Air pollution: its impact on health and possible solutions.

Christopher Whitty

Gresham College 2018

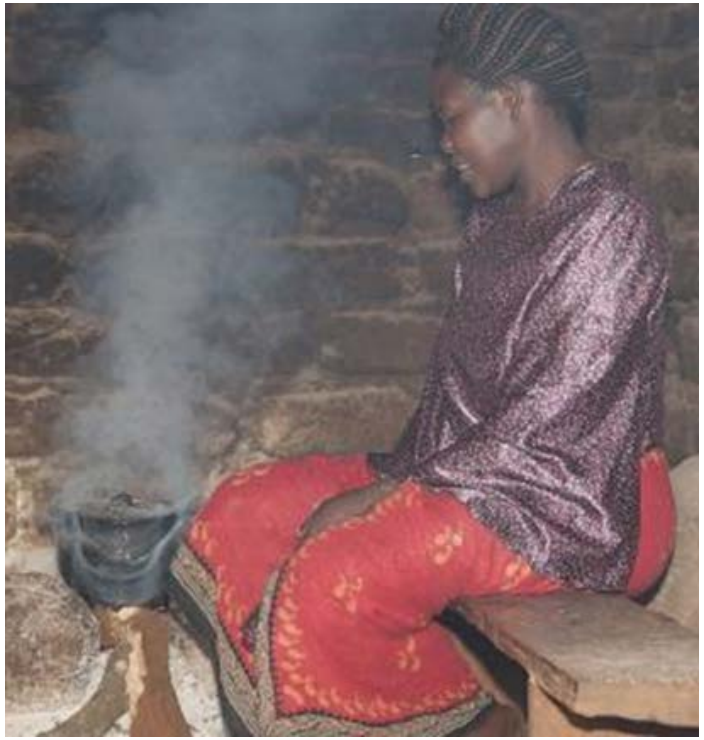
Pollutants get into us by several routes.

But only three have substantial public health importance.

- The lung.
- The gut (food and water).
- The skin. A fairly impervious barrier.

Professor Michael Faraday gives his card to Father Thames. "And we hope the Dirty Fellow will consult the learned Professor " *(Punch, 1885).*

Air pollution predates Gresham College, and remains common. Much is indoor.



Bruce Kirenga, Lancet. Uganda.

Hampton Court kitchen (circa 1529). Pinterest.

London's pre-eminence as a global city came at a cost in air pollution (but was a boon for art).

The yellow fog that rubs its back upon the window-panes,

The yellow smoke that rubs its muzzle on the window-panes,

Licked its tongue into the corners of the evening,

Lingered upon the pools that stand in drains,

Let fall upon its back the soot that falls from chimneys….

Curled once about the house, and fell asleep.

The love song of J. Alfred Prufrock.

TS Eliot 1920.

Trouée de soleil dans le brouillard.

C. Monet 1904.

Attempts to address air pollution are not new.

- King Edward I banned the use of sea-coal in London 1272.
- John Evelyn's *Fumifugium, or, The inconveniencie of the aer and smoak of London dissipated* 1661.
- Recommended removing polluting industries like lime-burning from London.

The Ballad of Gresham College (1663, anon).

....He shewes that 't is the seacoale smoake

That allways London doth Inviron,

Which doth our Lungs and Spiritts choake,

Our hanging spoyle, and rust our Iron.

The biggest spur to UK action in recent times was the Great Smog of 1952.

- A combination of cold and atmospheric conditions.
- At least 4000 people died (maybe up to 12,000) and 100,000 made unwell over 3 days of severe smog.
- Led to the Clean Air Act of 1956.

Piccadilly Circus in a pea-souper 1952. *Unknown photographer*.

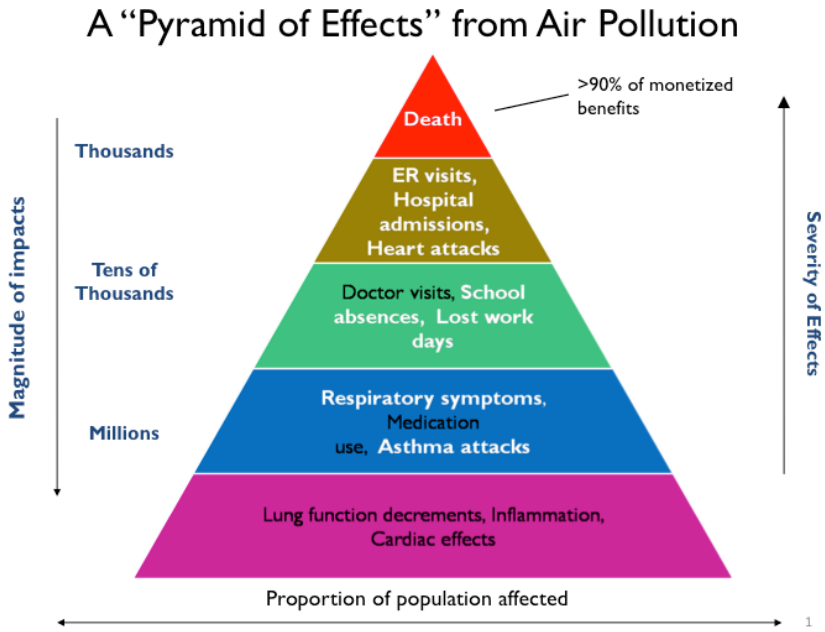
Not all air pollution is human-created.

- In some parts of the world it is a minority.
- Volcanoes, dust storms, forest fires, lightning examples of highly polluting events.
- The last major eruption of Laki (1783) killed around 23,000 people in the UK.
- In most industrialised countries most air pollution is from human activity.

Mt. St. Helens 1980

Air pollution has effects on the lung, but many pollutants have wider effects.

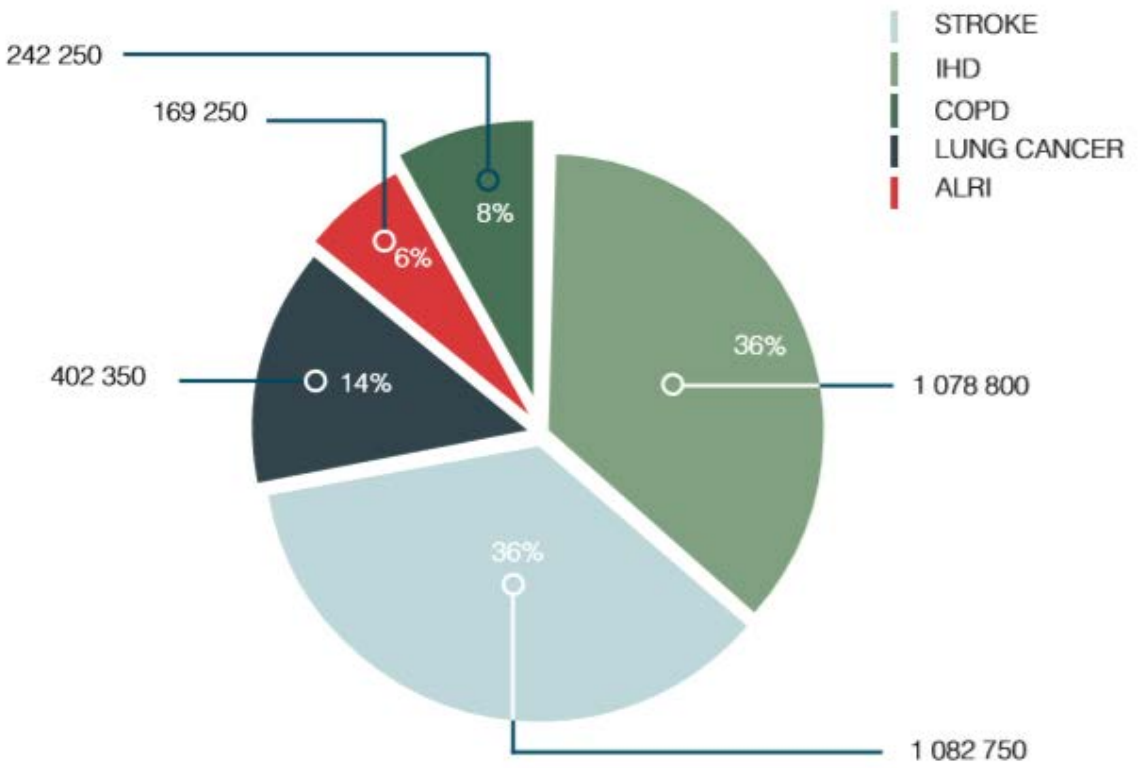
- Several types with different causes and effects.
- This lecture will concentrate on:
- Lead.
- Particulate matter (PM10 and PM2.5).
- Sulphur dioxide (SO_2).
- Nitrogen oxides (NOx: NO and NO_2).
- Ammonia.



US Environmental Protection Agency.

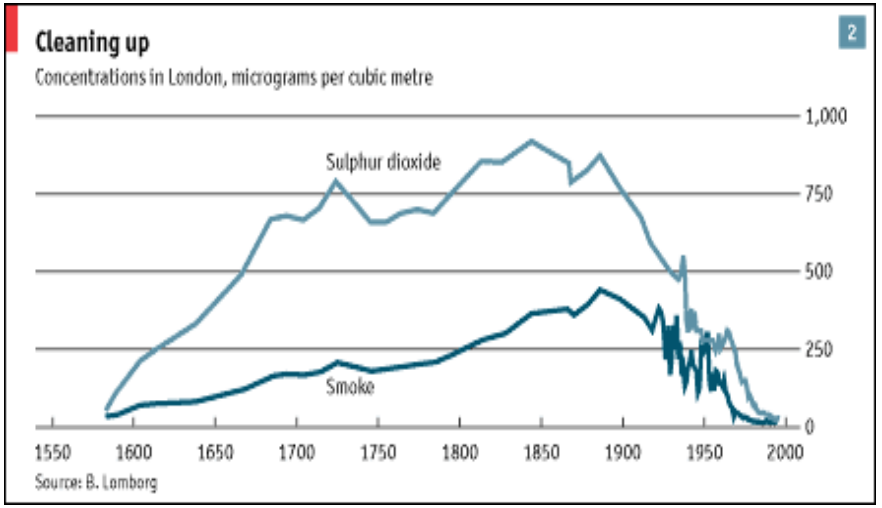
World Health Organization global estimates (2016).

- 1 in every 9 deaths due to air pollution.
- Around 3 million deaths attributable solely to ambient (outside) air pollution.
- Heart disease (36%), stroke (36%), lung cancer (14%) and lung disease dominate.



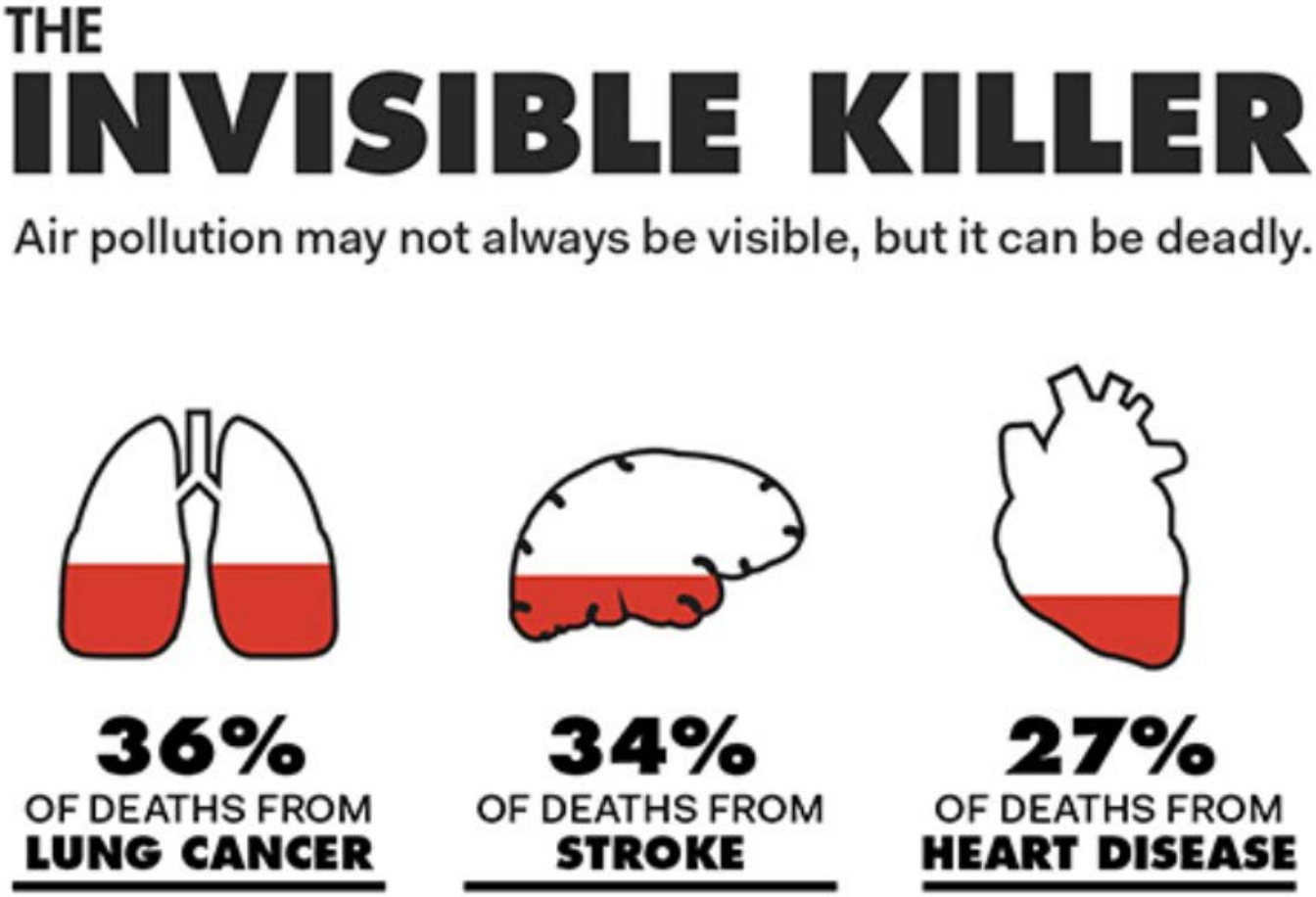
Air pollution is subject to strong advocacy positions, in both directions.

- There are trade-offs between optimising economic and health outcomes.
- The least wealthy countries, and the least wealthy in a society can bear the brunt of both.
- But especially the health effects.



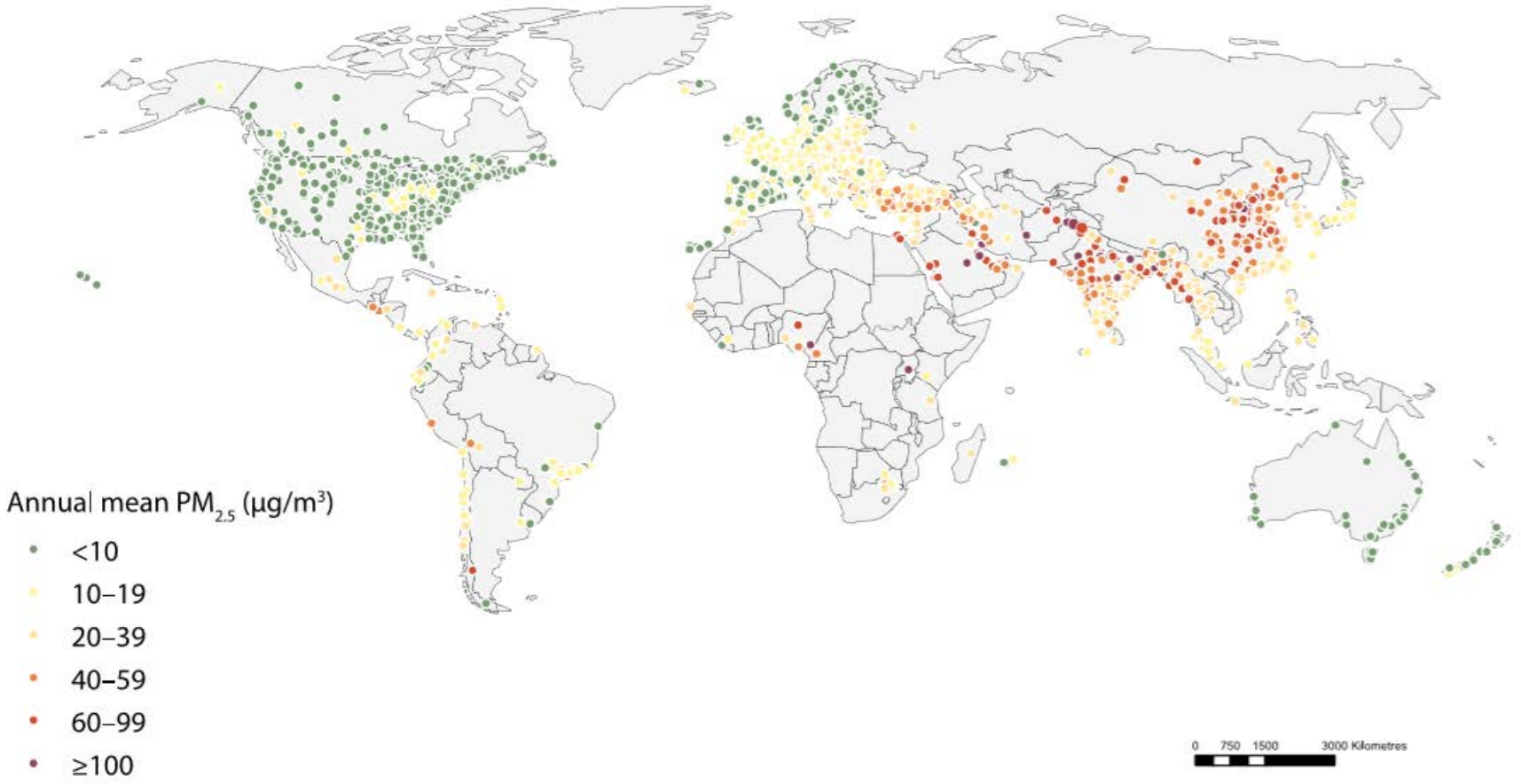
Bjorn Lomborg, Economist 2001

This talk will concentrate on outdoor (ambient) air pollution in high-income countries but it is a major global problem. WHO infographic on global situation.

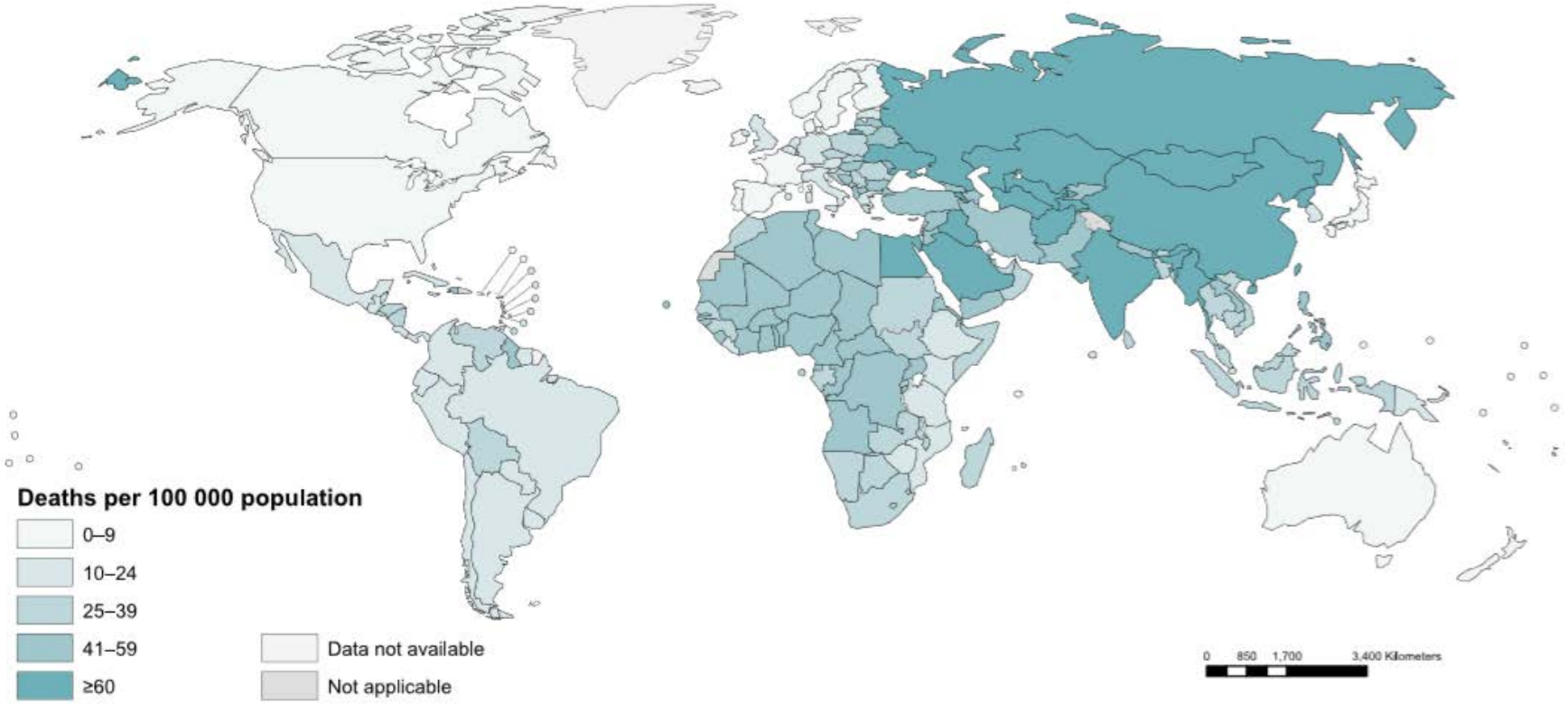


There is broad support for the role of the state in reducing air pollution across the political spectrum.

Global data are best in wealthier countries. The burden of pollution is heaviest in poorer and industrialising countries. WHO data, 2008-15.



Age-standardised deaths/100,000 due to ambient air pollution. WHO estimates 2016.



Risk depends on exposure. High pollution with few people may be much less dangerous than lower pollution and many people.

Yallourn W brown-coal power station Victoria, Australia. Marcus Wong.

VE Day, London 1945

Degree of certainty about health effects varies by pollutant and disease.

Strong evidence:

- Lead
- Particulate matter PM2.5 and PM10
- Sulphur dioxide

Less certain current evidence on size of effect:

- Nitrogen oxides (NOx)
- Ozone
- Ammonia

- Easiest for sudden medical events, short intense exposure
- Asthma
- Stroke
- Heart attack

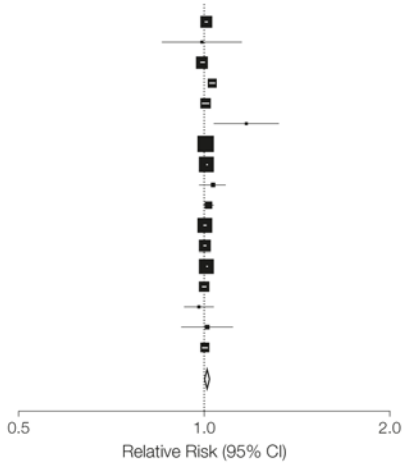
- Less easy for gradual-onset events, chronic low-grade exposure
- Dementia
- Cancer

Myocardial infarction (heart attack) and particulate matter systematic review.

Mustafic et al, JAMA 2012

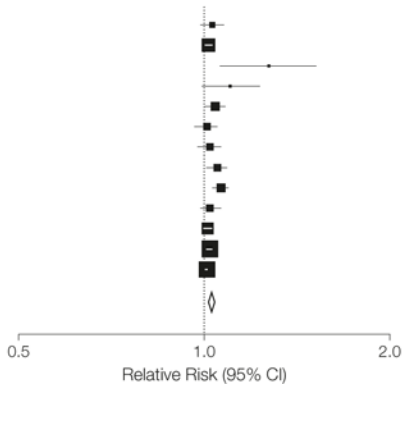
A PM_{10} analysis

Source	Study Design	Relative Study Weight, %	Relative Risk (95% CI)	*P* Value
Belleudi et al,[41] 2010	Case-crossover	8.80	1.007 (0.999-1.015)	.09
Berglind et al,[10] 2010	Case-crossover	0.06	0.990 (0.851-1.152)	.90
Bhaskaran et al,[46] 2011	Case-crossover	6.95	0.992 (0.982-1.002)	.12
Hsieh et al,[34] 2010	Case-crossover	4.78	1.031 (1.017-1.045)	<.001
Nuvolone et al,[42] 2011	Case-crossover	5.10	1.004 (0.991-1.017)	.55
Peters et al,[20] 2001	Case-crossover	0.08	1.169 (1.034-1.322)	.01
Zanobetti and Schwartz,[45] 2006	Case-crossover	14.10	1.006 (1.003-1.009)	<.001
Braga et al,[7] 2001	Time-series	13.10	1.007 (1.003-1.011)	.001
Cendon et al,[11] 2006	Time-series	0.45	1.032 (0.979-1.087)	.24
Cheng et al,[33] 2009	Time-series	2.82	1.015 (0.996-1.035)	.13
Hoek et al,[32] 2000	Time-series	11.97	1.001 (0.996-1.006)	.70
Lanki et al,[24] 2006	Time-series	8.77	1.003 (0.995-1.011)	.46
Linn et al,[12] 2000	Time-series	12.02	1.010 (1.005-1.015)	<.001
Mann et al,[39] 2002	Time-series	5.63	0.999 (0.987-1.011)	.87
Medina et al,[26] 1997	Time-series	0.41	0.979 (0.927-1.034)	.45
Sharovsky et al,[40] 2004	Time-series	0.13	1.010 (0.914-1.116)	.84
Stieb et al,[28] 2009	Time-series	4.84	1.002 (0.989-1.016)	.77
Combined (I^2 = 57%, Egger regression test, *P* = .61)			1.006 (1.002-1.009)	.002



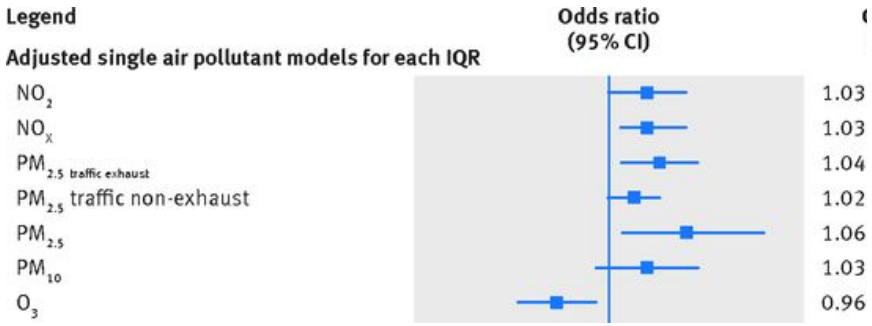
B $PM_{2.5}$ analysis

Source	Study Design	Relative Study Weight, %	Relative Risk (95% CI)	*P* Value
Barnett et al,[9] 2006	Case-crossover	3.93	1.031 (0.983-1.082)	.21
Belleudi et al,[41] 2010	Case-crossover	13.82	1.018 (1.001-1.036)	.04
Peters et al,[20] 2001	Case-crossover	0.33	1.272 (1.061-1.525)	.009
Peters et al,[43] 2005	Case-crossover	0.89	1.105 (0.991-1.232)	.07
Pope et al,[35] 2006	Case-crossover	5.58	1.042 (1.003-1.083)	.04
Rich et al,[21] 2010	Case-crossover	4.43	1.010 (0.966-1.056)	.66
Sullivan et al,[22] 2005	Case-crossover	4.50	1.020 (0.976-1.066)	.38
Zanobetti and Schwartz,[45] 2006	Case-crossover	5.25	1.051 (1.010-1.094)	.02
Maté et al,[25] 2010	Time-series	7.26	1.066 (1.033-1.101)	<.001
Stieb et al,[28] 2009	Time-series	5.14	1.024 (0.983-1.066)	.25
Ueda et al,[38] 2009	Time-series	11.31	1.013 (0.991-1.035)	.24
Zanobetti et al,[30] 2009	Time-series	17.53	1.022 (1.011-1.034)	<.001
Zanobetti and Schwartz,[31] 2009	Time-series	20.03	1.011 (1.004-1.018)	.002
Combined (I^2 = 51%, Egger regression test, *P* = .004)			1.025 (1.015-1.036)	<.001



Mortality not the only outcome- pregnancy.

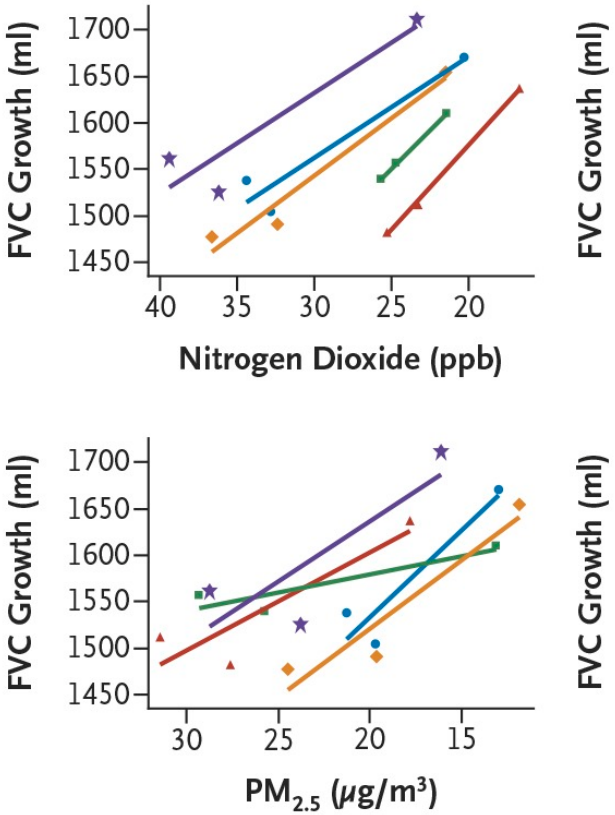
- Low birth weight in children born to mothers exposed to air pollution lower.
- Data on the right from London- low birth weight by pollutant.
- Various confounding factors.



R Smith et al, BMJ 2017

Children are more vulnerable to many environmental issues, including air pollution.

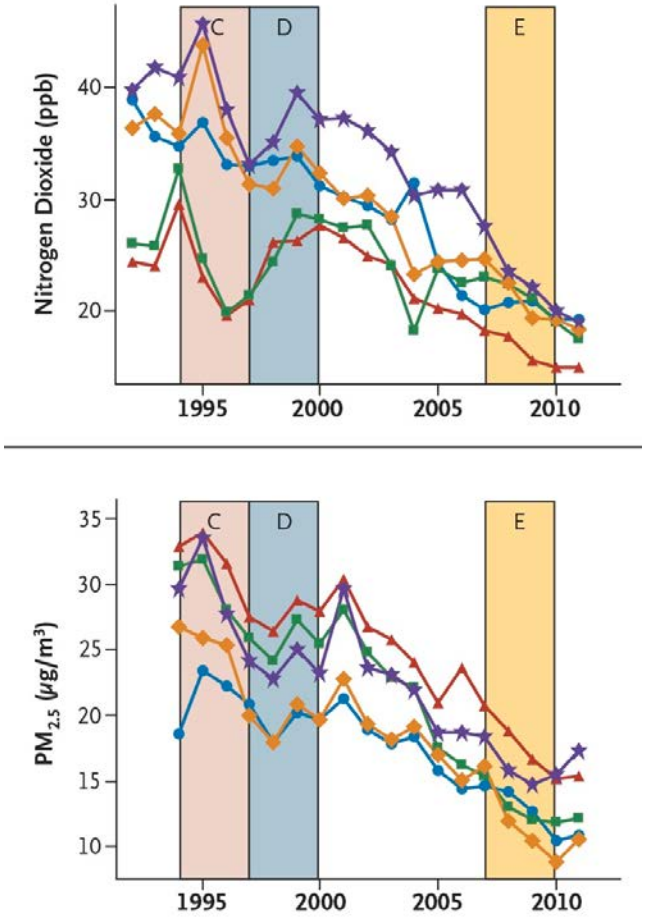
- Developing brains and bodies.
- Good evidence for association between lead and brain development in foetuses and children.
- Good evidence of association between lung development and air pollutants.

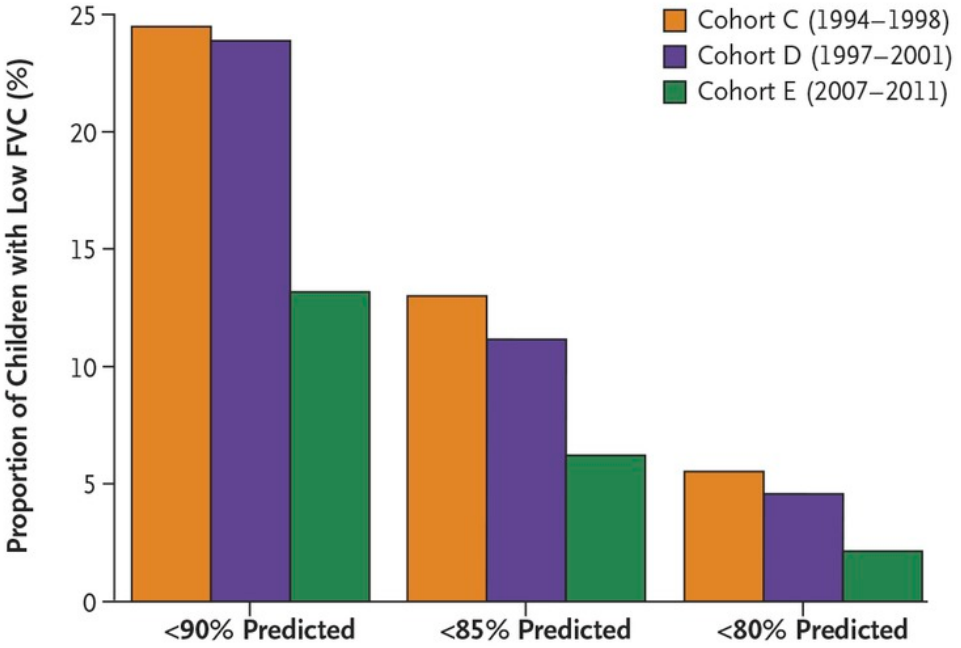


Children 11-15 years in 5 sites in USA Gauderman et al, NEJM 2015.

As pollution reduces child lung function improves. Data from 5 areas of California.

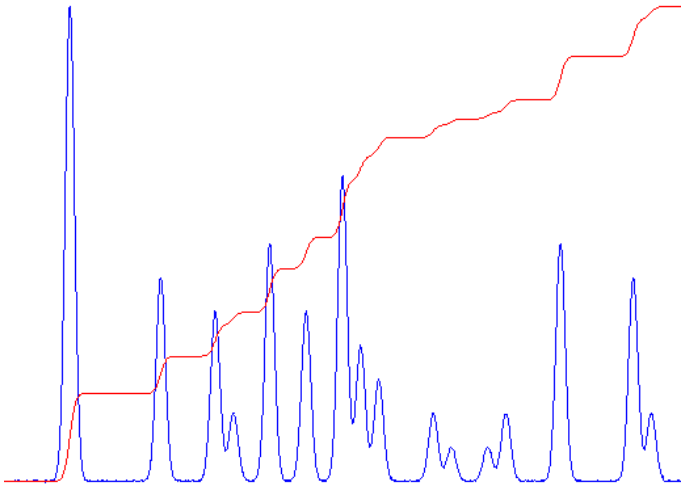
Gauderman et al. NEJM 2015





We can obsess too much about the exact number of deaths and illnesses. The numbers are large. We have sufficient information to act.

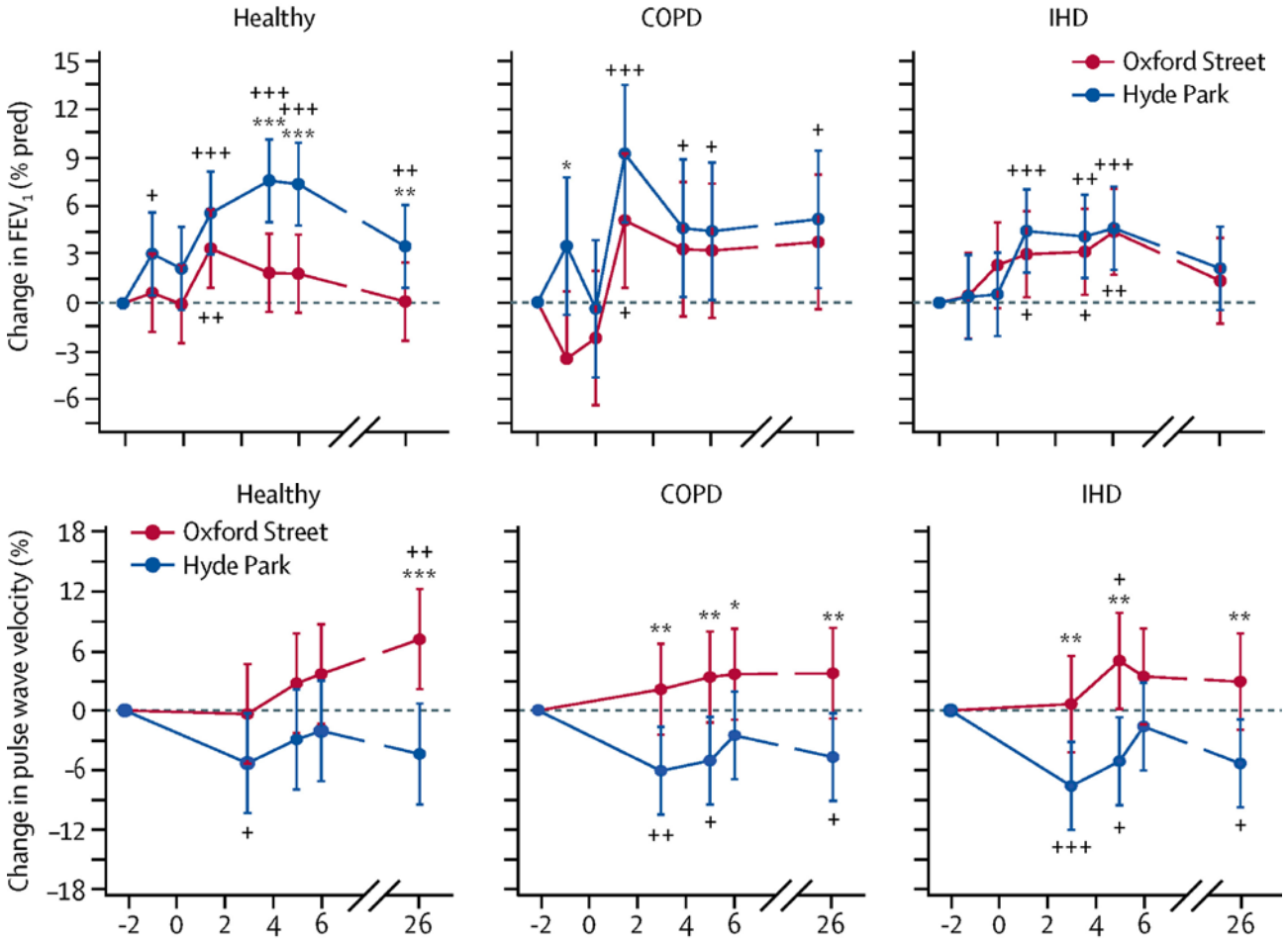
- Waiting for more data is often the right thing to do.
- For lead, particulates, SO_2, NOx in particular the evidence of harm is easily good enough to be confident reducing them is beneficial to health for many people.
- There is an important technical question on to what extent harm is a peak/threshold risk, or cumulative lifetime risk.



T O'Haver

Effects of a 2 hour walk in Hyde Park or Oxford Street on lung function (top) and arterial stiffness.

Sinharay et al Lancet 2018. Time in hours, participants over 60.



Lead in petrol. An instructive if extreme example.

- Known to be toxic at high levels for 2 millennia.
- Tetraethyllead (TEL) developed by General Motors added to petrol from the 1920s.
- One of several potential engineering solutions to increased compression (ethyl alcohol another).
- Clear warnings of toxicity from the off.
- For 3 decades research dominated (monopolised) by the industry.

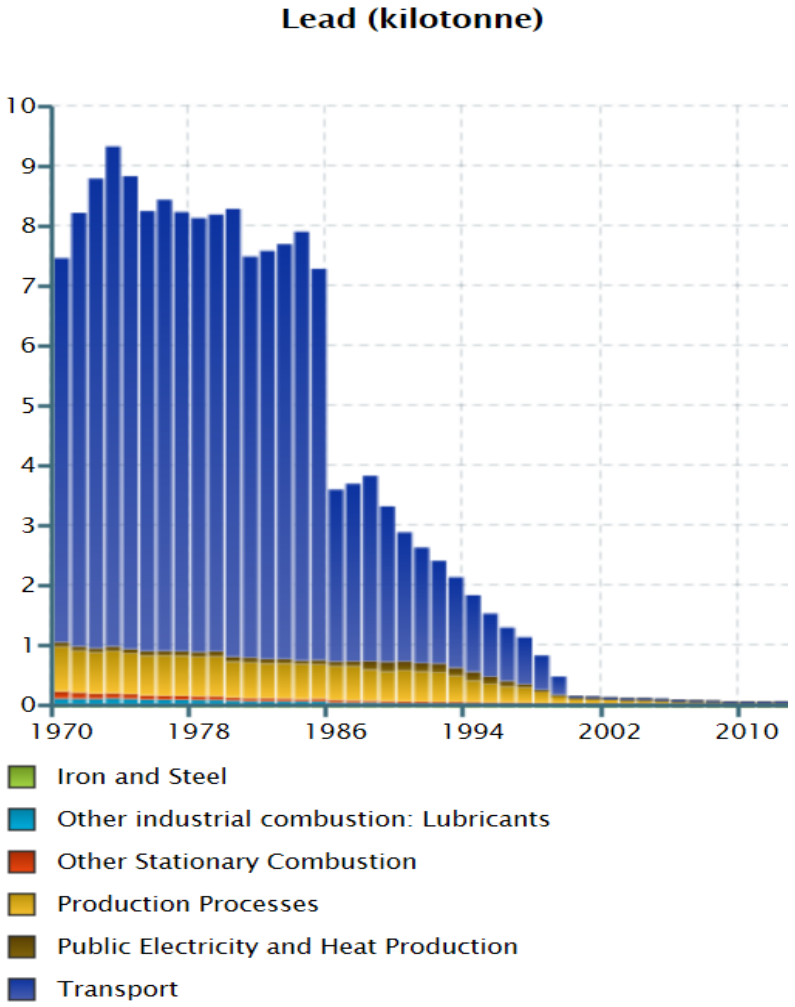
Thomas Midgely

Alice Hamilton

Lead.

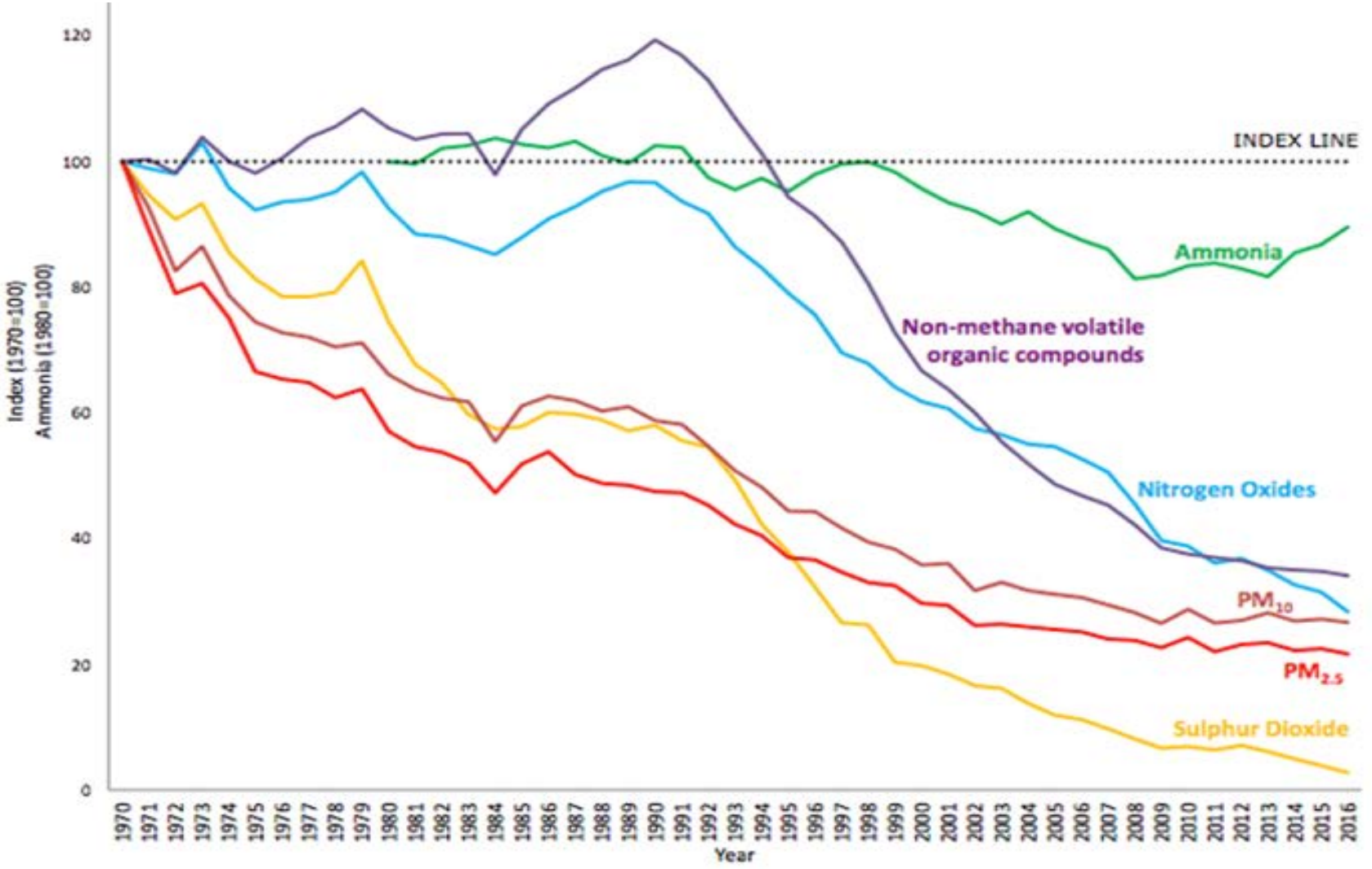
(UK data: National Atmospheric Emissions Inventory (NAEI) 2018)

- Biggest effect on brains of foetuses and children. Reduces IQ. Possible links to crime.
- Reasonable evidence from the 1960s.
- Restrictions begun in 1970s (US).
- Average American child's blood lead level 13.7 µg/dl 1976, in 2000 it was 2.0.
- UK ban on 4-star in 1998, although being phased down before.
- Officially petrol lead-free worldwide from 2013.



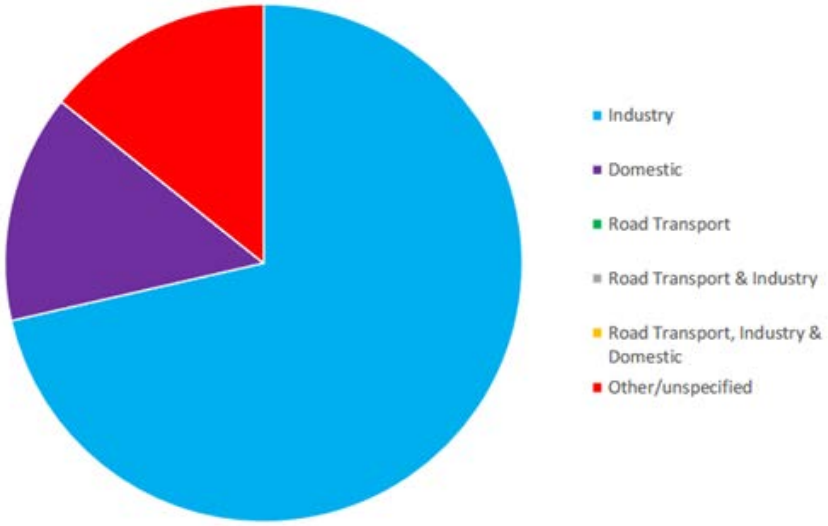
The UK is doing fairly well in tackling emissions of many of the main air pollutants.

DEFRA Emissions of air pollutants in the UK, 1970 to 2016. ONS.



Sulphur dioxide (SO_2) has several health effects.

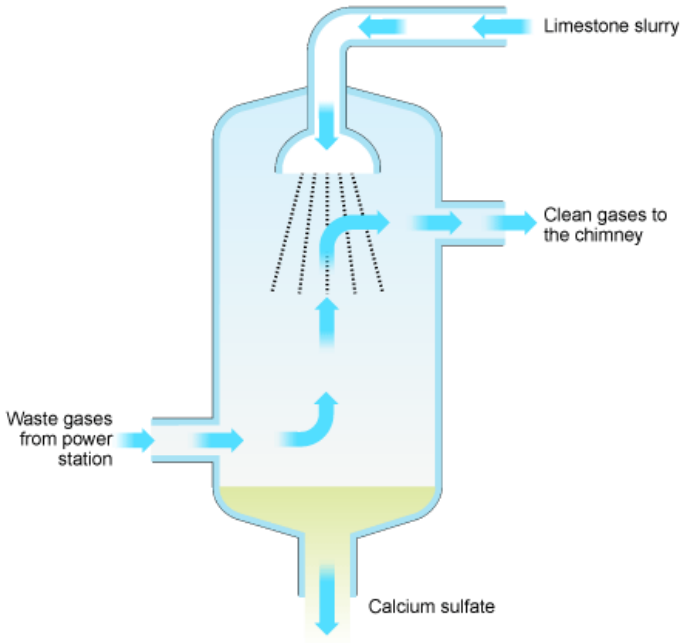
- Triggers asthma attacks. Causality clear. Dose dependent.
- Respiratory effects more widely.
- Associated with preterm birth.
- Associated with excess mortality.
- Contributes to particulate matter (PM).



Proportion of air quality management areas from various sources for SO_2.
DEFRA 2017

Methods to reduce SO_2 and SOx.

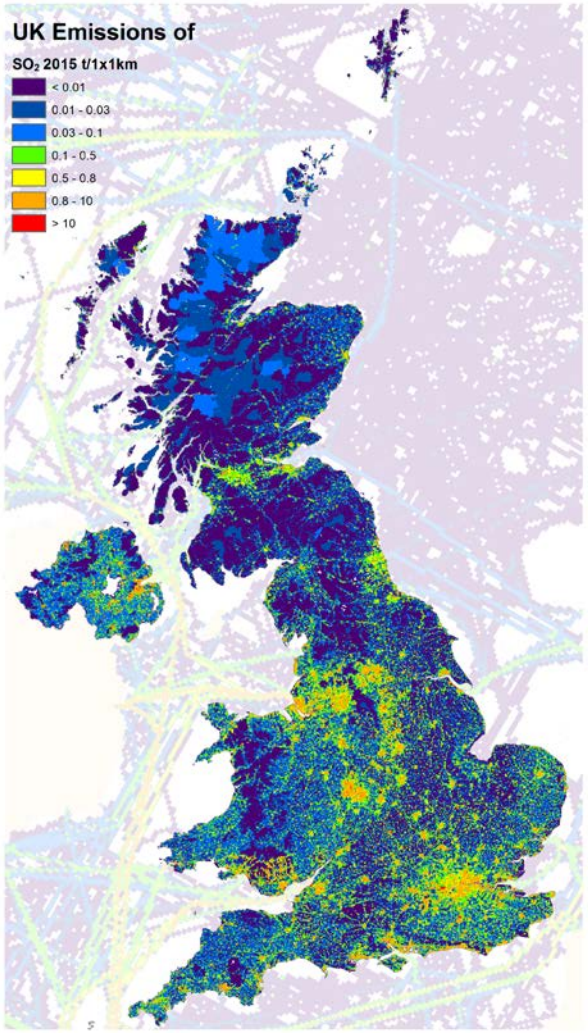
- Coal a major source of SO_2.
- In power: burn less coal.
- If you burn coal, use low-sulphur coal. Lowest sulphur coal up to 85% less SO_2 but more expensive.
- Various methods to reduce SO_2 from waste gas ('scrubbers').
- Low sulphur fuels in transport. Relatively small amounts, but near many people.
- Industrial processes. Petrol refineries, ore processing etc. Remove SO_2 on site.

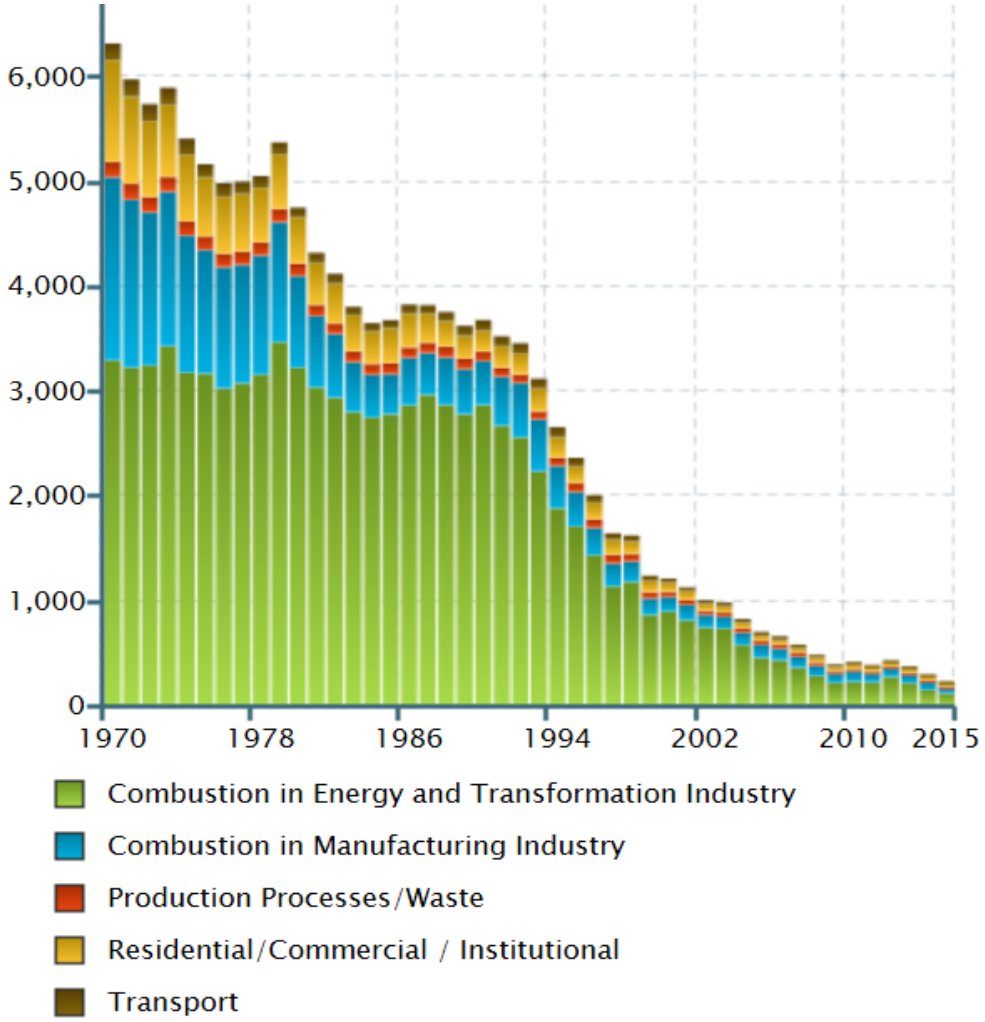


BBC

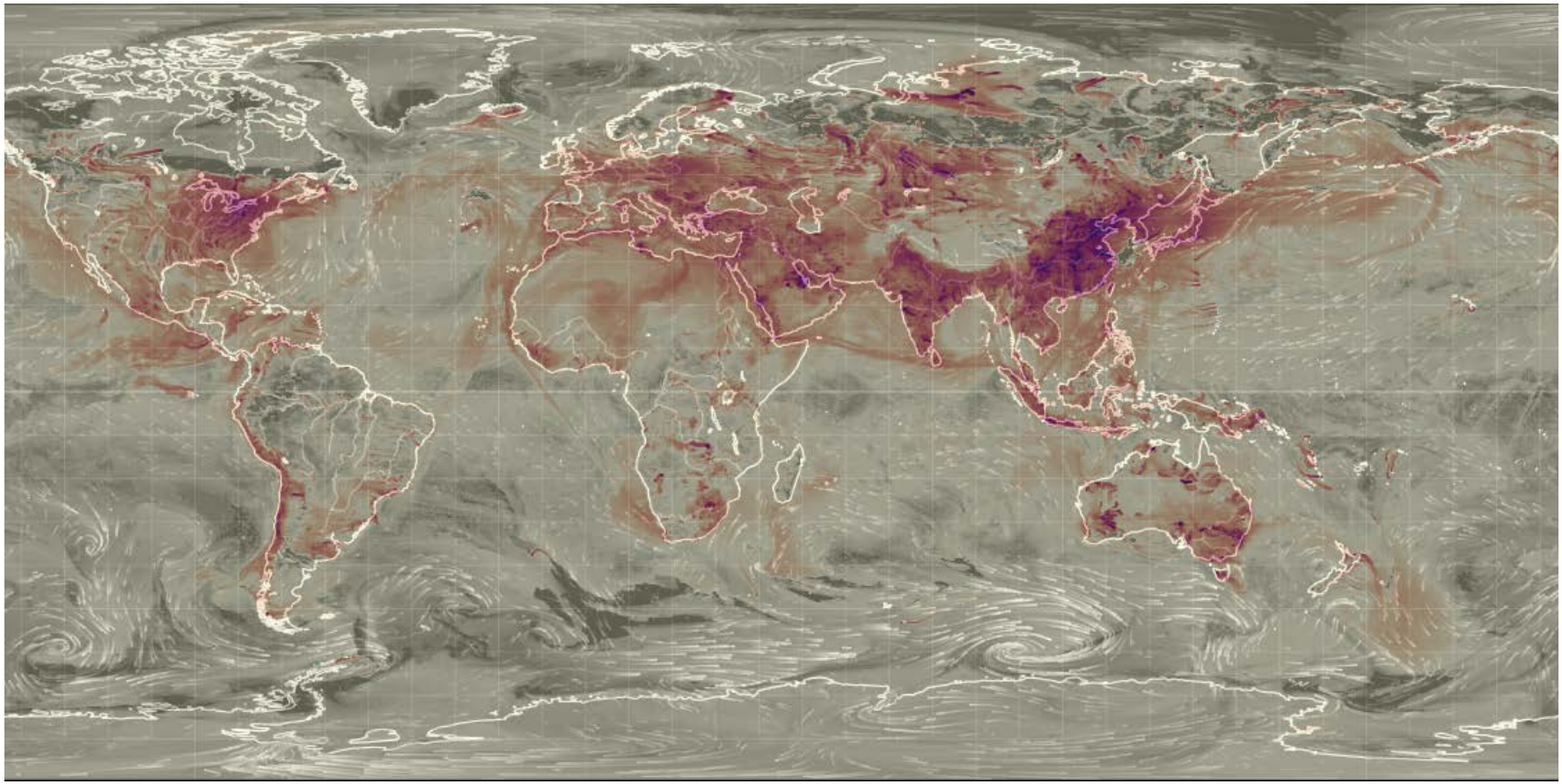
Sulphur dioxide (SO_2). UK 96% reduction since 1970, mainly reduced coal, and in towns fuel mix.

NAEI 2018.





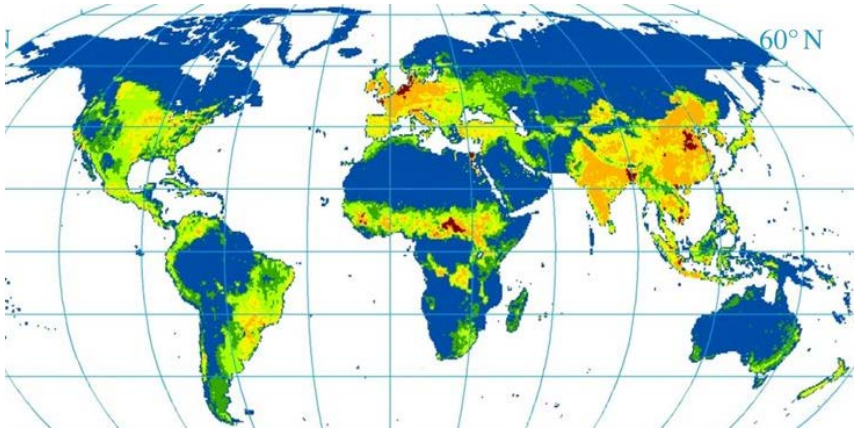
Sulphur dioxide, one day in 2017.



Global Modeling and Assimilation Office (GMAO) at NASA, 2017

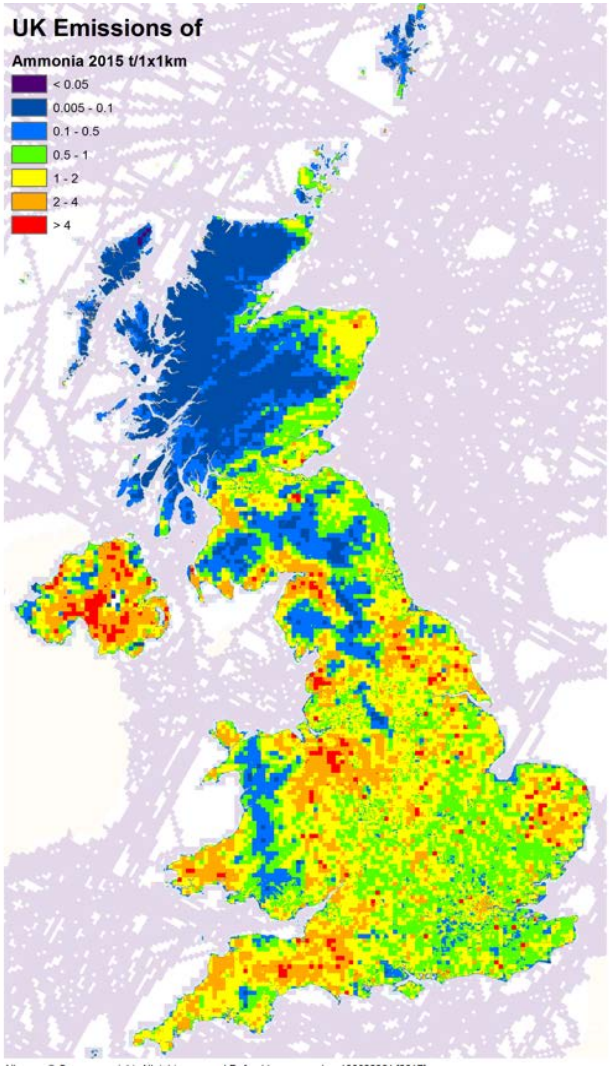
Ammonia health effects.

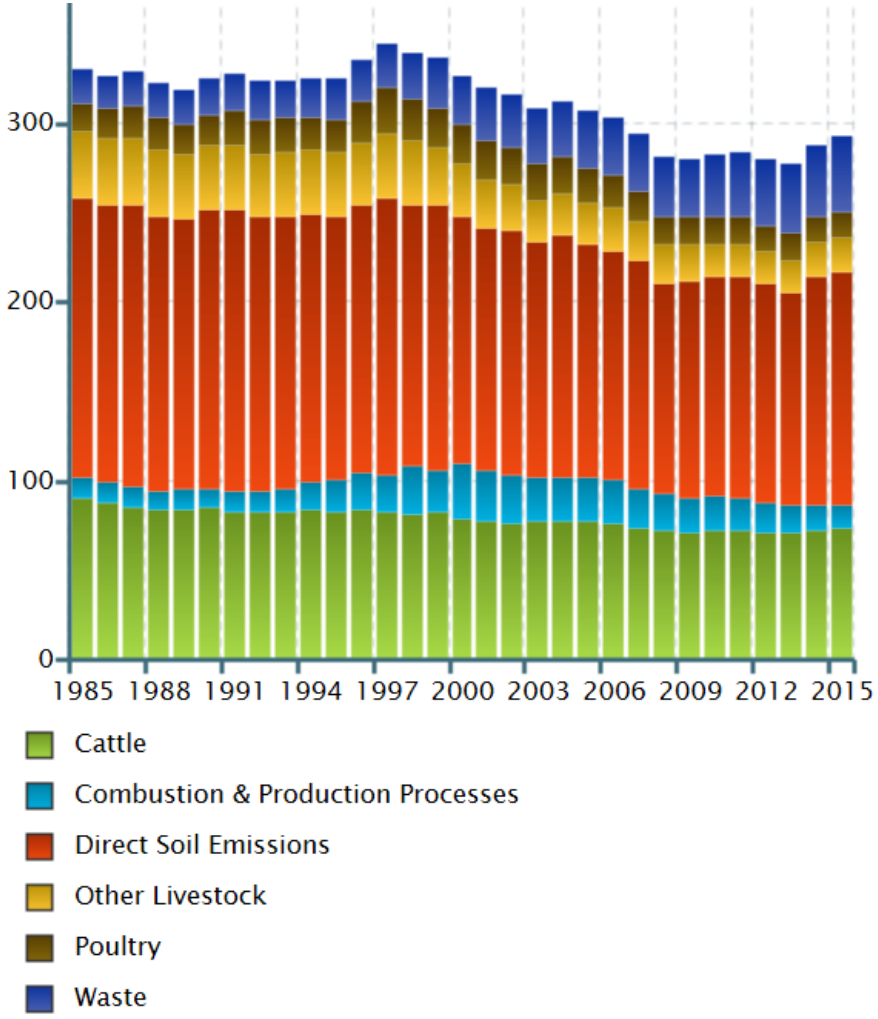
- At high doses very irritant, can trigger asthma.
- Other than those occupationally exposed, no *current* evidence of substantial effects of prolonged low-level exposure.
- Contributes to particulate matter (PM) formation. This may be important in some settings.



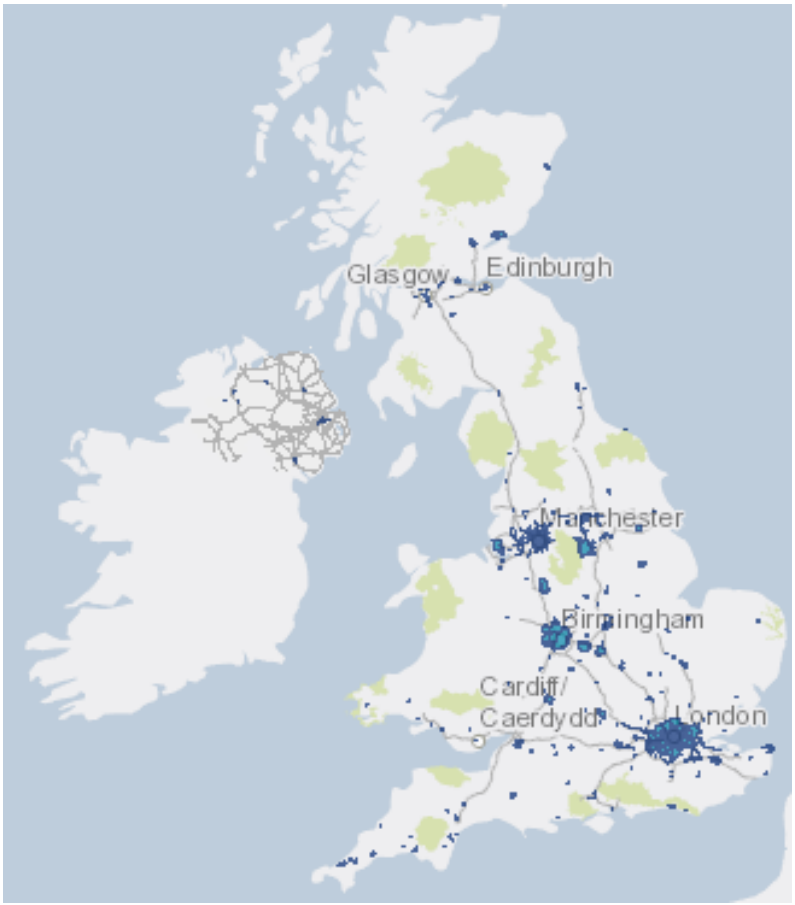
Sutton M et al Phil Trans R Soc 2013

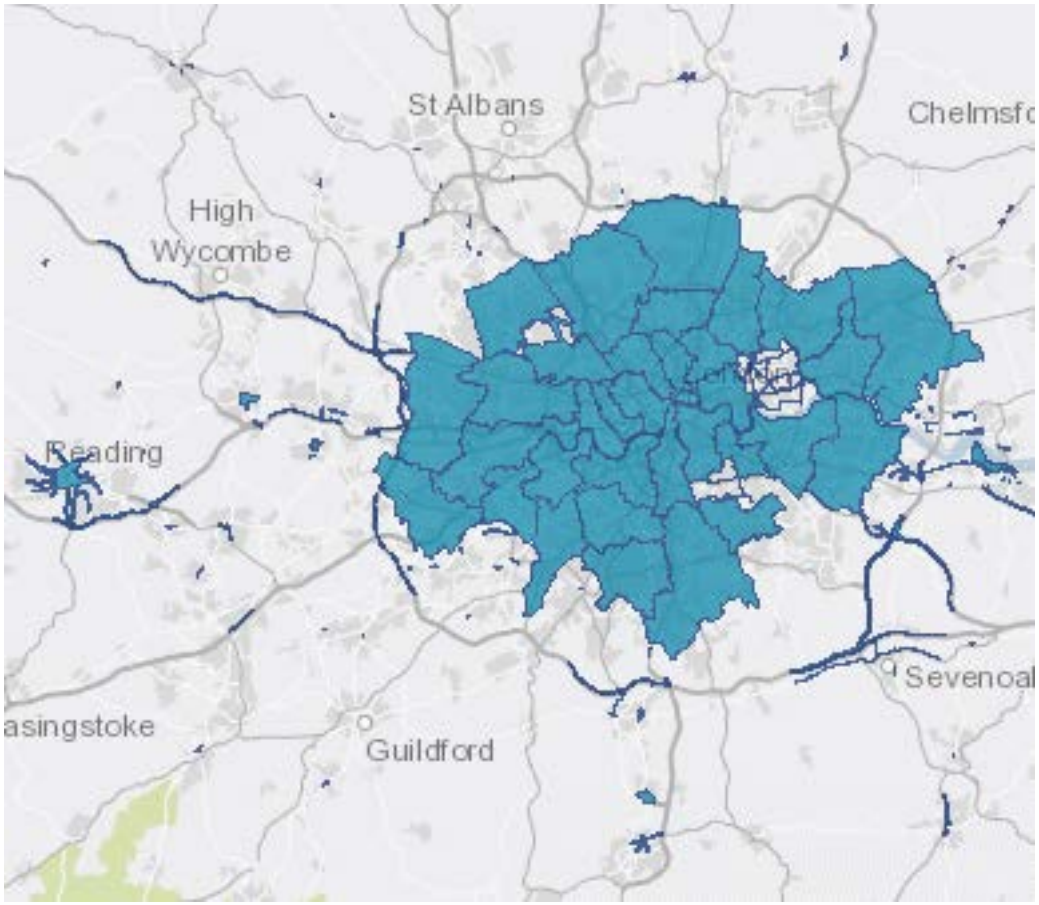
Ammonia. Almost all agricultural, especially fertiliser, cattle and poultry. *NAEI 2018*



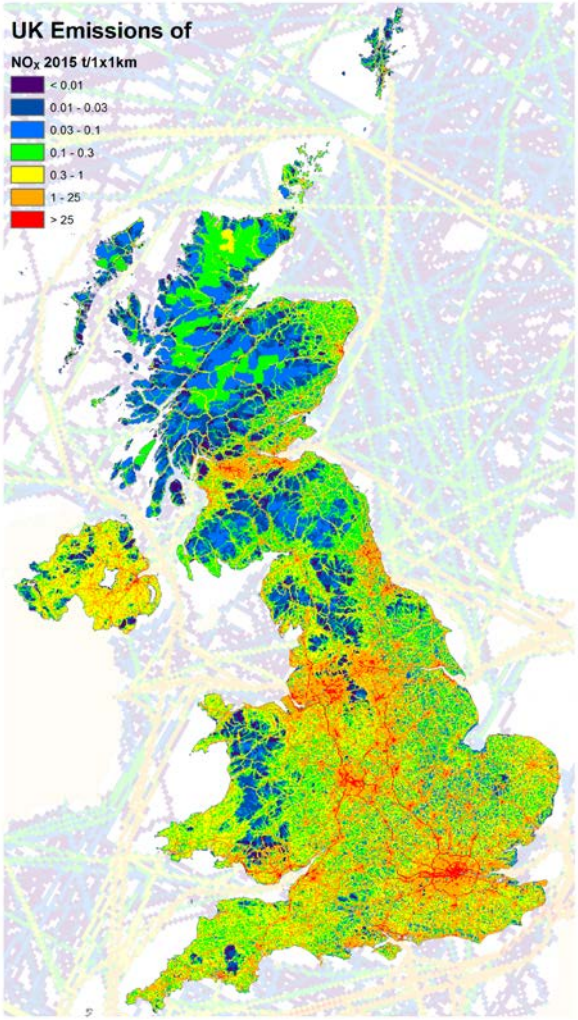


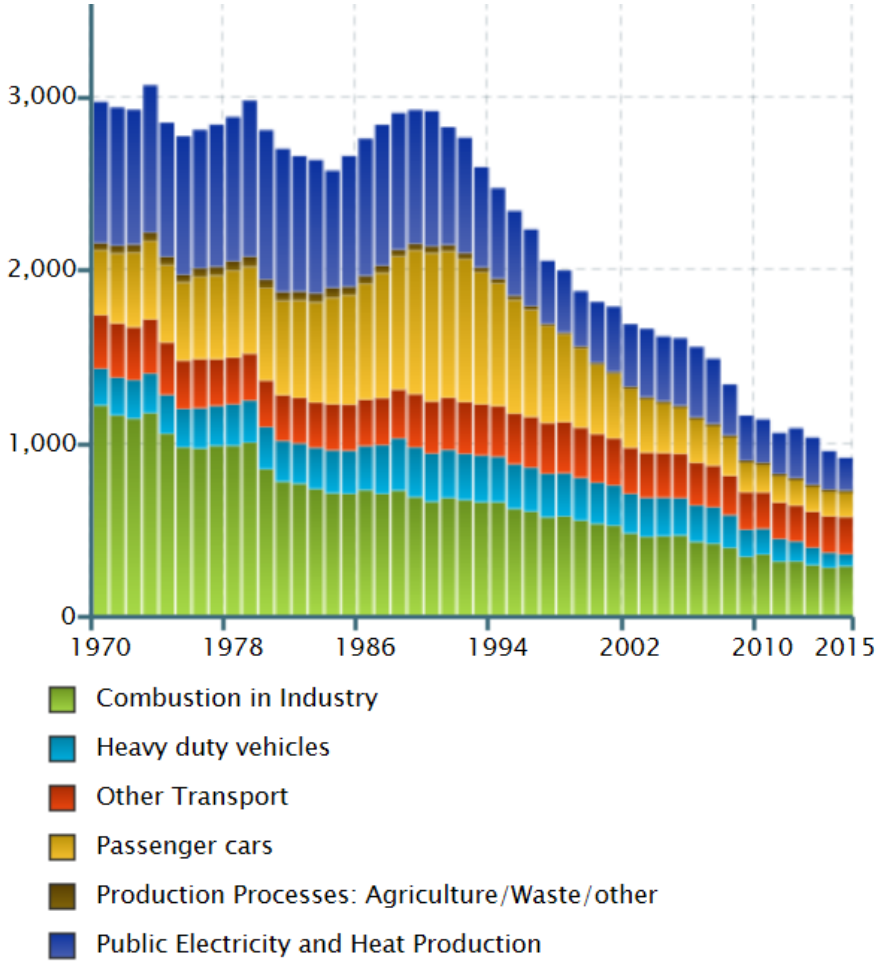
DEFRA air quality management areas (AQMA). UK and Greater London area.



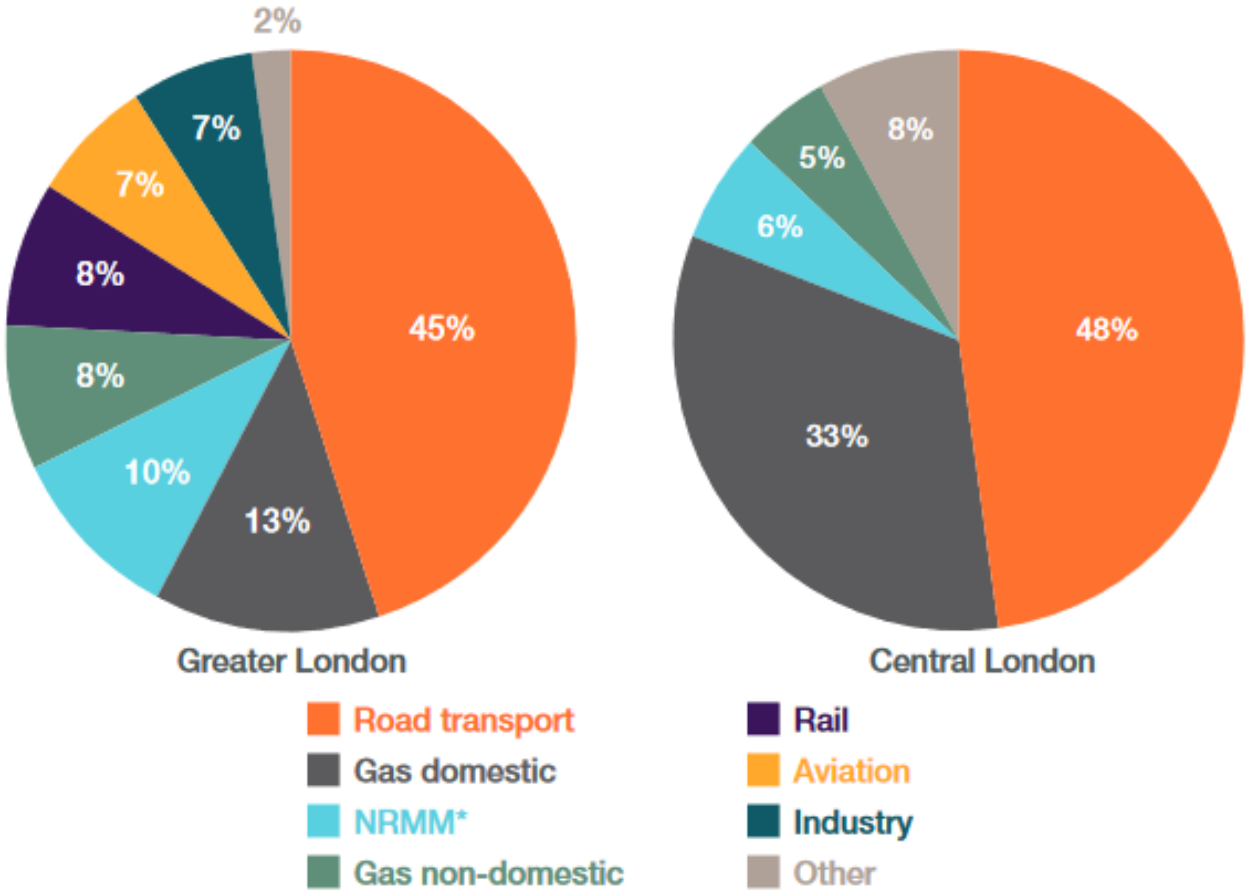


Nitrogen oxides (NOx). *NAEI 2018*



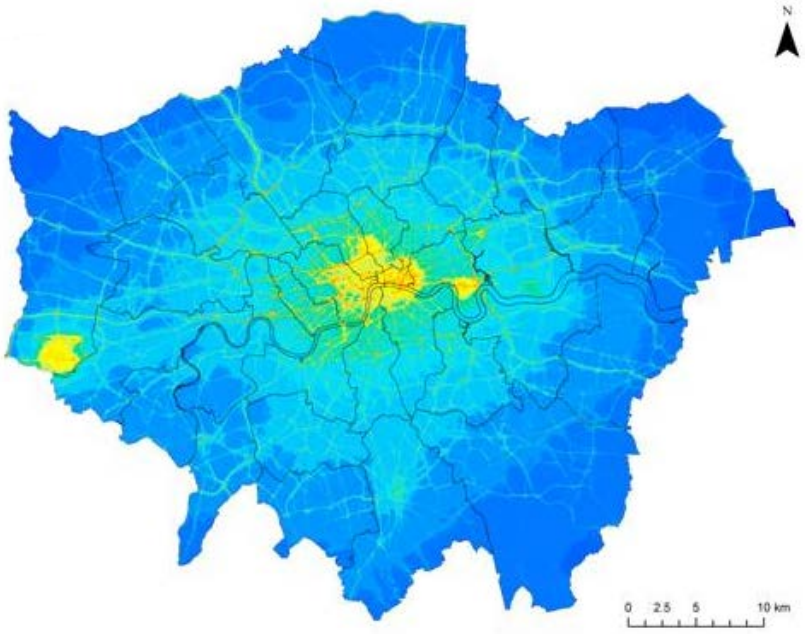


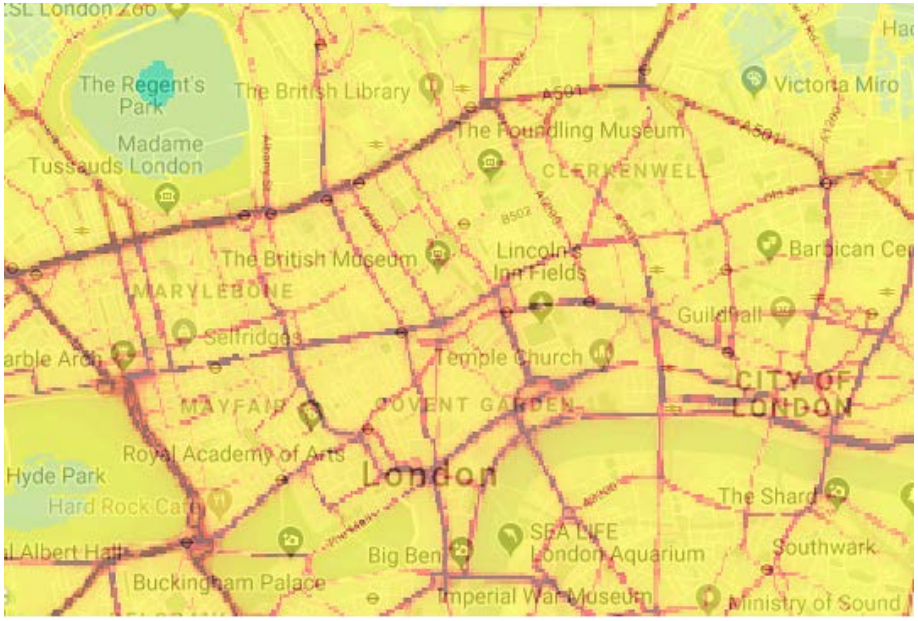
In cities impact of transport is greater. NOx: greater London L, central London R 2010. *GLA 2010 data.*



Modelled NO_2, London.

London Atmospheric Emissions Inventory, London Air/GLA/TFL.



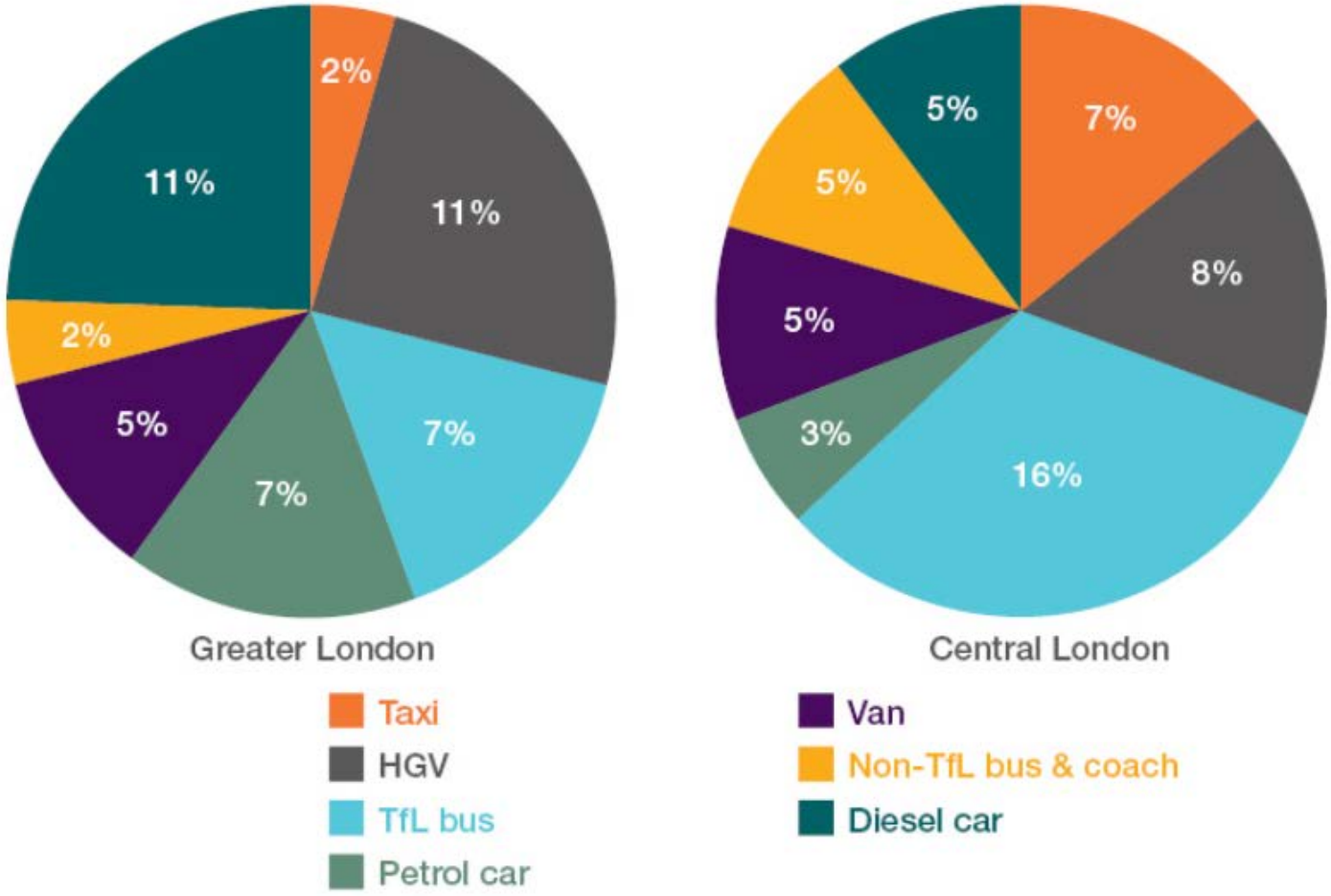


Key: Annual mean NO2 air pollution for 2013, in microgrammes per metre cubed (ug/m3)

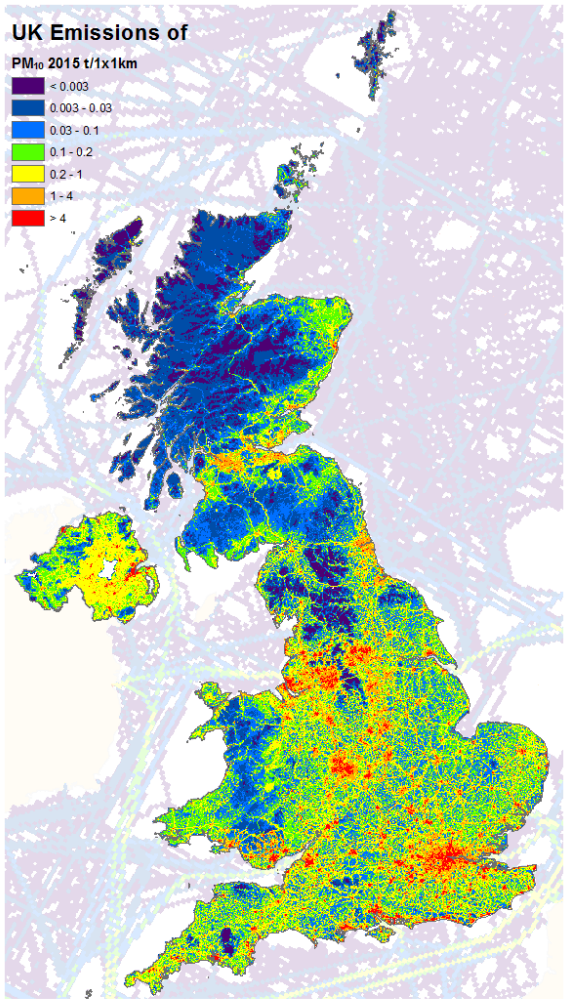
<16 16 19 22 25 28 31 34 37 40 43 46 49 52 55 58 61 64 67 70 73 76 79 82 85 88 91 94 >97

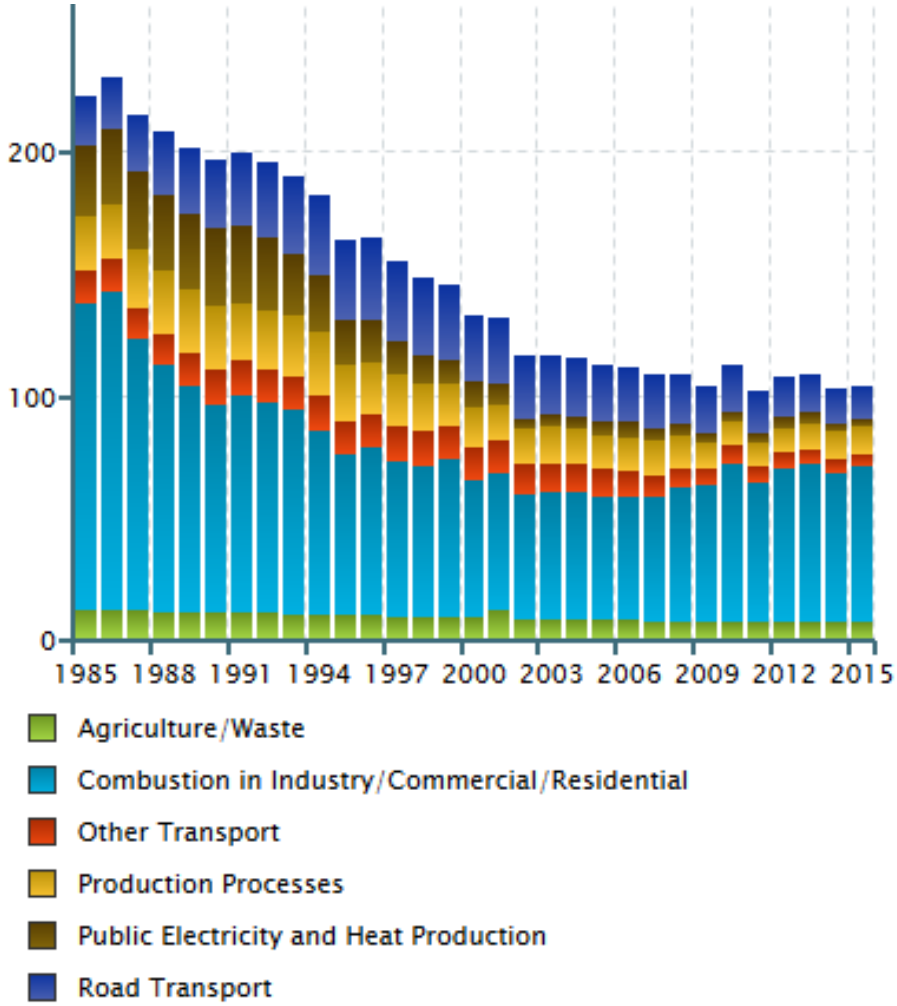
Passes annual mean objective **Fails annual mean objective**

Transport mix for NOx, London 2010. *GLA data, IPPR.*

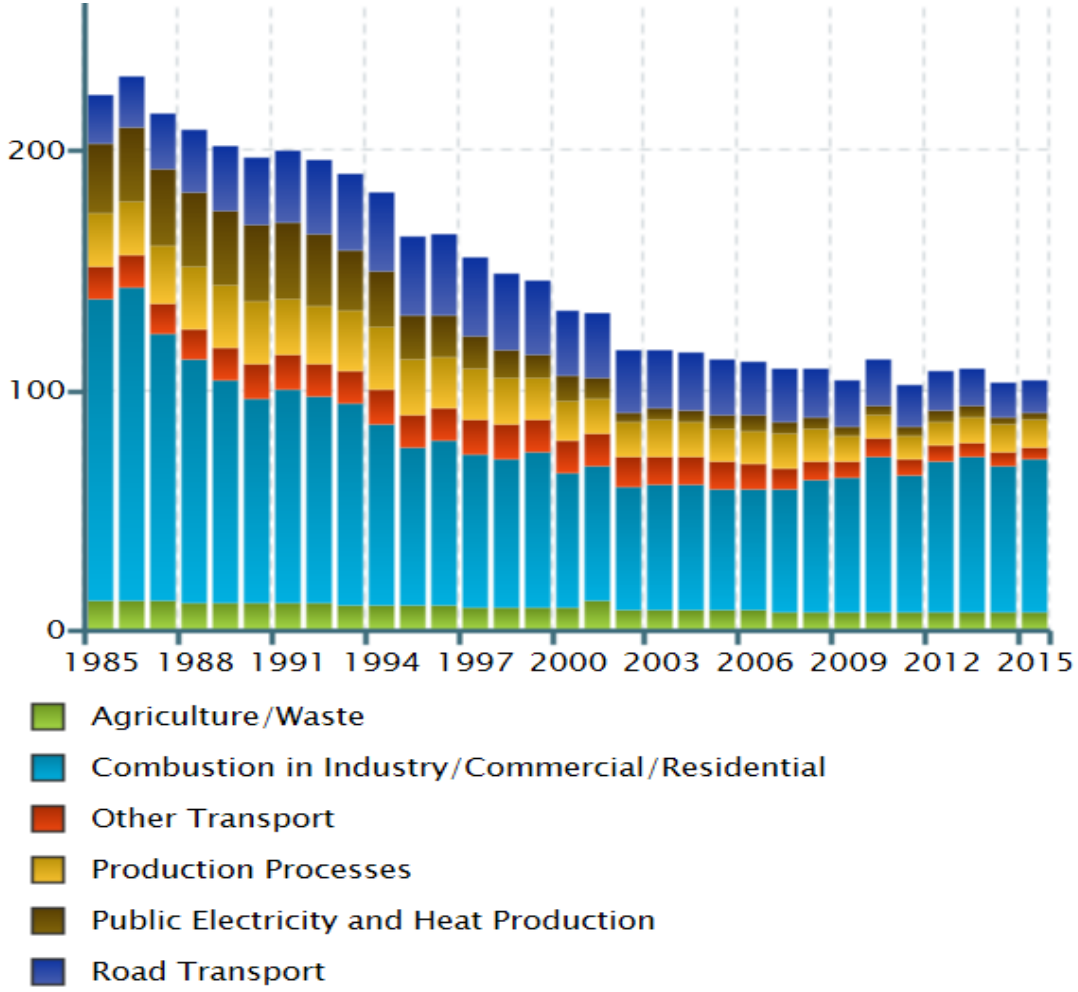


Particulate matter. PM10. *NAEI 2018*





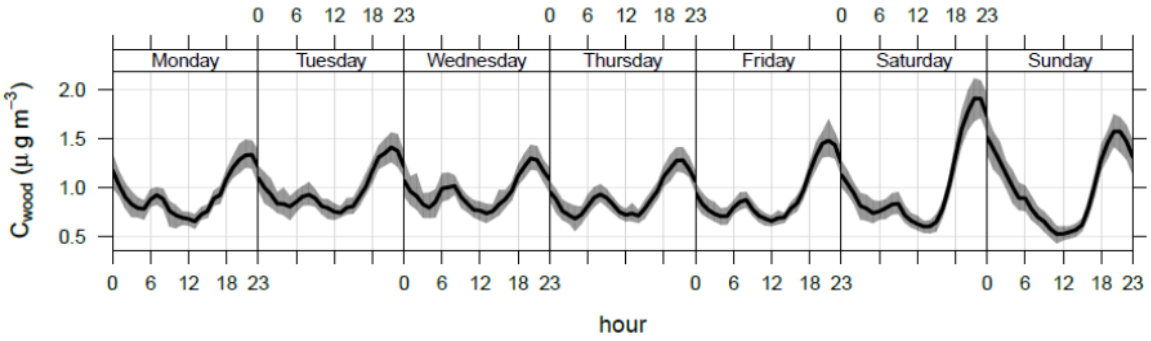
PM2.5. Fall due in large part to reduction in coal. Recent increase due to domestic wood burning.



- Emissions from power stations have fallen by 91% since 1990.
- 85% of domestic combustion emissions in 2015 wood, 13% in 1990.
- In 2015, residential combustion accounted for 37% of PM1.0 emissions, of which 77% of emissions wood burning.
- *NAEI. Data in Kt.*

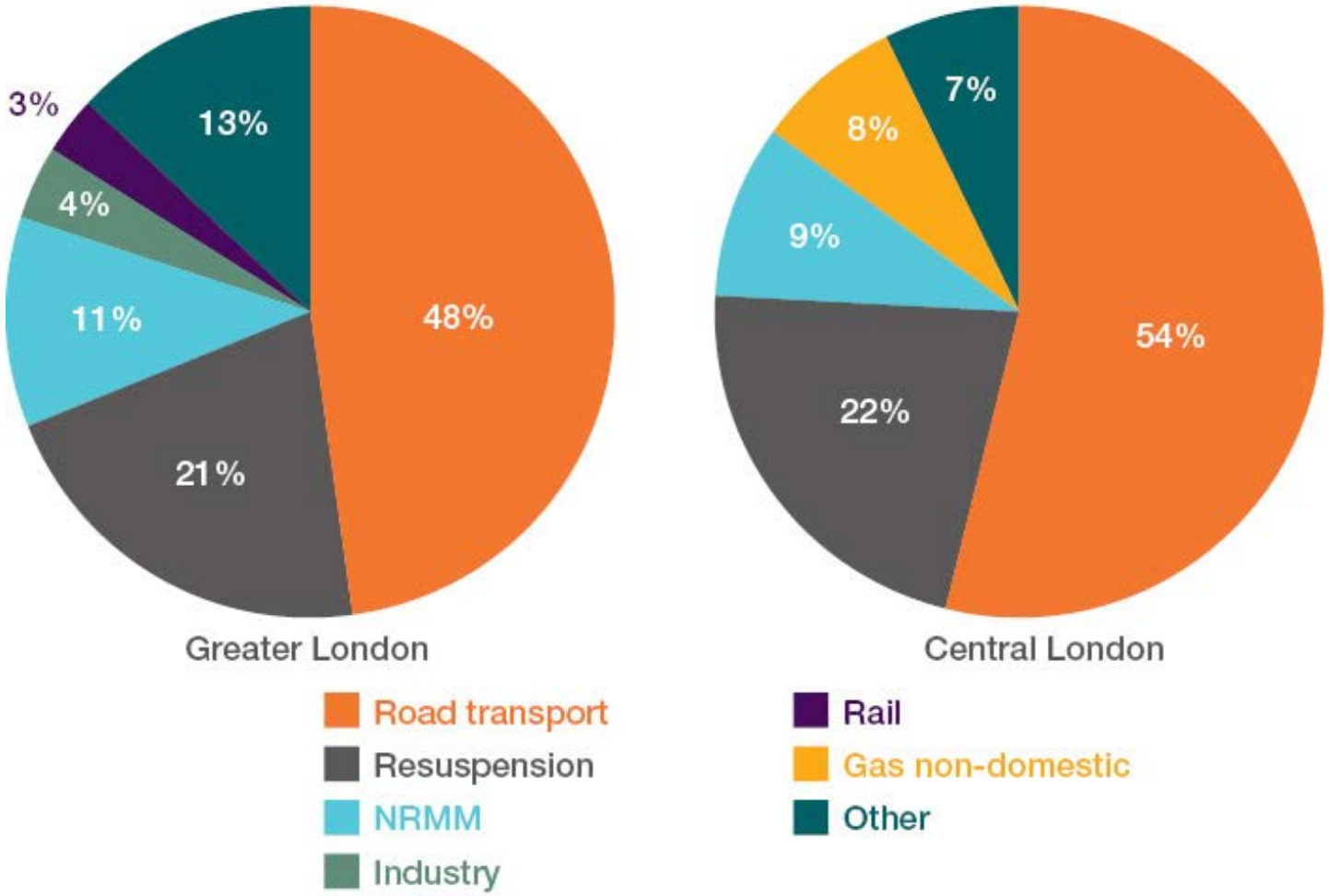
Wood burning stoves are great aesthetically, less great for PM2.5

- Wood burning between 23 and 31% of the urban derived PM2.5 in London and Birmingham.
- Daily variation in North Kensington in winter.



Kings College / NPL for DEFRA 2017

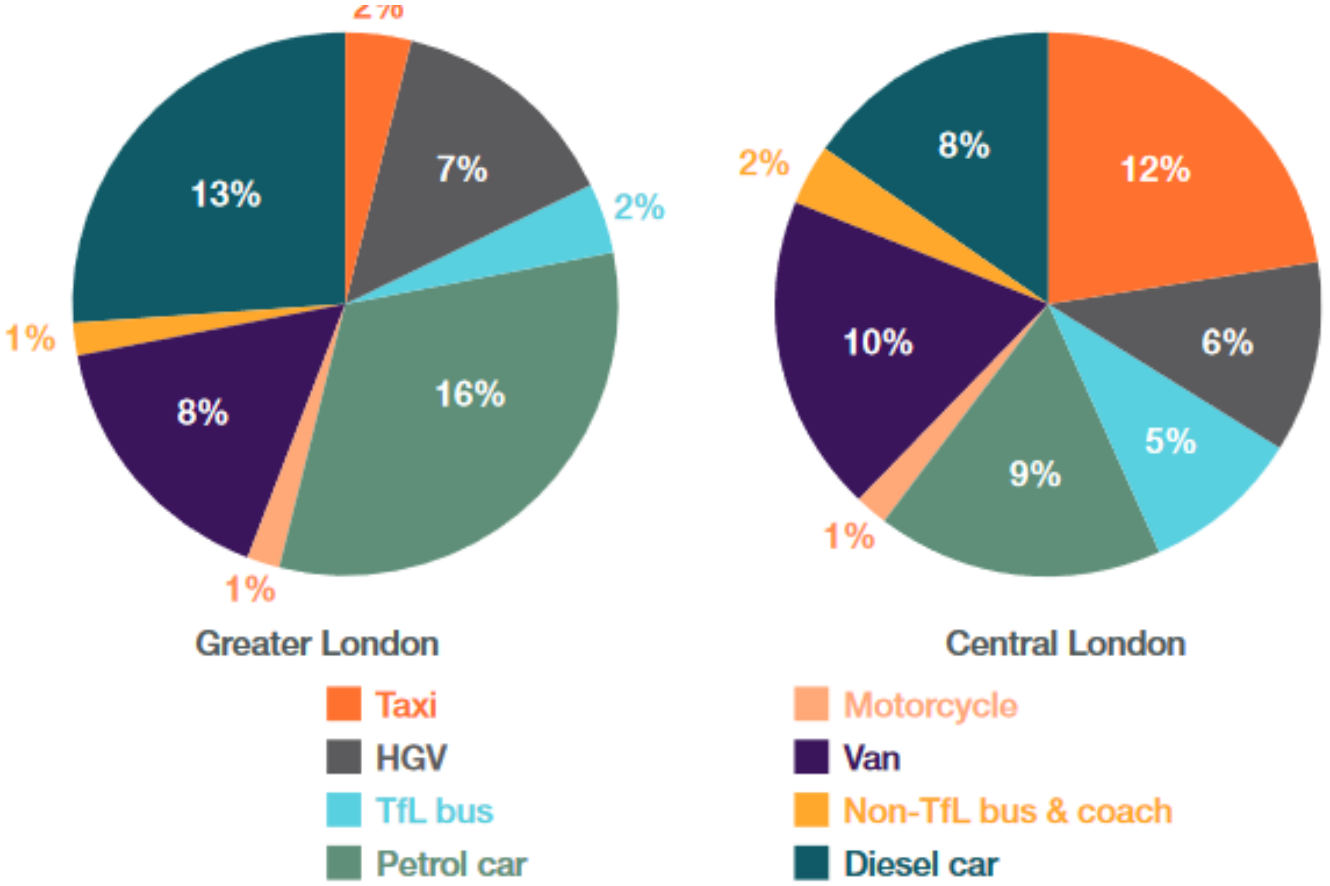
PM10 by source, London 2010. *GLA, 2010 data summary IPPR.*



PM from transport not just about exhaust fumes. Includes tyres, brakes, tube and resuspension.

The transport mix for emissions, London PM10.

(GLA 2010 data)

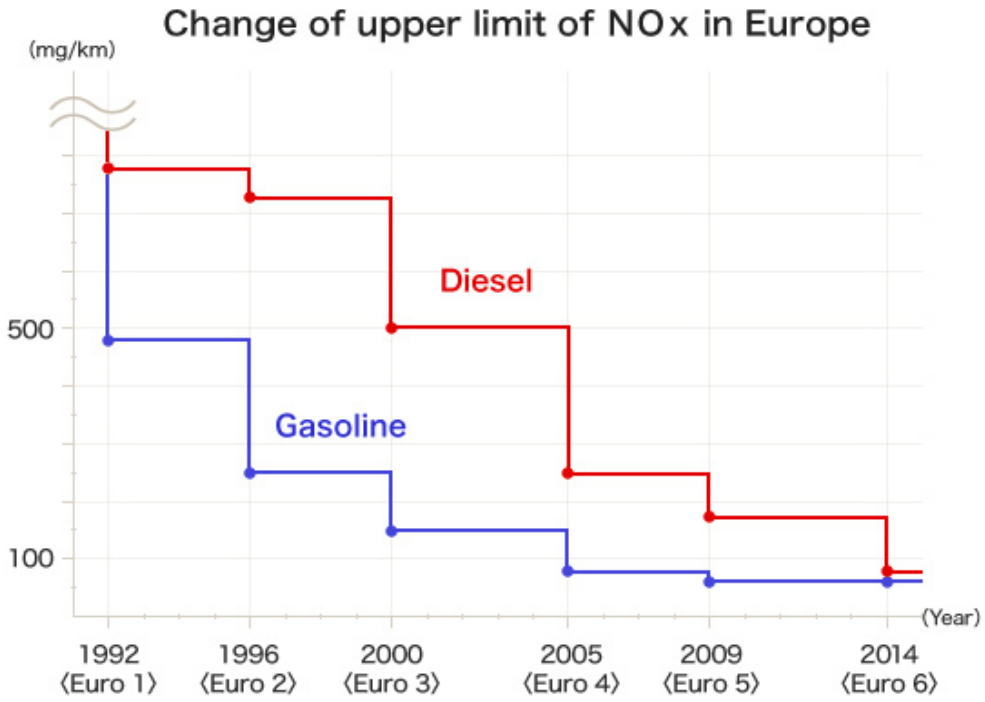


Tightening regulation spurs engineering innovation. (This only works if manufacturers do not cheat). Some innovations less effective as vehicles age.

Vehicle emissions control in Europe

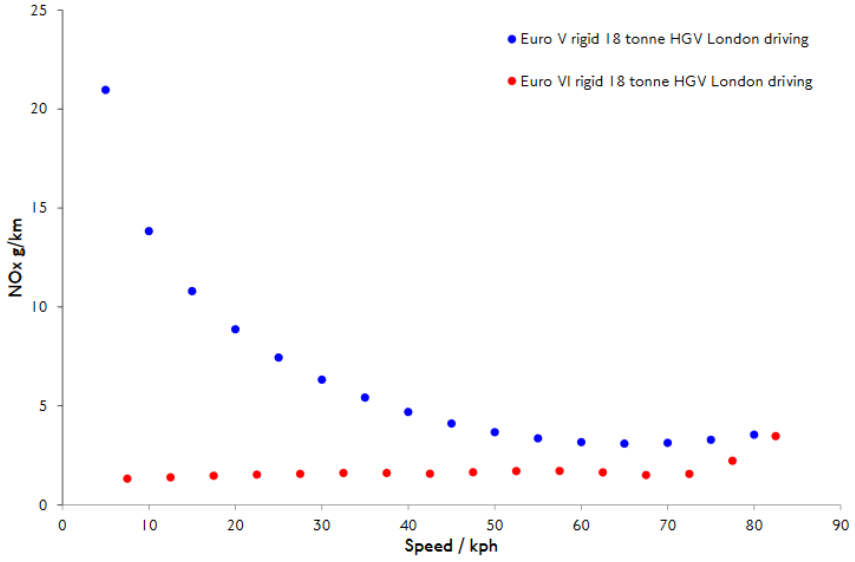
	Effective date	Upper limit (mg/km)		
	New model	Gasoline	Diesel	
		NOx	NOx	PM
Euro 0	October 1991	1,000	1,600	Not regulated
Euro 1	July 1992	490	780	140
Euro 2	January 1996	250	730	100
Euro 3	January 2000	150	500	50
Euro 4	January 2005	80	250	25
Euro 5	September 2009	60	180	5
Euro 6	September 2014	60	80	5

Reference: European Automobile Manufacturers Association



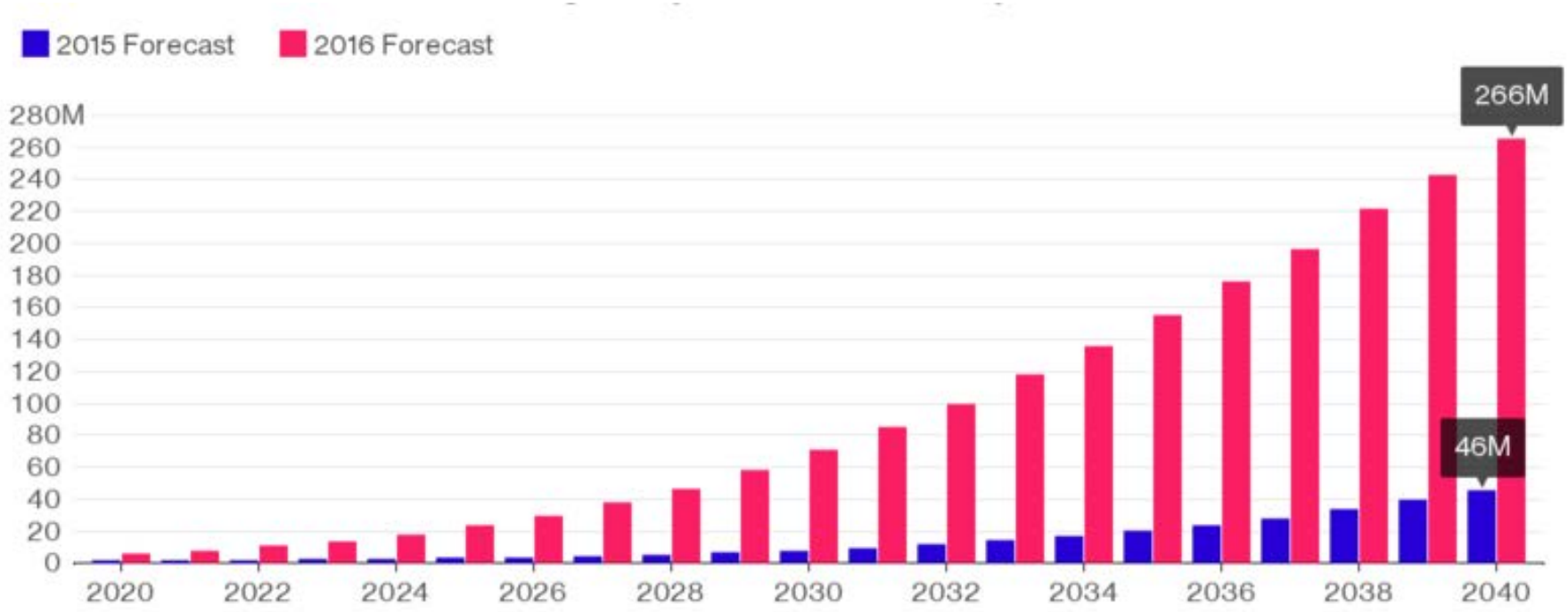
Need for strong emphasis on the sectors and areas with high density of pollution.

- Taxis.
- Public transport.
- Delivery vans.
- HGVs- 18 tonne, Euro V compared to Euro VI at R (TFL data).
- Diesel cars.
- Ultra-low emission zones.

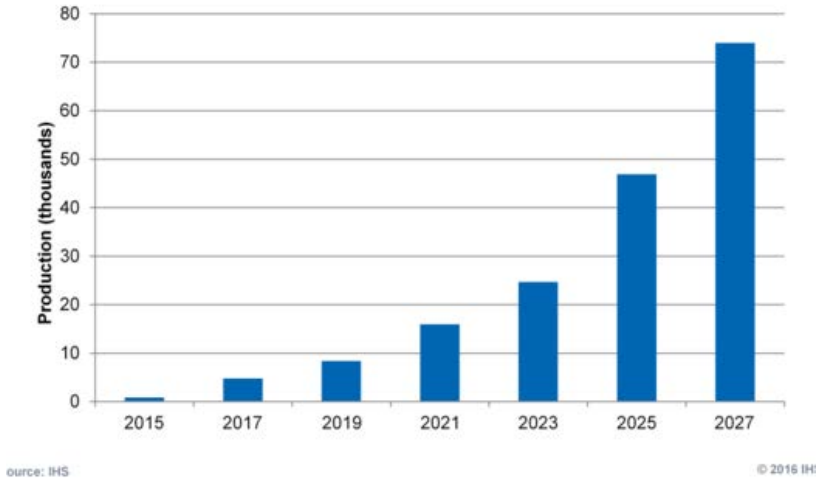


Electric vehicles. There is no doubt the market is growing. OPEC forecast change 2015 to 2040. Battery technology, charging infrastructure, grid capacity, regulation, consumer demand are factors.

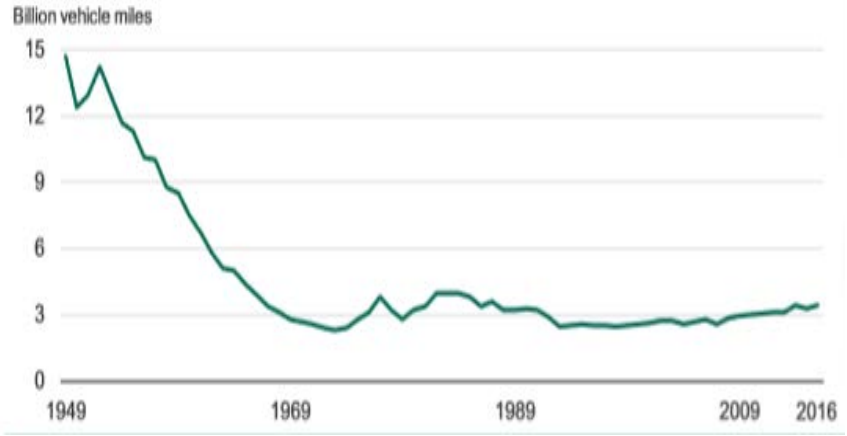
Bloomberg New Energy Finance. Roughly 500% change.



Hydrogen fuel cells- currently a niche product but renewed interest. Projected global hydrogen fuel cell electric vehicle production.
Hydrogen central heating being explored in UK. *(IHS)*

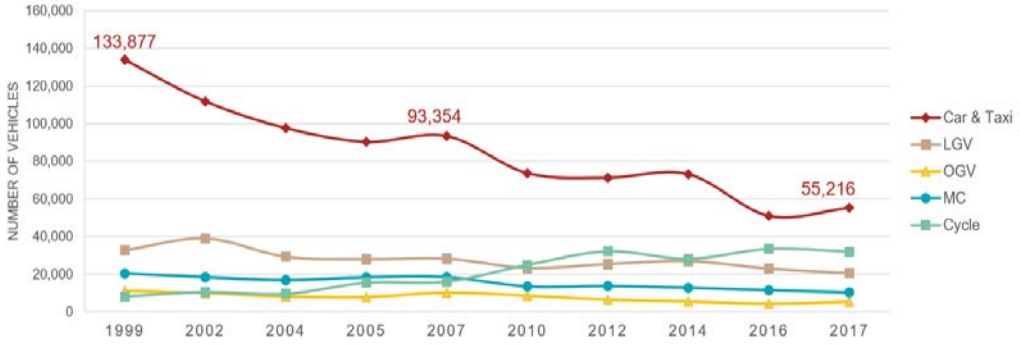


Cycling and active transport. Back to the future?



UK pedal cycle miles 1949-16.

Department of Transport, 2018

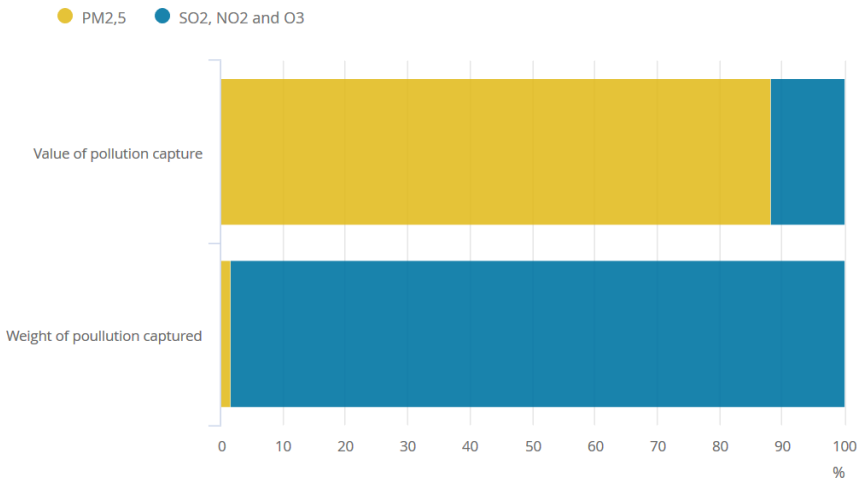


Change in travel, City of London 1999-2017. 292% increase cycles.

Dept Built Environment 2018.

Pollution capture by vegetation, especially trees.

(ONS/CEH 2017)



- In 2015 natural pollution removal by plants in UK, ONS estimated:
- 5,800 fewer respiratory hospital admissions,
- 1,300 fewer cardiovascular hospital admissions,
- 27,000 fewer life years lost,
- 1,900 fewer premature deaths.

aurélien

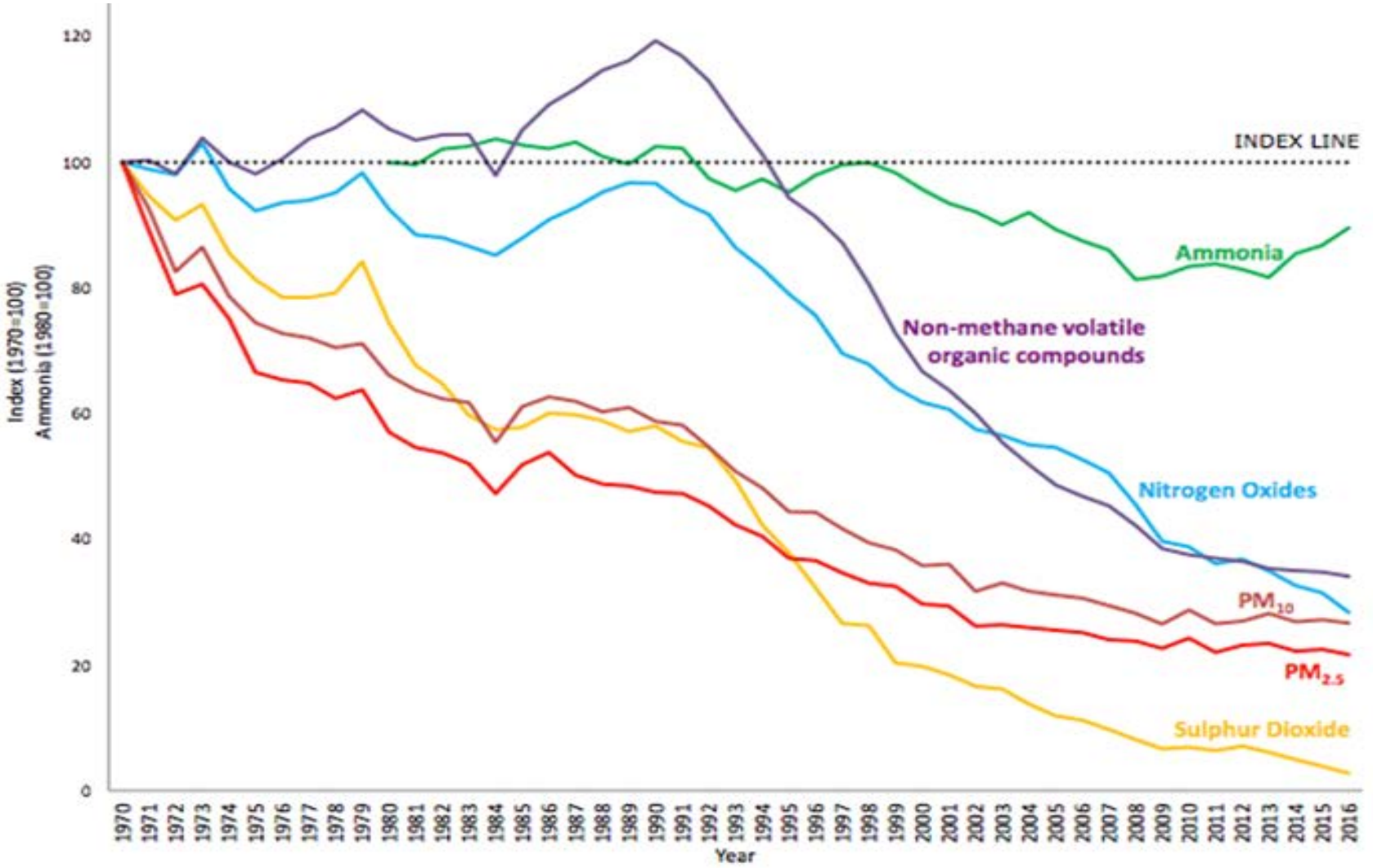
Ladder of state intervention.

- Ban.
- Tax heavily.
- Regulate.
- ‘Nudge’ tax or intervention.
- Mass voluntary programme.
- Engage with industry.
- Inform.
- Leave up to individuals.

Reducing air pollutants is possible without crashing the economy. It requires transnational action.

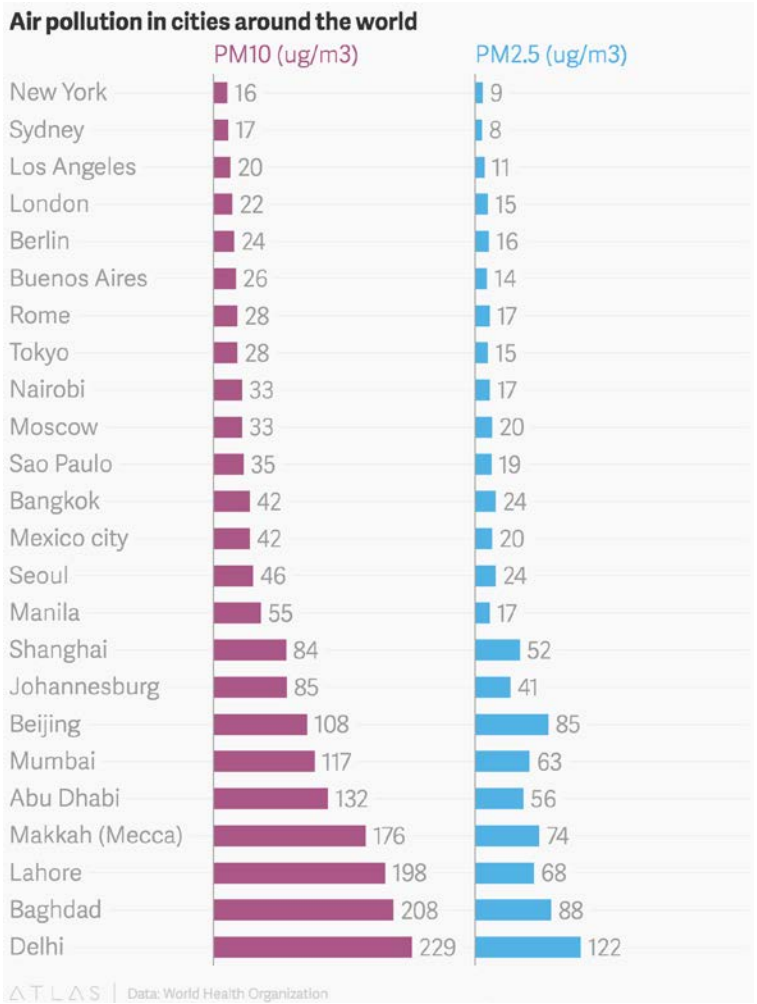
UK 1990-2016 -71% NOx, -95% SO_2, -54% PM2.5

DEFRA/ONS 2018.

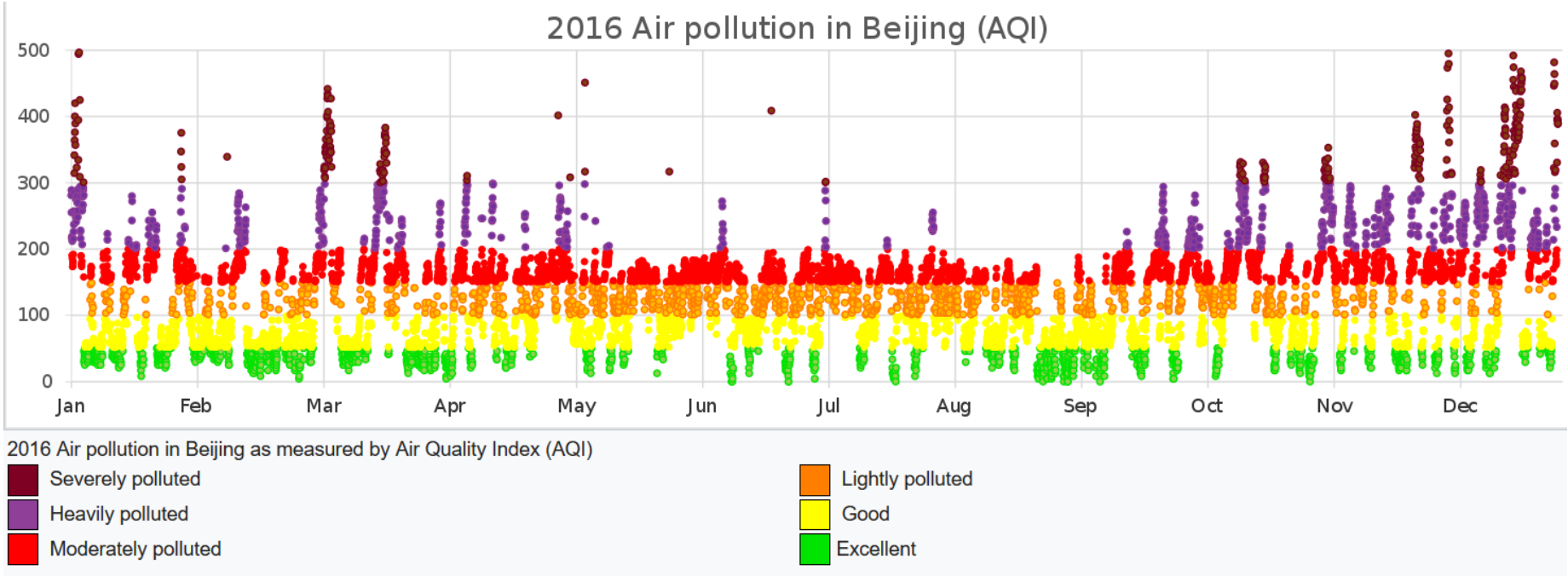


Substantial variation between cities. Beijing roughly 5x more particulates and Delhi around 10x those of London on average. *(WHO data/ATLAS)*

Wikimedia



In all cities the amount of pollution varies over time as well as distance. In Beijing AQ has probably been improving, but still a challenge for much of the year.



Wikimedia, data UK Department of States 2017.

Reducing air pollution substantially is technically possible and essential for health. But not cost-free.

- For many pollutants substantial progress already.
- For NOx there are engineering solutions to much of the risk.
- Particulates are harder, but the health impacts are substantial.
- An international problem.
- Real trade-offs between rapid industrialisation and pollution. But the poorest still suffer most from health effects.

JMW Turner C 1830. *The Thames above Waterloo Bridge.*