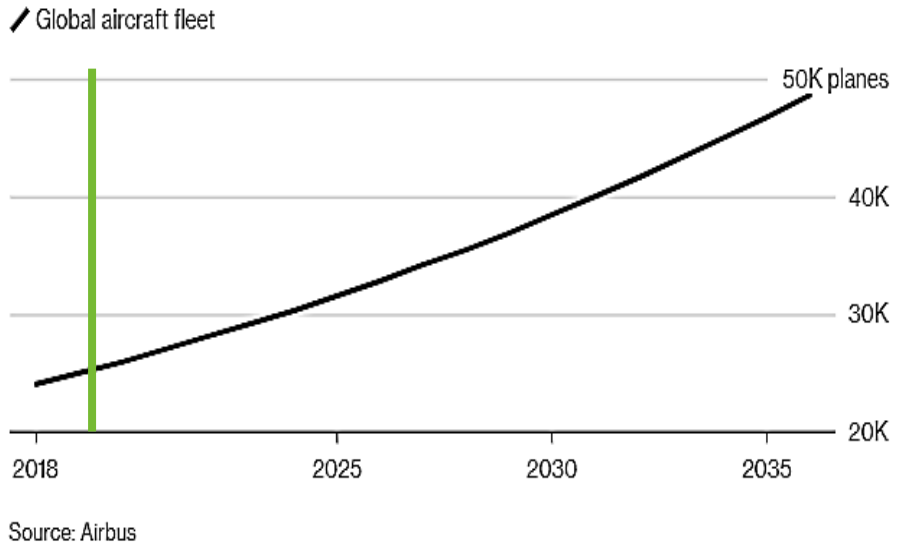
https://www.sciencedirect.com/science/article/abs/pii/S0360544218302743

Aviation

Aviation

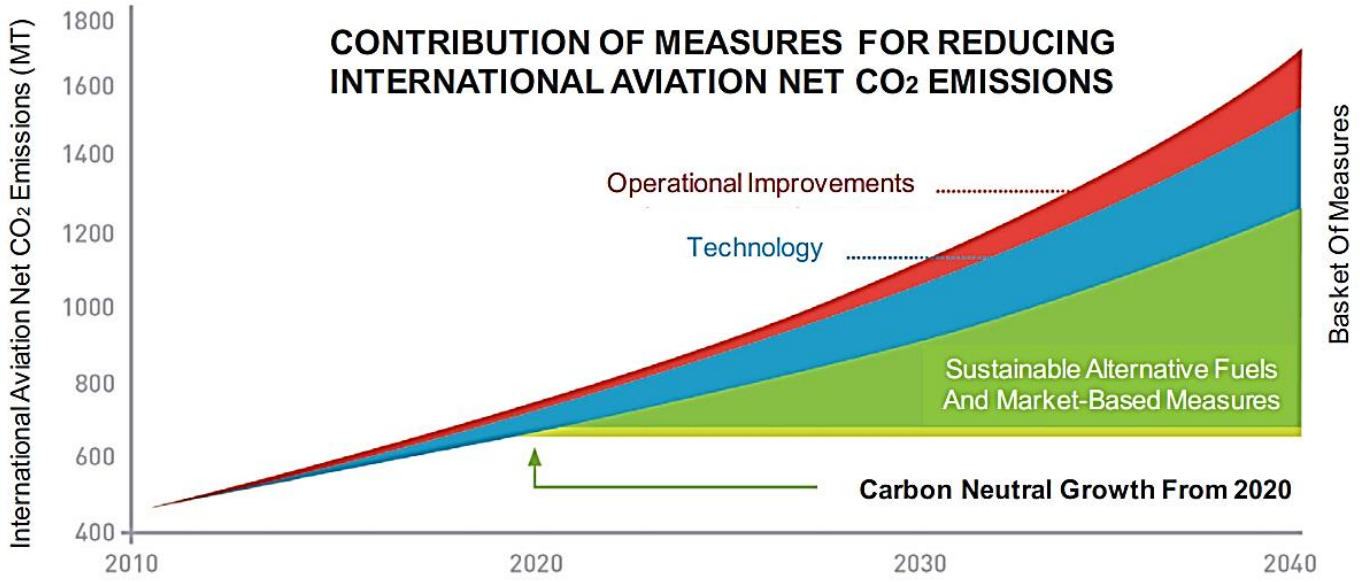
1. Aviation carried 4.3 billion people in 2018 on 24,000 aeroplanes.
2. Aviation accounts 2% Global Emissions, producing same emission contaminants as road transport.
3. Only NO_x, CO & HC have engine certification requirement.
4. Aircraft & operational efficiency is improving but it is offset by the growth (to double in next 20 years).

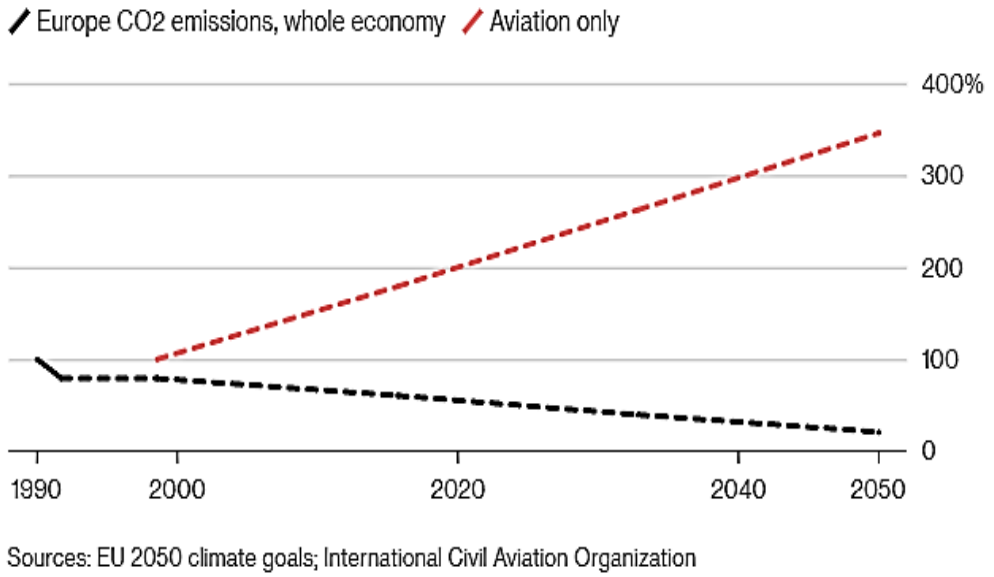




Aviation

1. Improved **technology**, including using sustainable low-carbon fuels.
2. More efficient aircraft **operations** (load factor, route optimisation, improved navigation).
3. **Infrastructure improvements**, including modernised air traffic management systems.
4. ICAO aims at Carbon neutral growth (mostly through offsets) but critics are sceptical.
5. Currently no incentives to promote new aircrafts, and no penalty for older aircrafts.





Sources: EU 2050 climate goals; International Civil Aviation Organization

Shipping

Shipping

1. >90% of worlds cargo transported by shipping on 90,000 vessels.
2. Shipping is the most efficient means of transporting cargo.

   (10 times & 100 times compared with road & air transport respectively)
3. However, Shipping produces ~4% global CO_2 emission, ~18-30% NO_x and ~13% SO_x due to usage of heavy fuel oil and minimal aftertreatment.

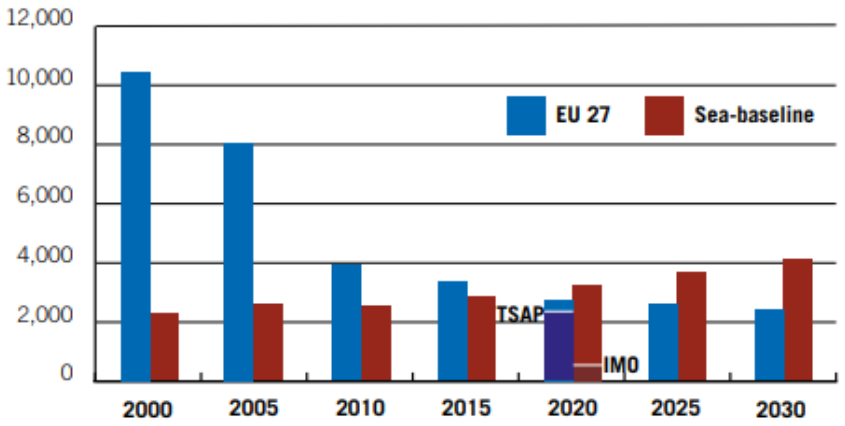


Figure 1: Emissions of SO_2 2000–2030 (ktonnes)

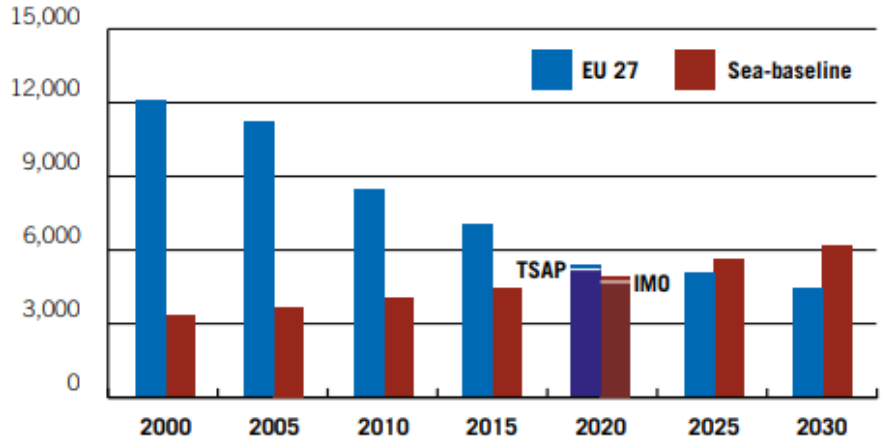


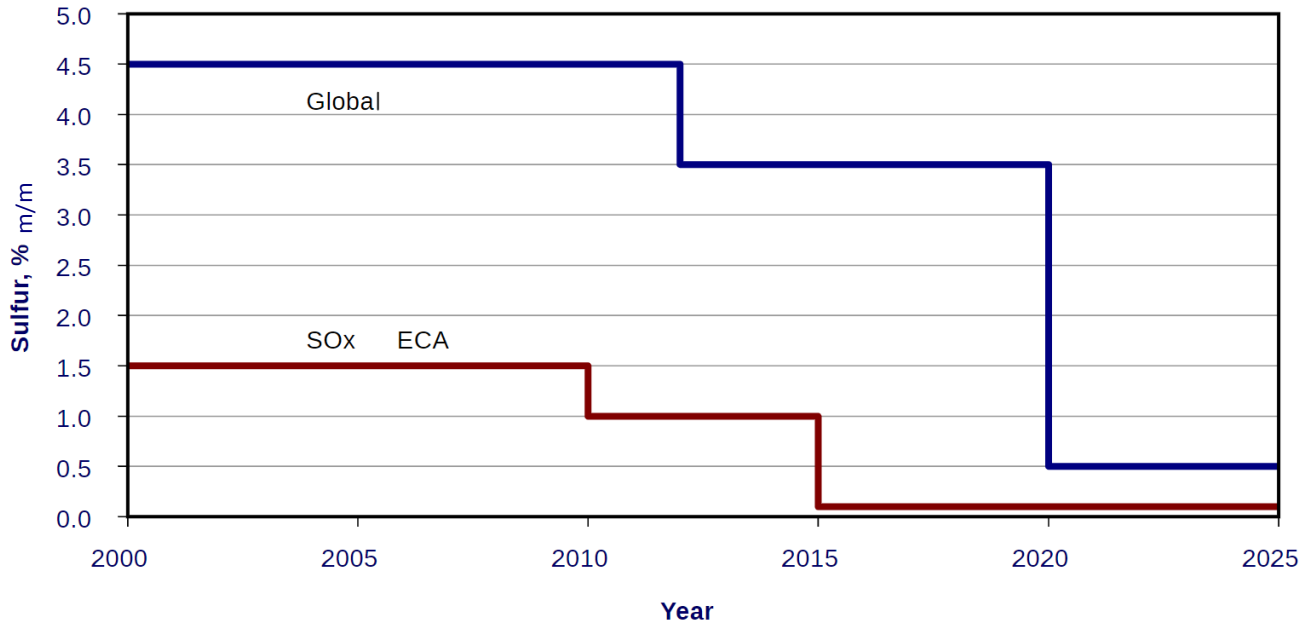
Figure 2: Emissions of NOx 2000–2030 (ktonnes)

	Sulphur	NOx-nitrogen
Denmark	39%	28%
Netherlands	31%	21%
Sweden	25%	25%
Norway	25%	23%
UK	18%	20%
France	18%	15%
Italy	15%	15%
Belgium	13%	16%
Finland	12%	17%
Germany	10%	10%

http://www.cleanshipping.org/download/111128_Air%20pollution%20from%20ships_New_Nov-11%283%29.pdf

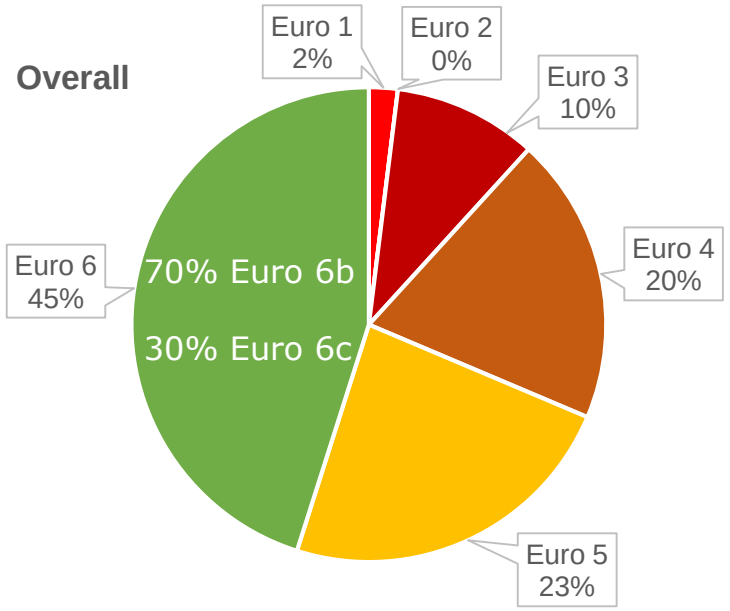
Shipping

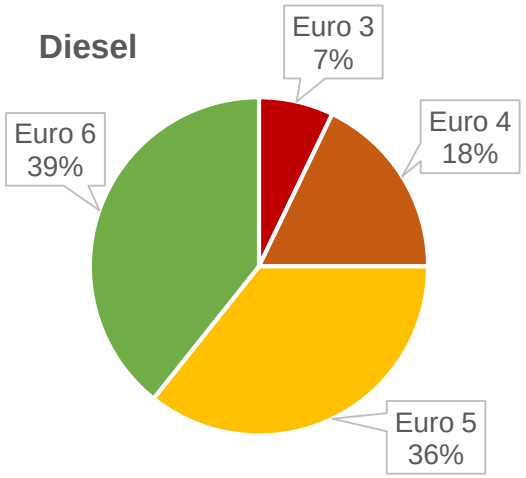
Tier	Date	NOx Limit, g/kWh		
		n < 130	130 ≤ n < 2000	n ≥ 2000
Tier I	2000	17.0	$45 \cdot n^{-0.2}$	9.8
Tier II	2011	14.4	$44 \cdot n^{-0.23}$	7.7
Tier III	2016†	3.4	$9 \cdot n^{-0.2}$	1.96
† In NOx Emission Control Areas (Tier II standards apply outside ECAs).				

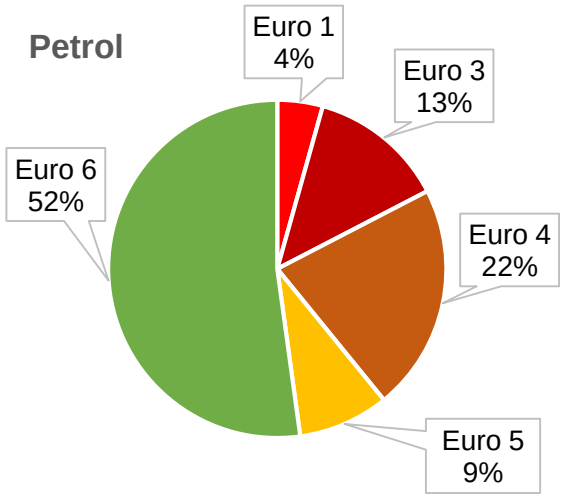


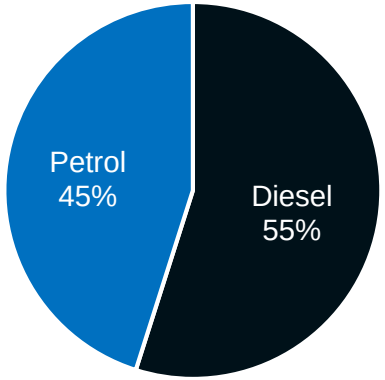
How do you commute?

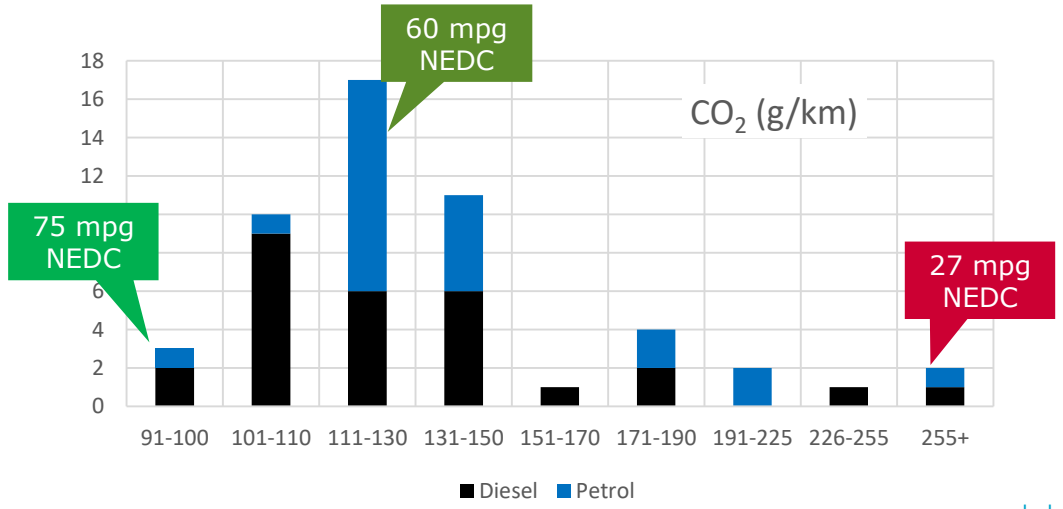
Analysis of 51 vehicles at workplace











What I’m really saying is, you ought to drive this!

World’s first Zero Emission/ Zero brake - tyre dust vehicle!


Thank You
AVL
www.avl.com