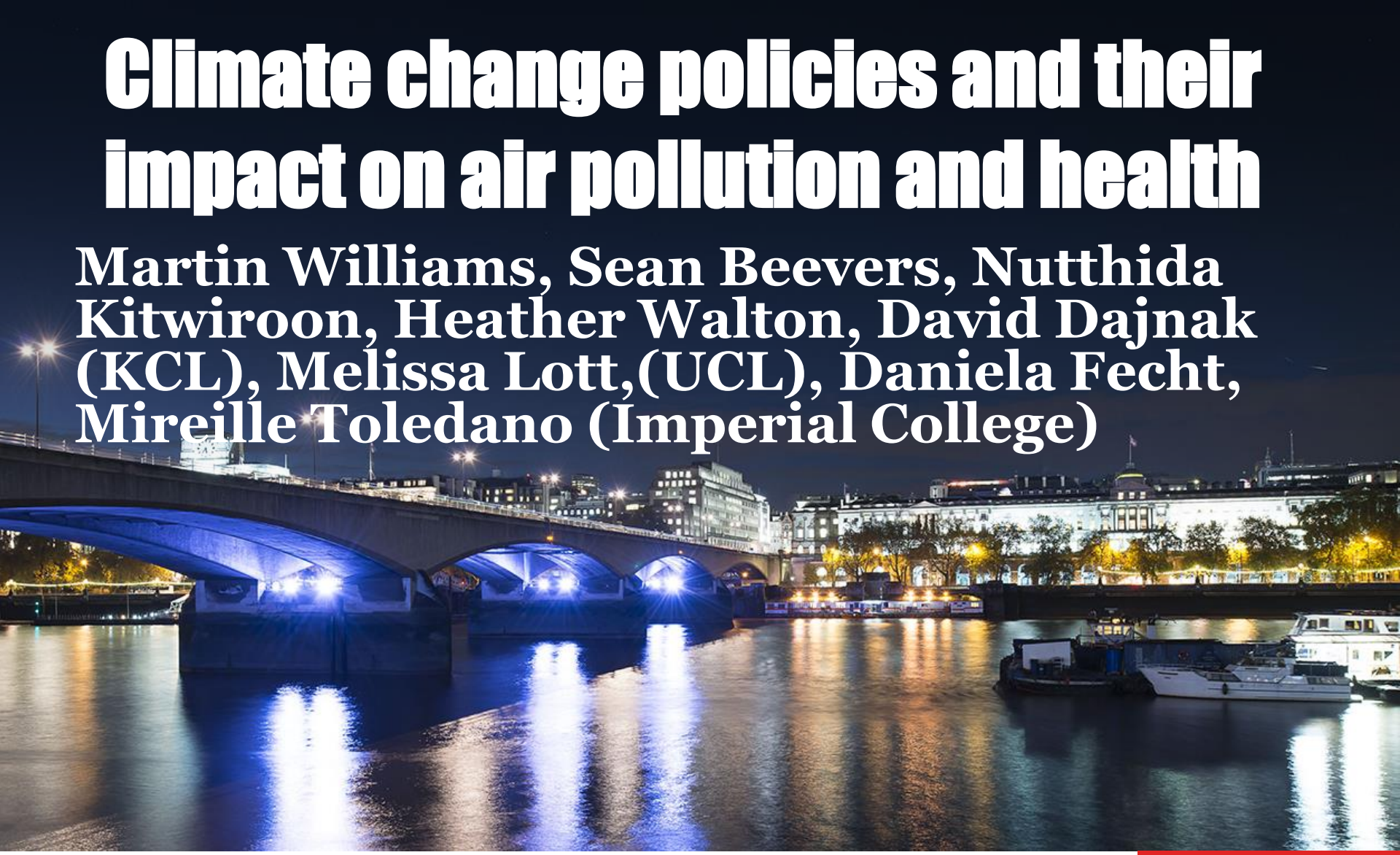
Climate change policies and their impact on air pollution and health

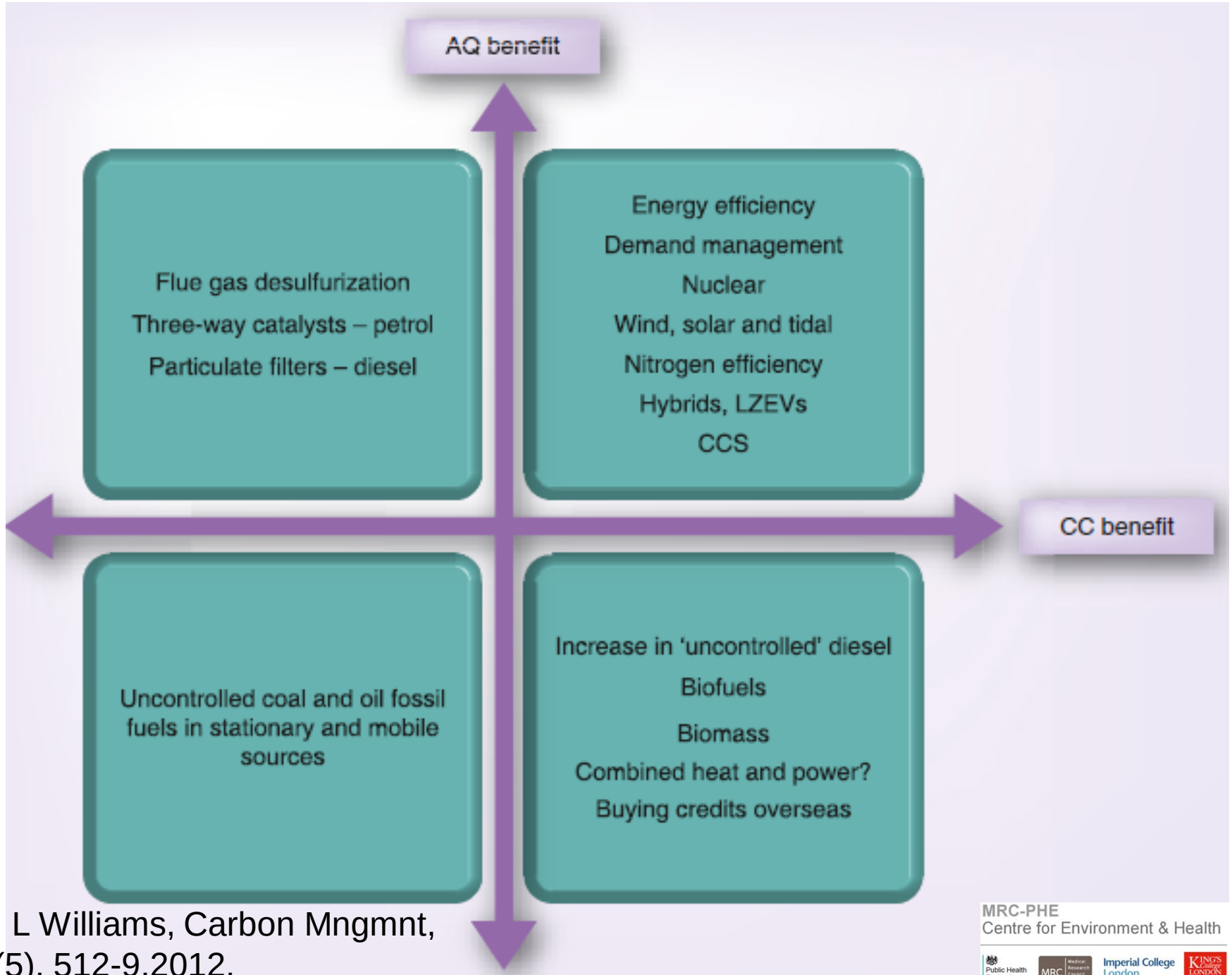
Martin Williams, Sean Beevers, Nutthida Kitwiroon, Heather Walton, David Dajnak (KCL), Melissa Lott,(UCL), Daniela Fecht, Mireille Toledano (Imperial College)



KING'S College LONDON

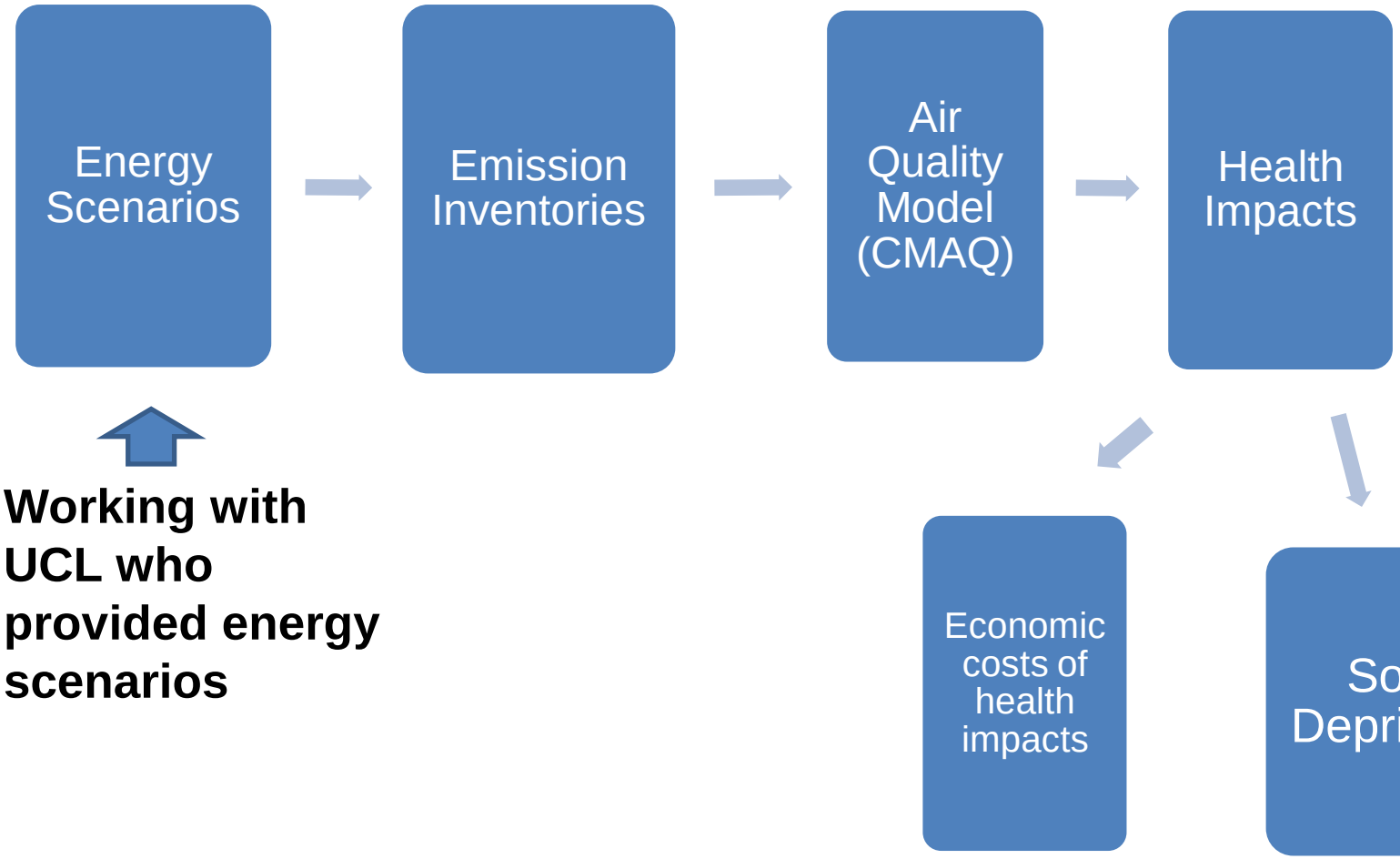
UK Climate Change Act 2008

- The UK has set a target of ***80% reduction in CO_2 equivalents by 2050*** (on a 1990 base)
- Making the right choices to achieve the Climate Change Act target offers potentially the biggest air quality & public health improvements since the Clean Air Act of 1956
- BUT – the policies need to be ***carefully chosen*** to avoid unnecessary adverse public health impacts – e.g. minimise diesel, biomass, CHP use in urban centres



M L Williams, Carbon Mngmnt, 3(5), 512-9,2012.

NIHR funded project

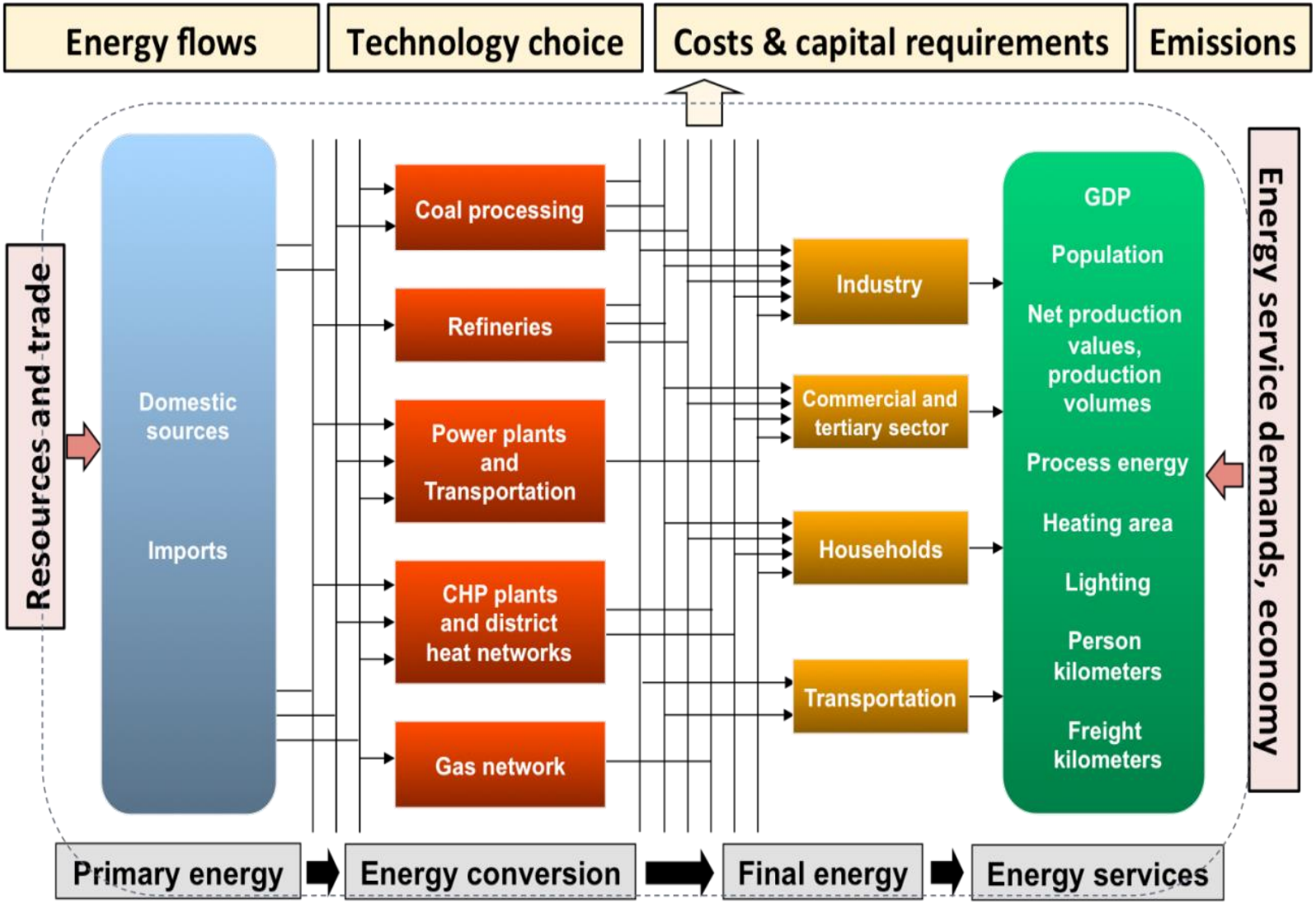


Working with UCL who provided energy scenarios

MRC-PHE
Centre for Environment & Health

Public Health England | MRC Medical Research Council | Imperial College London | King's College London

TIMES Model Generic Structural Diagram



Linking UK Times outputs to UK and European Emissions

UKTimes is the energy systems model for the UK as used by Government in assessing climate policies

We have ‘soft linked’ the UK Times model which outputs energy use (PJ) - use this to ‘scale’ the 2011 NAEI 1km emissions to 2050.

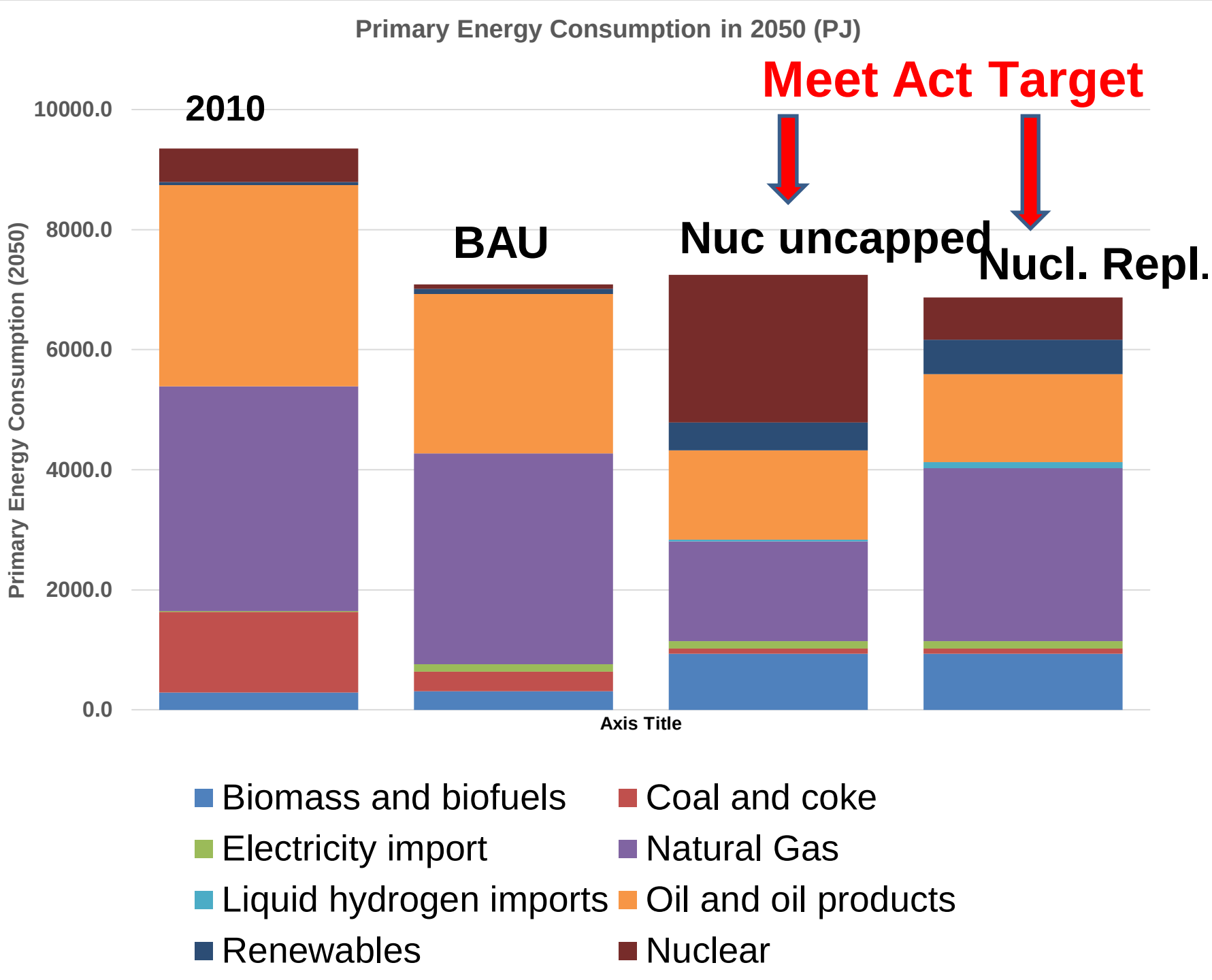
Emission factor changes are made using NAEI assumptions up to 2030 and maintained between 2030 and 2050

For road transport we are currently running King’s ‘bottom up’ emissions calculation between now and 2050 using detailed vehicle counts, speed and stock.

VOC and NH3 are taken from Eclipse 5a

MRC-PHE
Centre for Environment & Health
Public Health England
MRC Medical Research Council
Imperial College London
King's College London

Scenario	Description	
DECC Baseline	DECC Baseline (no further carbon mitigation)	Nuclear phasing out
Reference	Same as Base + 30 GBP/tonne carbon price - increasing linearly from 0-30 GBP over the period of 2010-2030 (0-30 GBP) and then plateaued at 30 from 2030 onward; no constraints on nuclear	Nuclear expansion
Low GHG	80% reduction by 2050 + interim carbon budgets (through the 4th budget); no damage costs included for non-GHG air pollutants	In addition to 2010 and 2050, will look at an interim year (2030/5) to show the impact of the mid-term increase in residential biomass use for CHP
Nuclear – replacement only	LowGHG scenario + constraint on nuclear so that it can only maintain its current capacity levels.	Nuclear capacity capped at 10 GW (i.e. current levels)

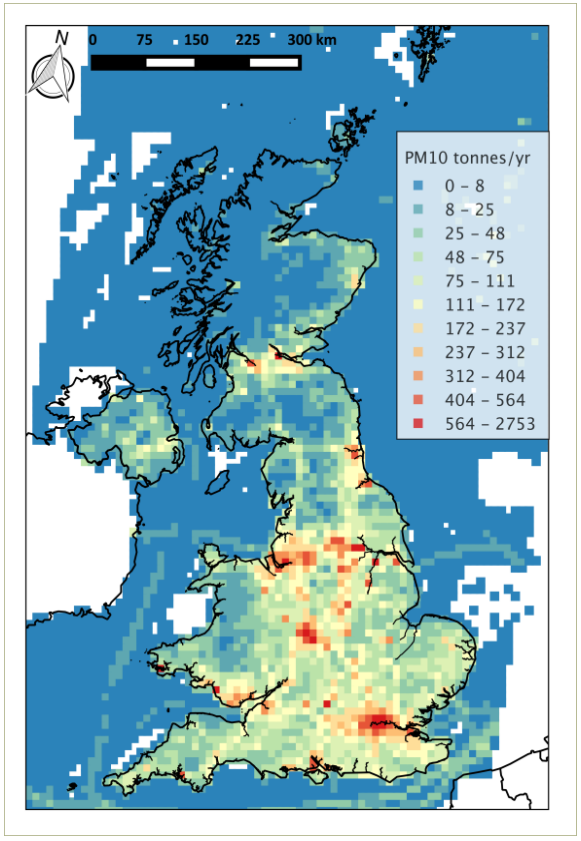

Primary Energy Consumption in 2050 (PJ)
Meet Act Target
2010
BAU
Nuc uncapped
Nucl. Repl.
10000.0
8000.0
6000.0
4000.0
2000.0
0.0
Primary Energy Consumption (2050)
Axis Title
Biomass and biofuels
Coal and coke
Electricity import
Natural Gas
Liquid hydrogen imports
Oil and oil products
Renewables
Nuclear

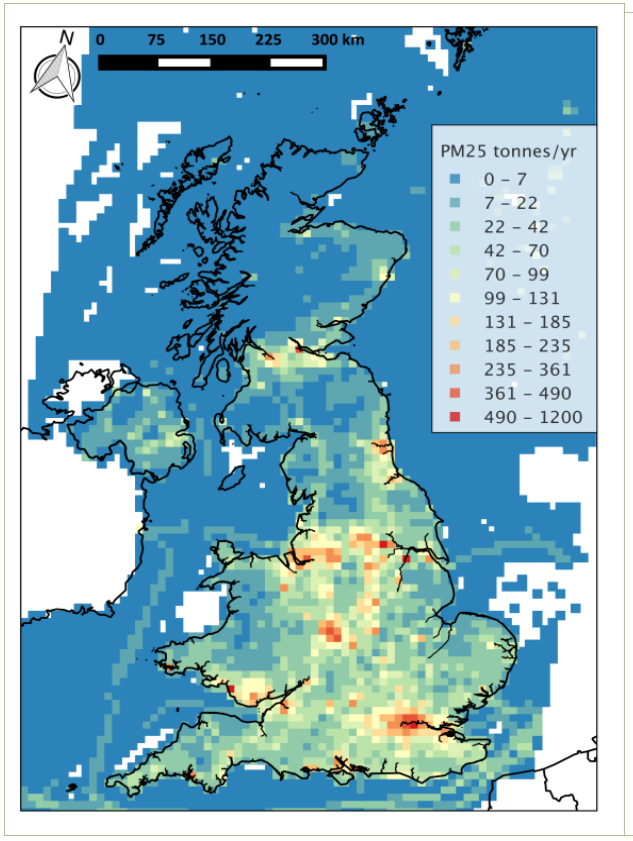
Non-combustion sources of air pollution are important

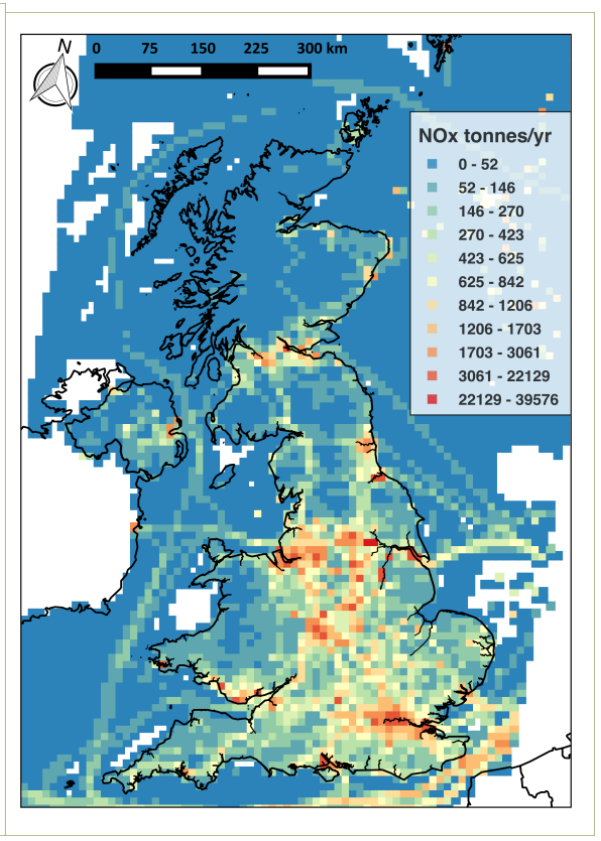
- Agriculture – emissions of ***ammonia*** from livestock and fertiliser use
- Solvent emissions of organics
- Particles from brake and tyre wear

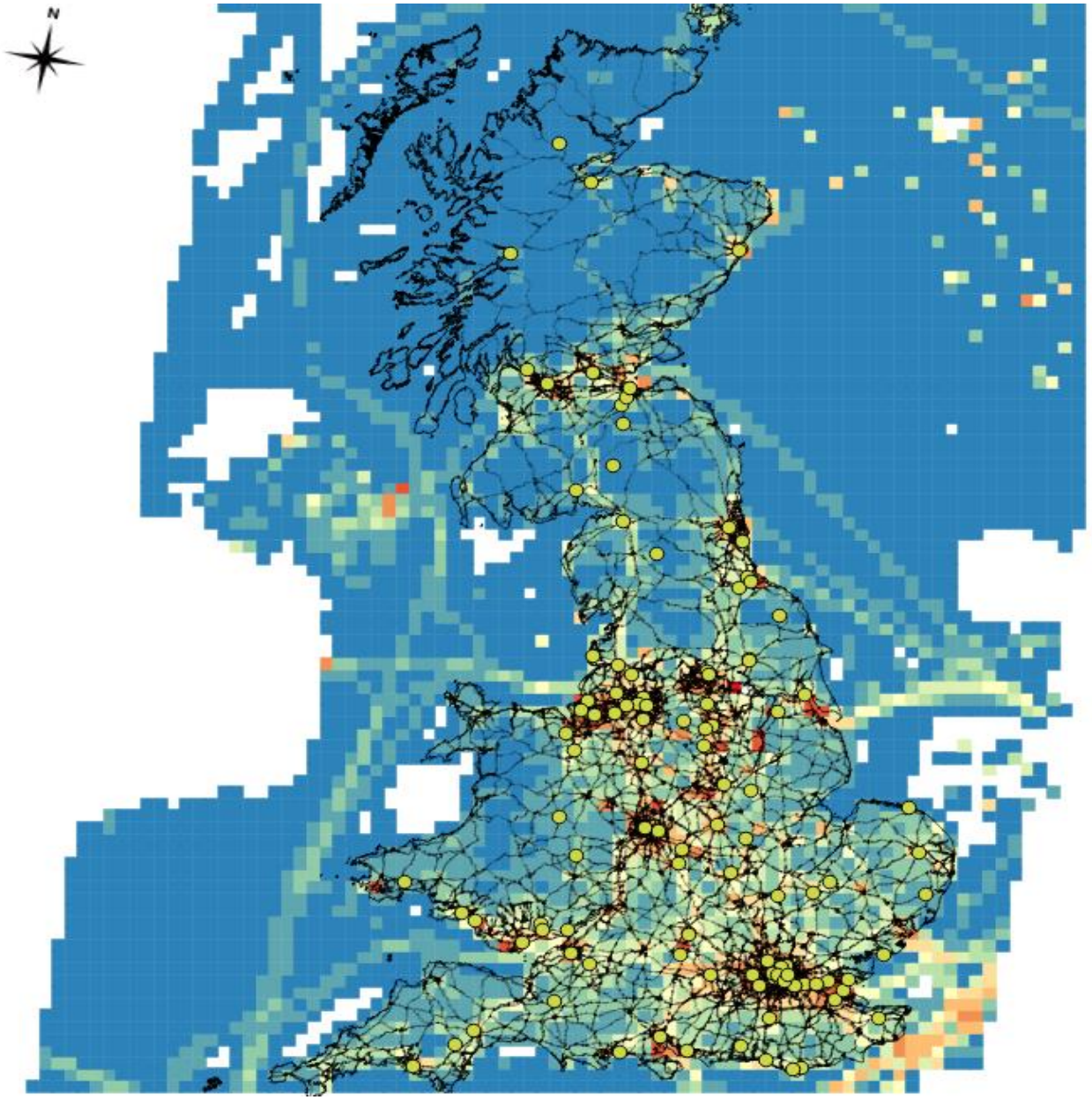
Non-combustion sources are important precursors of secondary aerosols – ammonium sulphate and ammonium nitrate, organic aerosol – these have LONG lifetimes and can travel 100s of kilometres

From the TIMES Energy Scenarios and data on non-combustion sources, we generate air pollution *emission* inventories



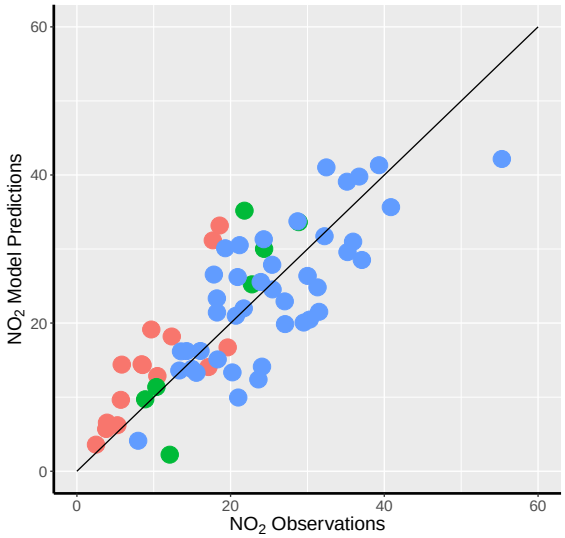


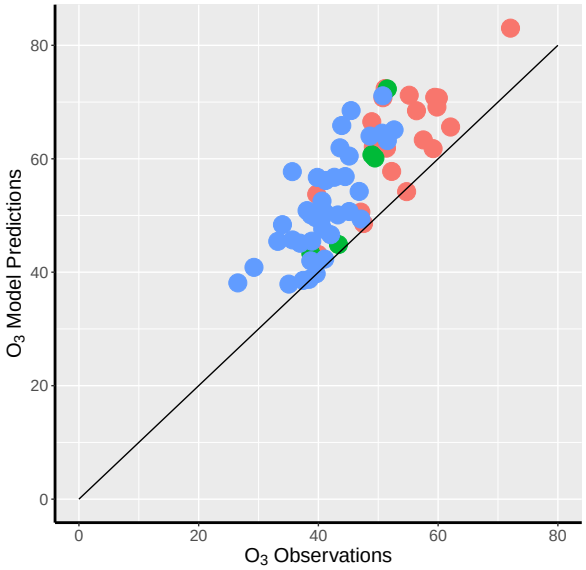




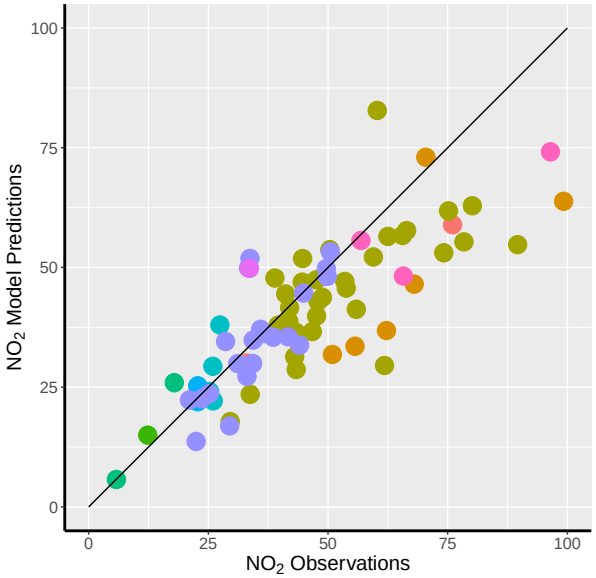
Measurement sites used to evaluate model performance

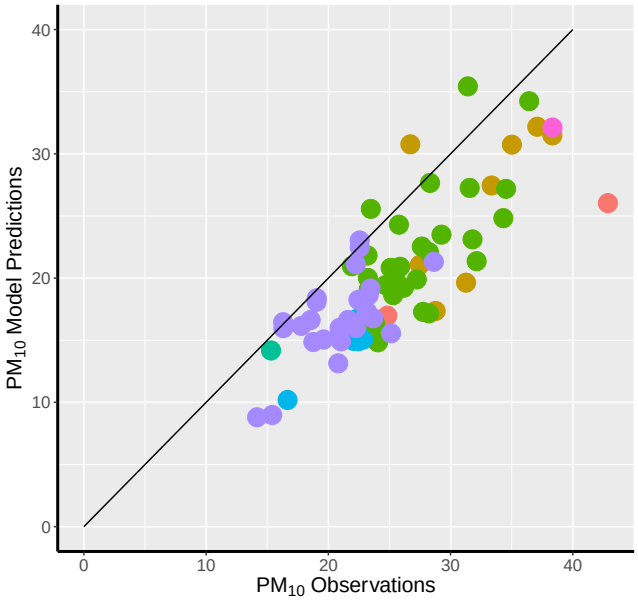
How good is the model?



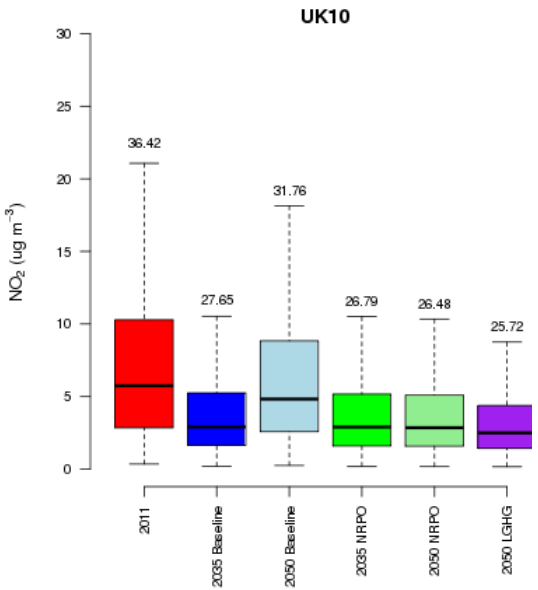


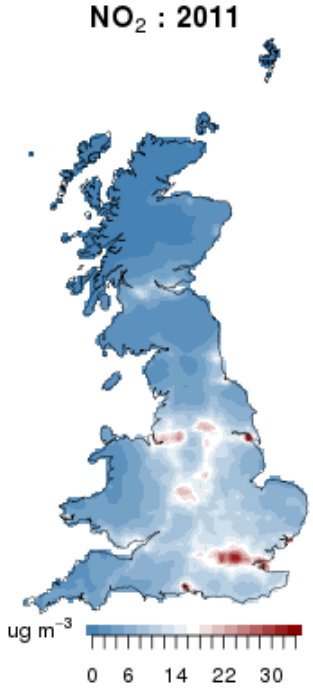
10km

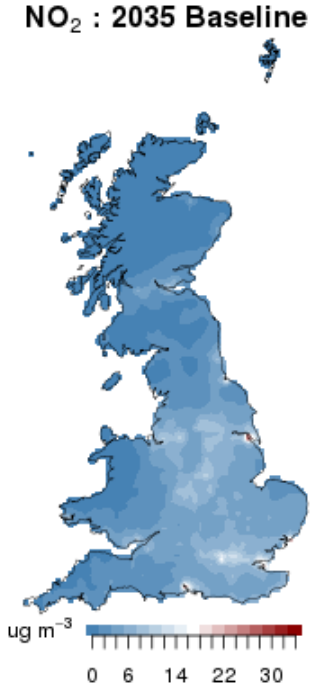


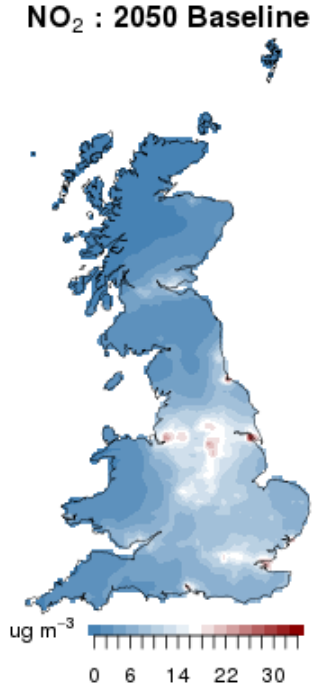


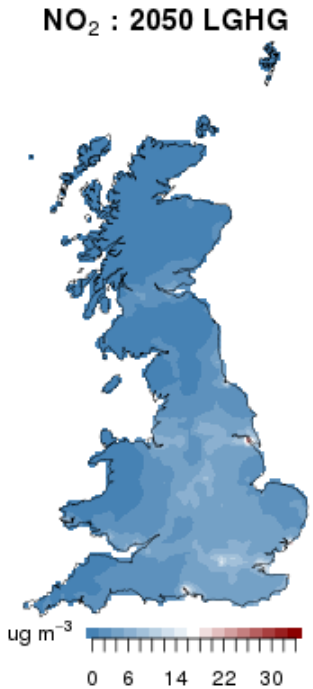
20metres

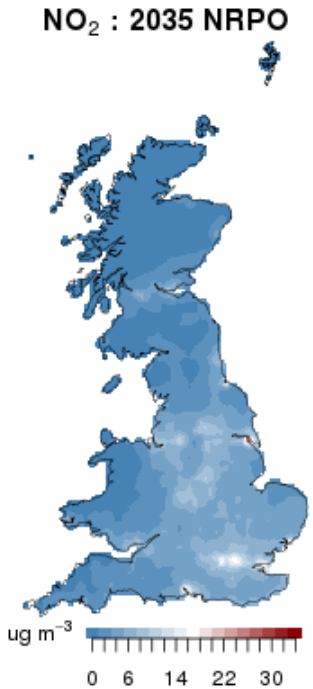

UK10
NO2 (ug m-3)
30
25
20
15
10
5
0
36.42
27.65
31.76
26.79
26.48
25.72
2011
2035 Baseline
2050 Baseline
2035 NRPO
2050 NRPO
2050 LGHG

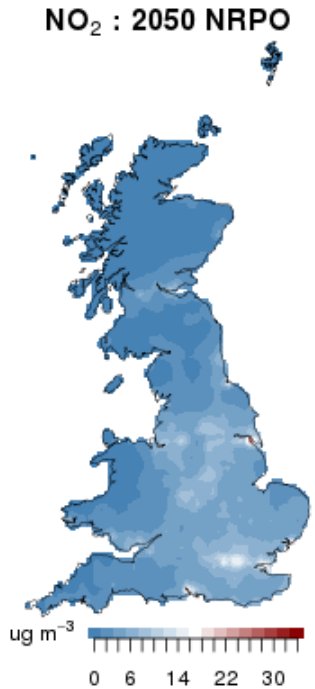

NO2 : 2011
ug m-3
0 6 14 22 30


NO2 : 2035 Baseline
ug m-3
0 6 14 22 30

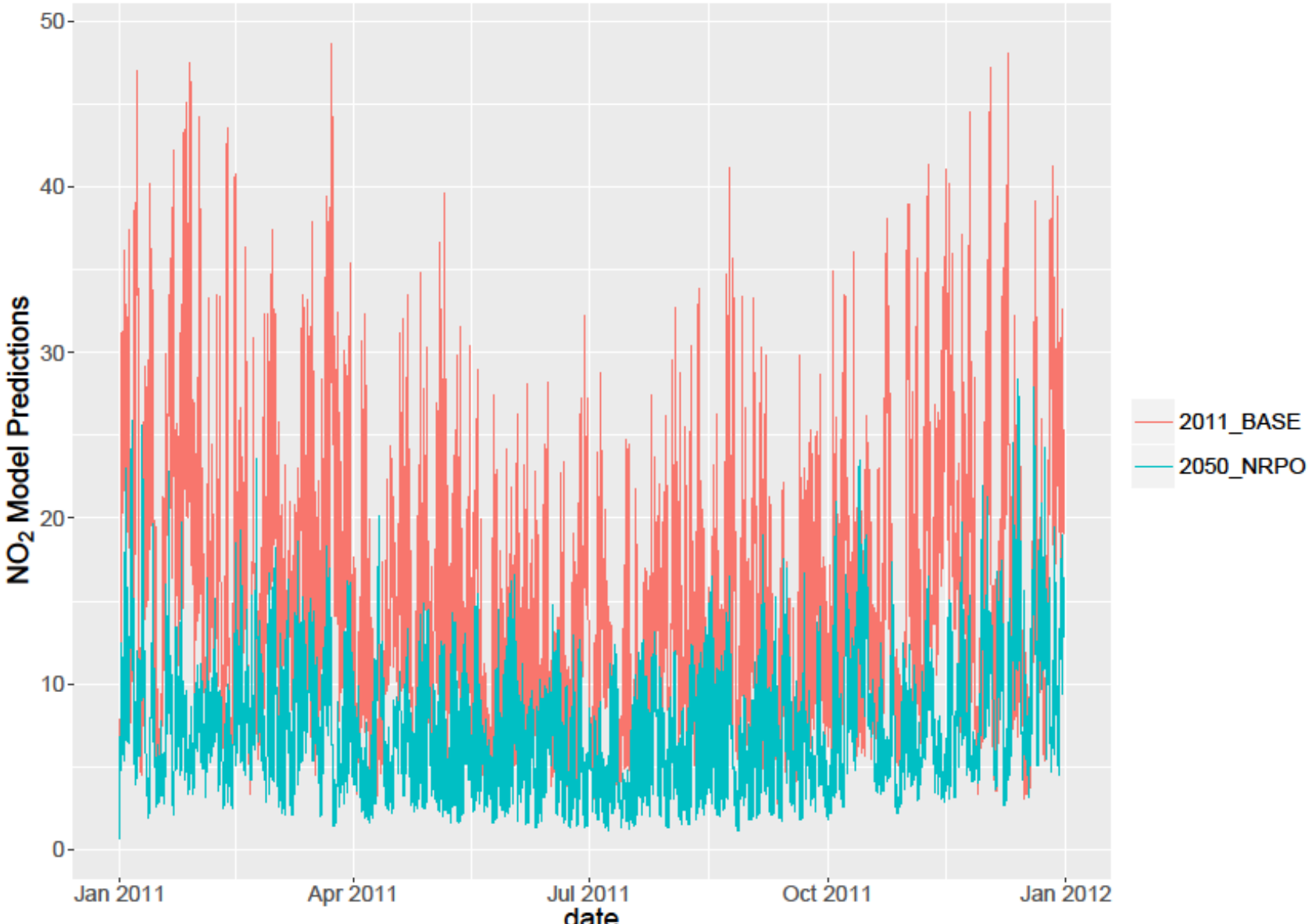

NO2 : 2050 Baseline
ug m-3
0 6 14 22 30

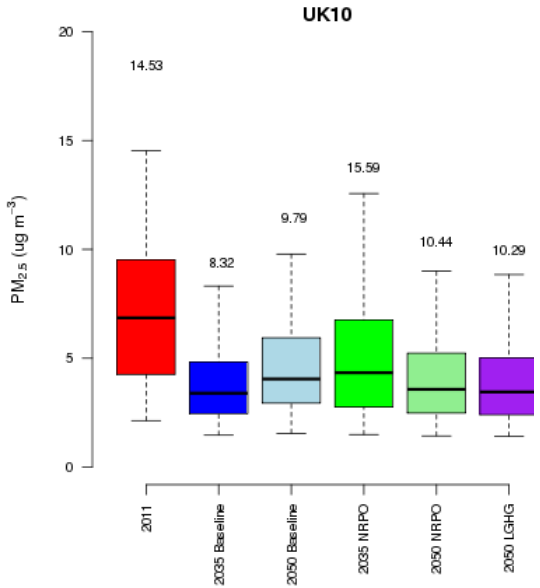

NO2 : 2050 LGHG
ug m-3
0 6 14 22 30

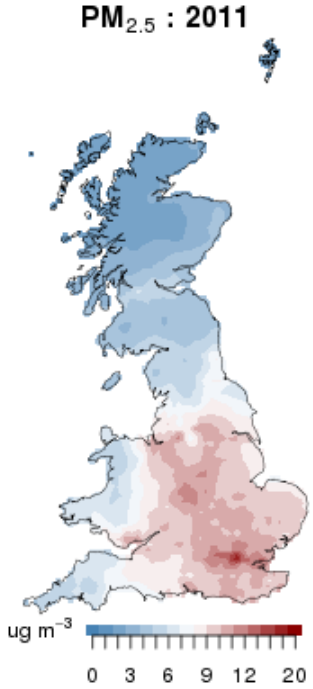

NO2 : 2035 NRPO
ug m-3
0 6 14 22 30

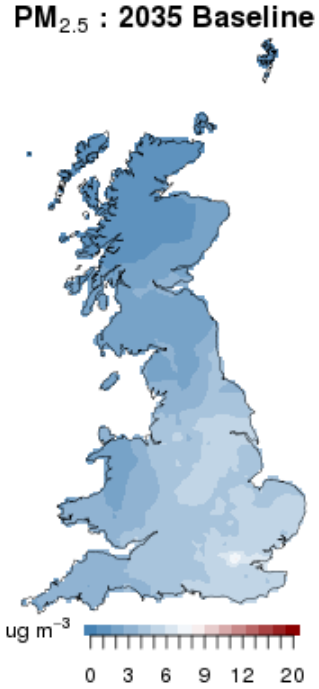

NO2 : 2050 NRPO
ug m-3
0 6 14 22 30

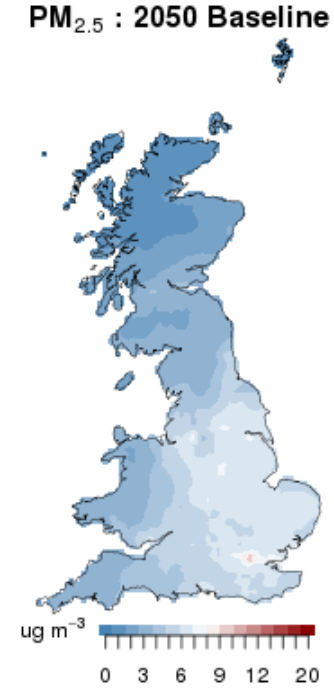
Hourly NO_2 concentrations – all GB sites

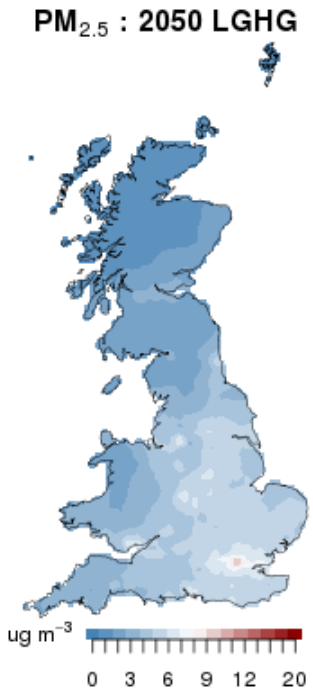


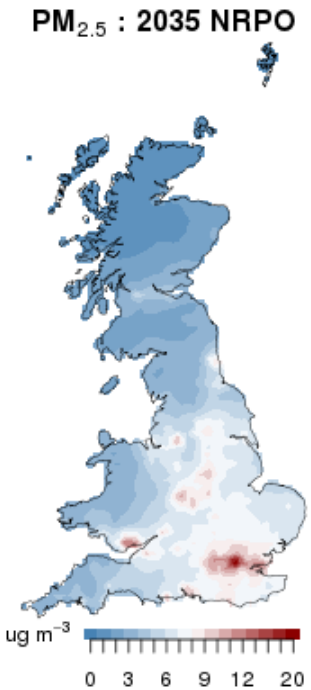

UK10
PM2.5 (ug m-3)
20
15
10
5
0
14.53
8.32
9.79
15.59
10.44
10.29
2011
2035 Baseline
2050 Baseline
2035 NRPO
2050 NRPO
2050 LGHG

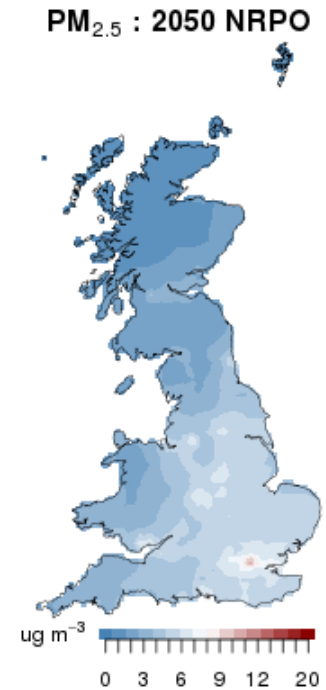

PM2.5 : 2011
ug m-3
0 3 6 9 12 20


PM2.5 : 2035 Baseline
ug m-3
0 3 6 9 12 20

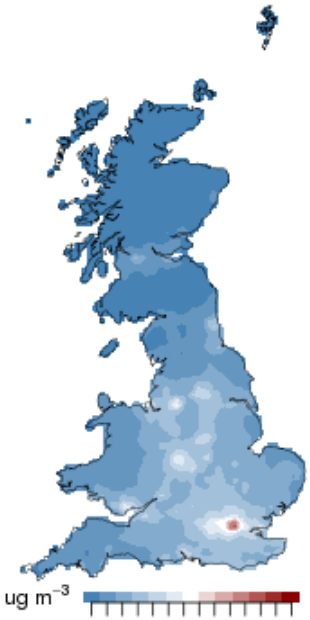

PM2.5 : 2050 Baseline
ug m-3
0 3 6 9 12 20


PM2.5 : 2050 LGHG
ug m-3
0 3 6 9 12 20

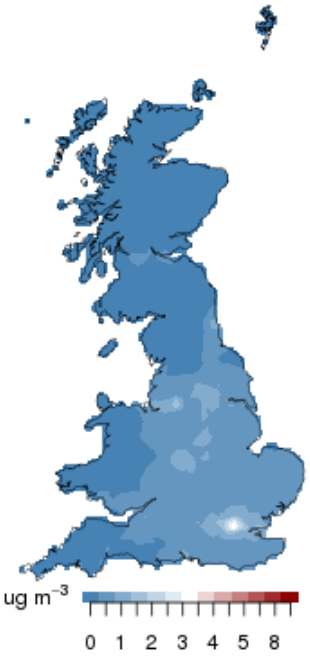

PM2.5 : 2035 NRPO
ug m-3
0 3 6 9 12 20


PM2.5 : 2050 NRPO
ug m-3
0 3 6 9 12 20

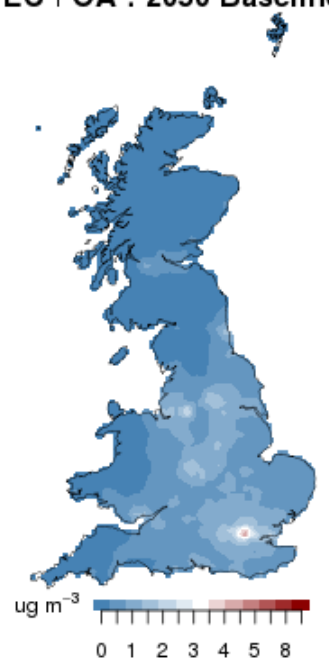
EC + OA : 2011



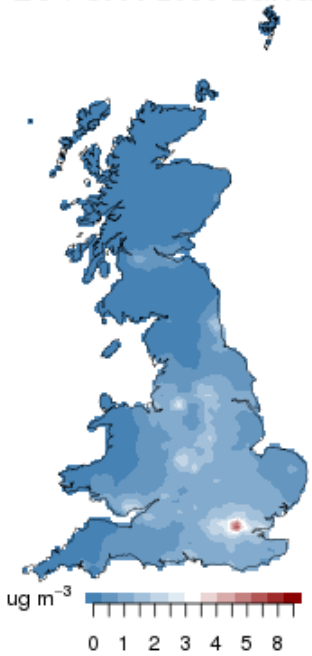
EC + OA : 2035 Baseline



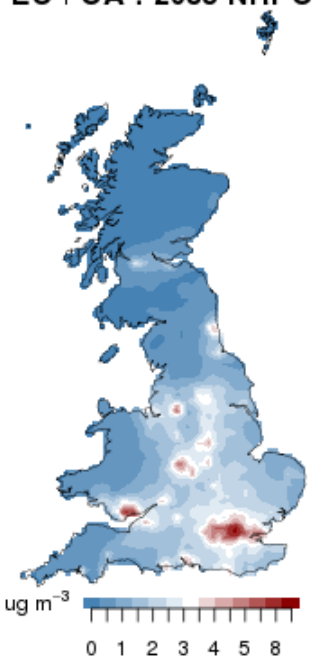
EC + OA : 2050 Baseline



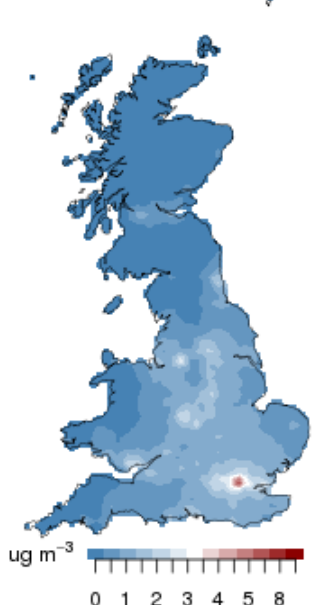
EC + OA : 2050 LGHG



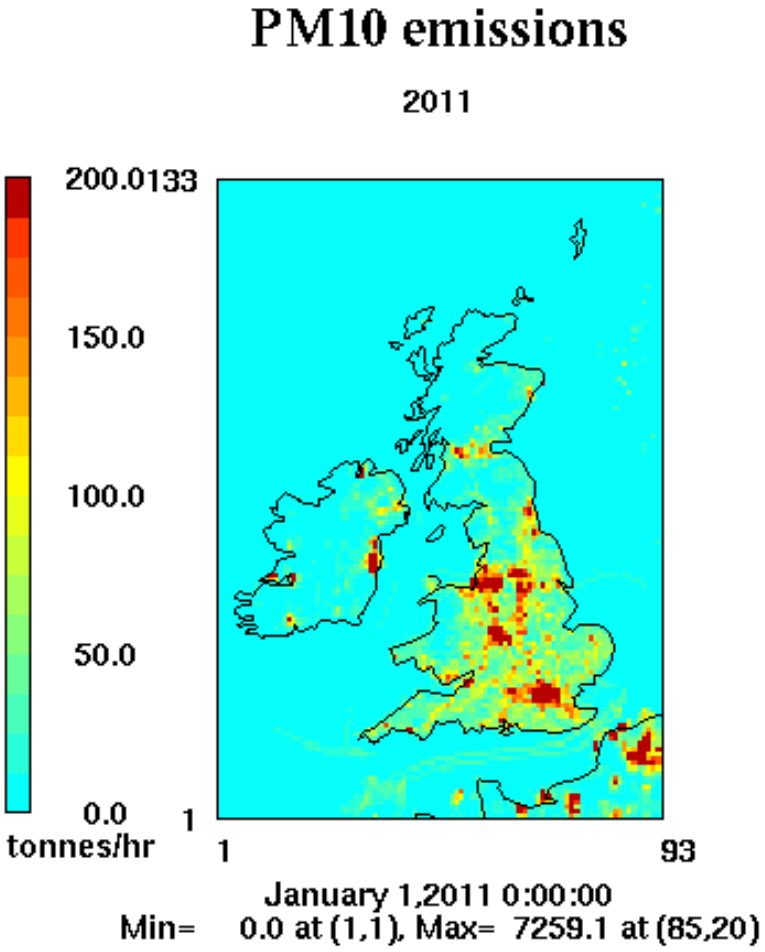
EC + OA : 2035 NRPO

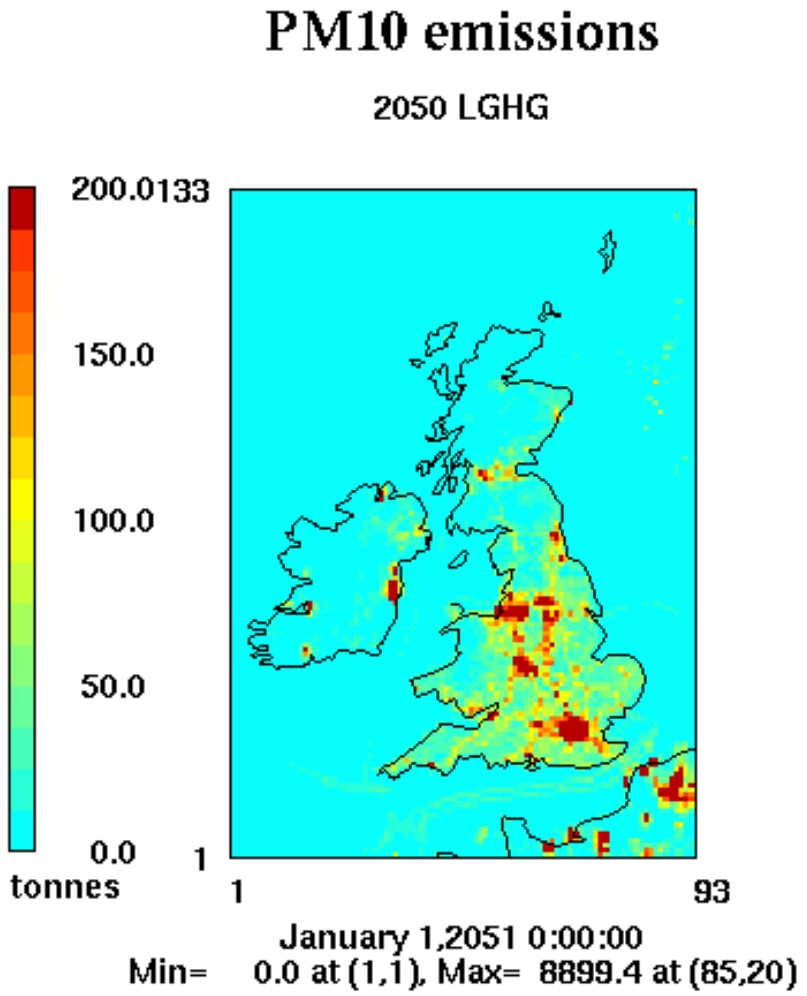


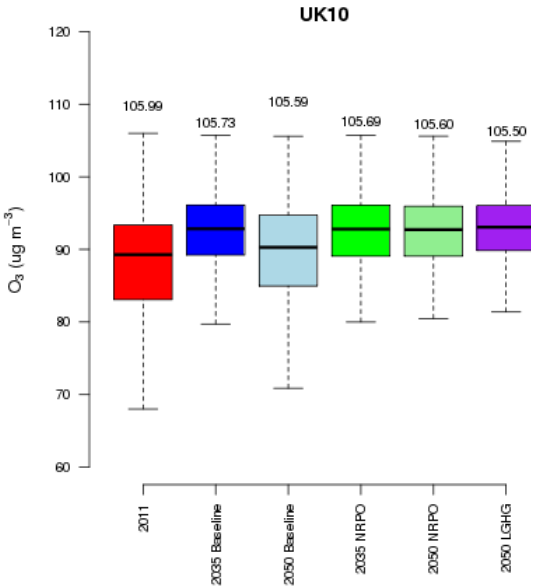
EC + OA : 2050 NRPO

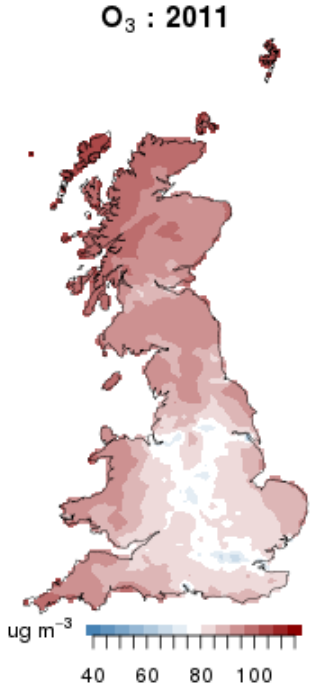


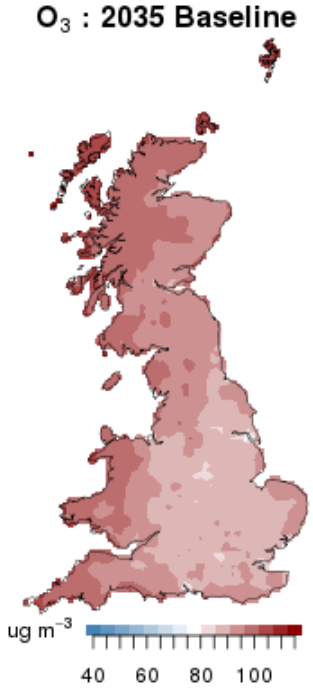
Primary PM10 emissions don't decrease – non – exhaust emissions important (toxicity?)

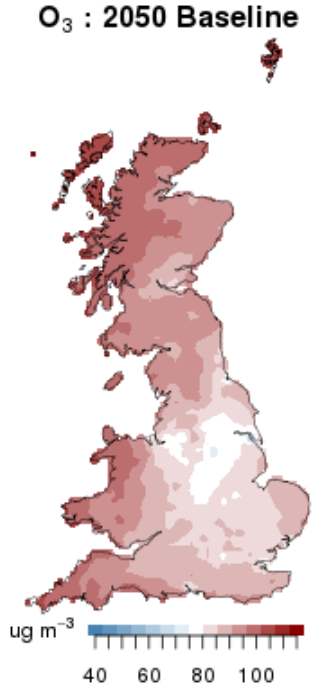


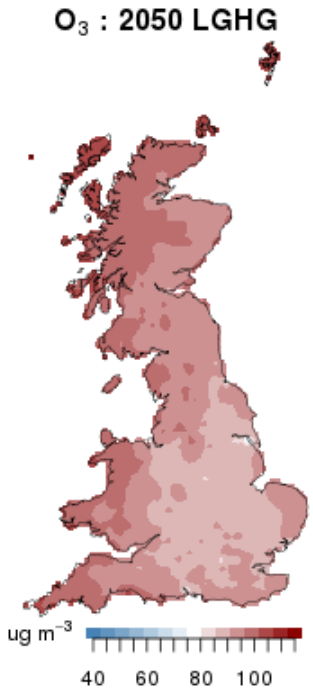


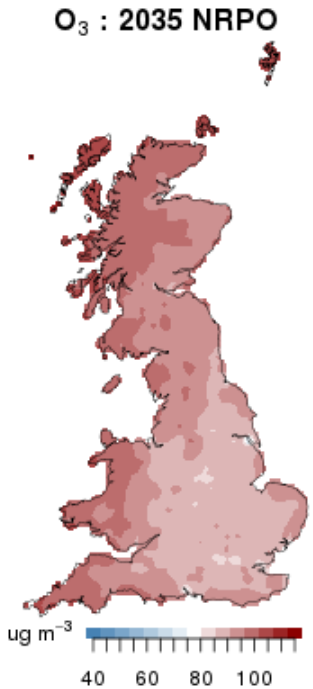

UK10
120
110
100
90
80
70
60
O_3 (ug m^{-3})
105.99
105.73
105.59
105.69
105.60
105.50
2011
2035 Baseline
2050 Baseline
2035 NRPO
2050 NRPO
2050 LGHG

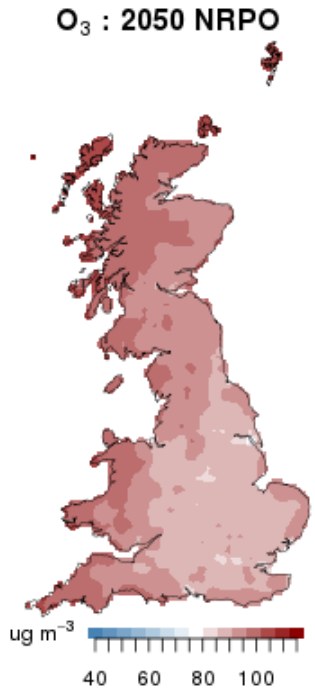

O_3 : 2011
ug m^{-3}
40 60 80 100


O_3 : 2035 Baseline
ug m^{-3}
40 60 80 100

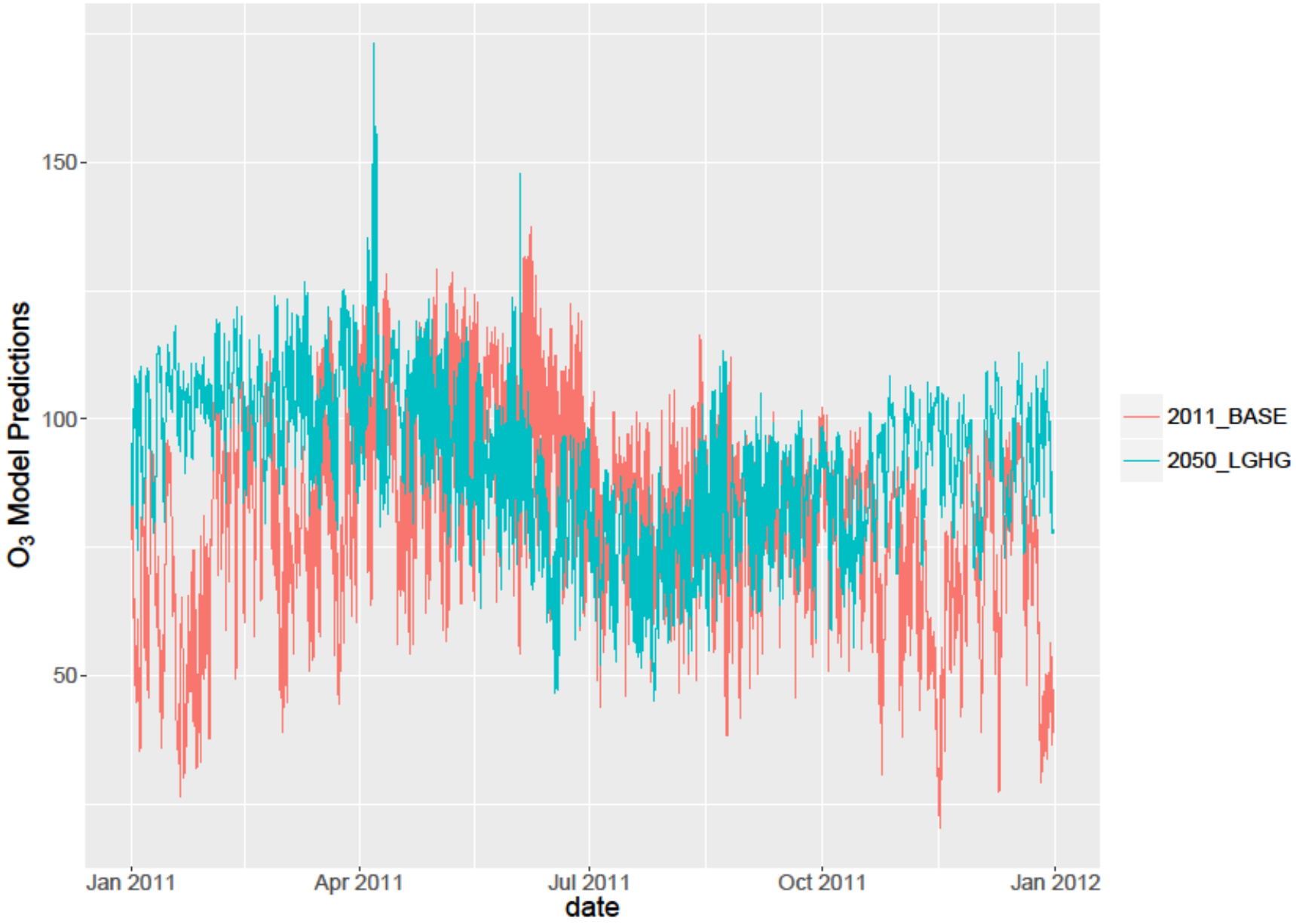

O_3 : 2050 Baseline
ug m^{-3}
40 60 80 100

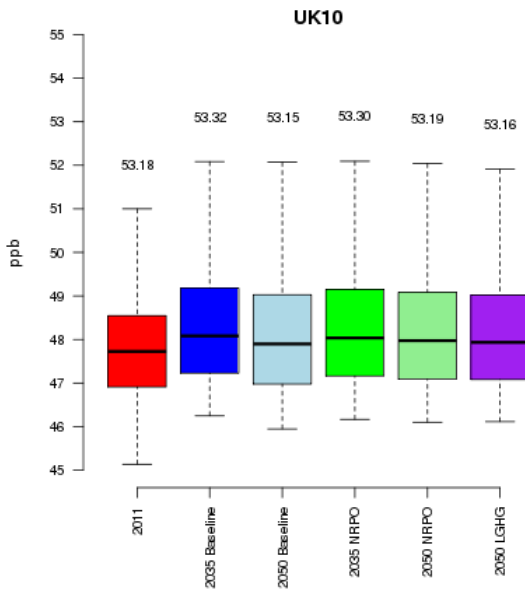

O_3 : 2050 LGHG
ug m^{-3}
40 60 80 100

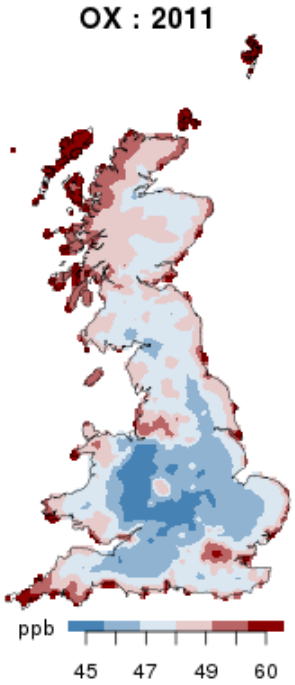

O_3 : 2035 NRPO
ug m^{-3}
40 60 80 100

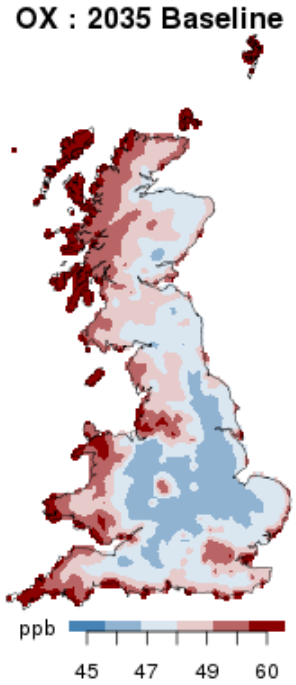

O_3 : 2050 NRPO
ug m^{-3}
40 60 80 100

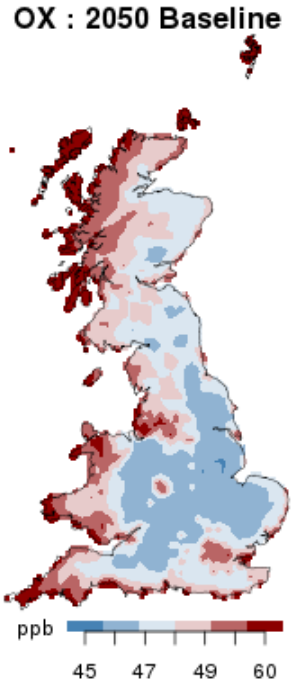
Hourly ozone concentrations

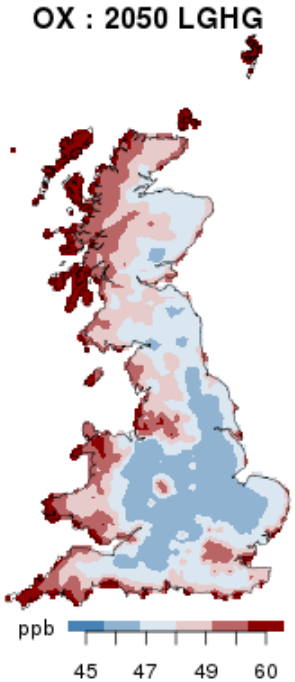


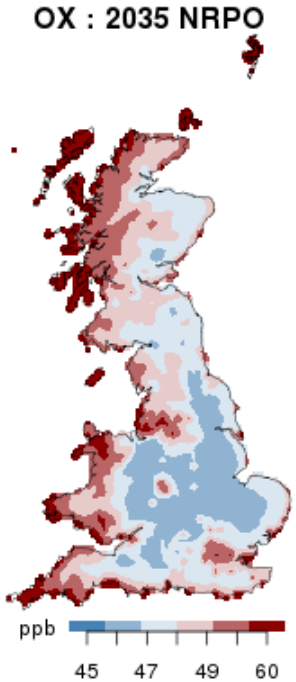

UK10
ppb
55
54
53
52
51
50
49
48
47
46
45
53.18
53.32
53.15
53.30
53.19
53.16
2011
2035 Baseline
2050 Baseline
2035 NRPO
2050 NRPO
2050 LGHG

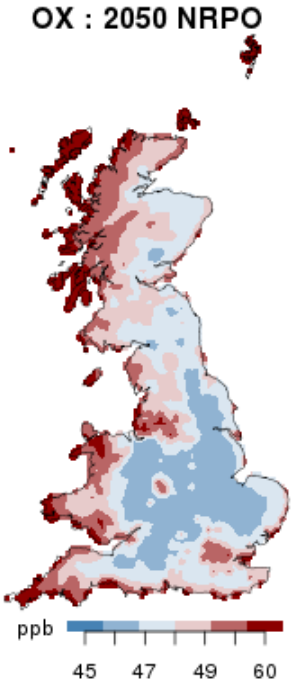

OX : 2011
ppb
45
47
49
60

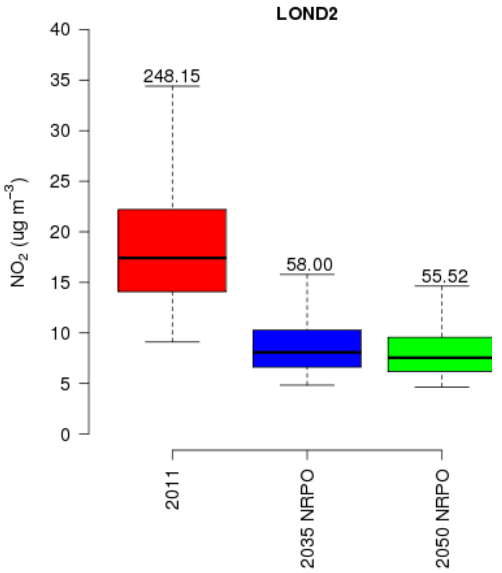

OX : 2035 Baseline
ppb
45
47
49
60

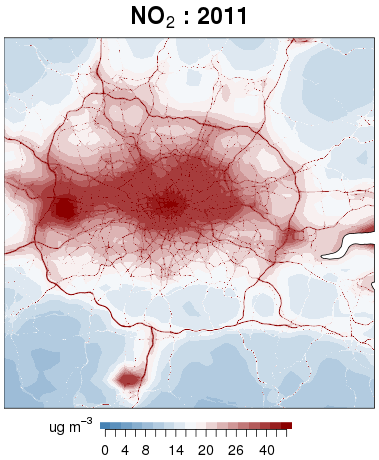

OX : 2050 Baseline
ppb
45
47
49
60

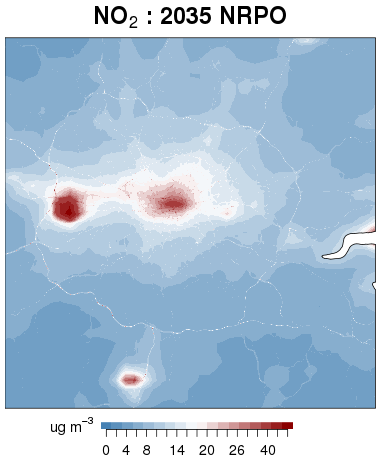

OX : 2050 LGHG
ppb
45
47
49
60

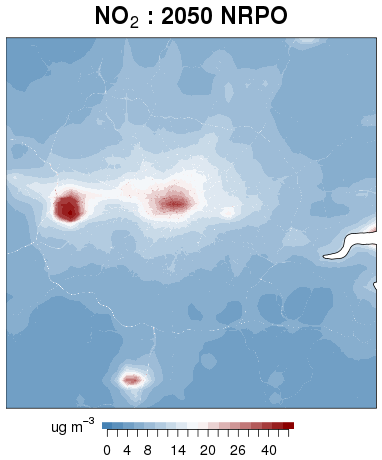

OX : 2035 NRPO
ppb
45
47
49
60


OX : 2050 NRPO
ppb
45
47
49
60

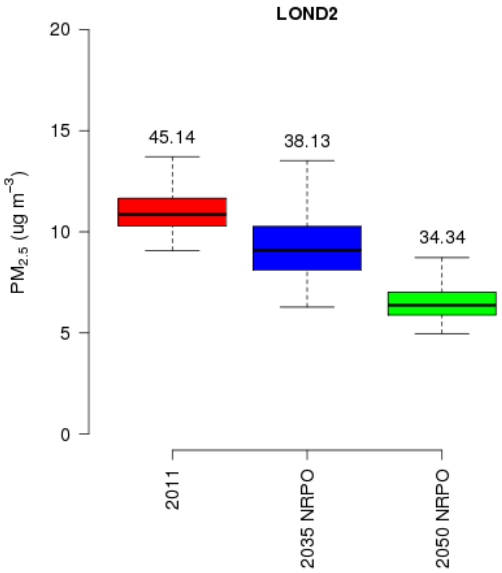


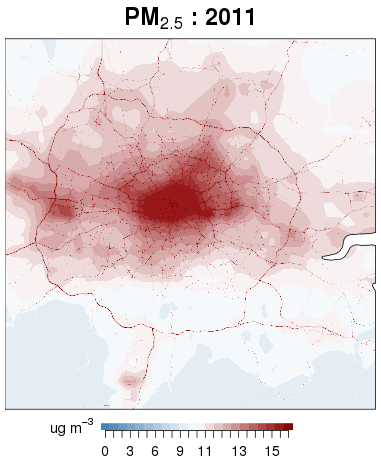


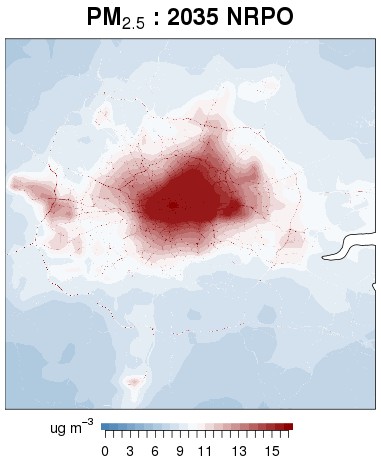


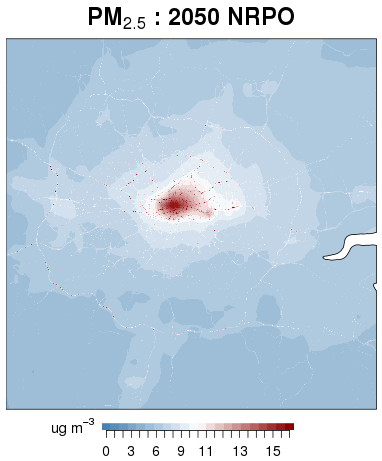


Modelling UK Major cities at 20m resolution





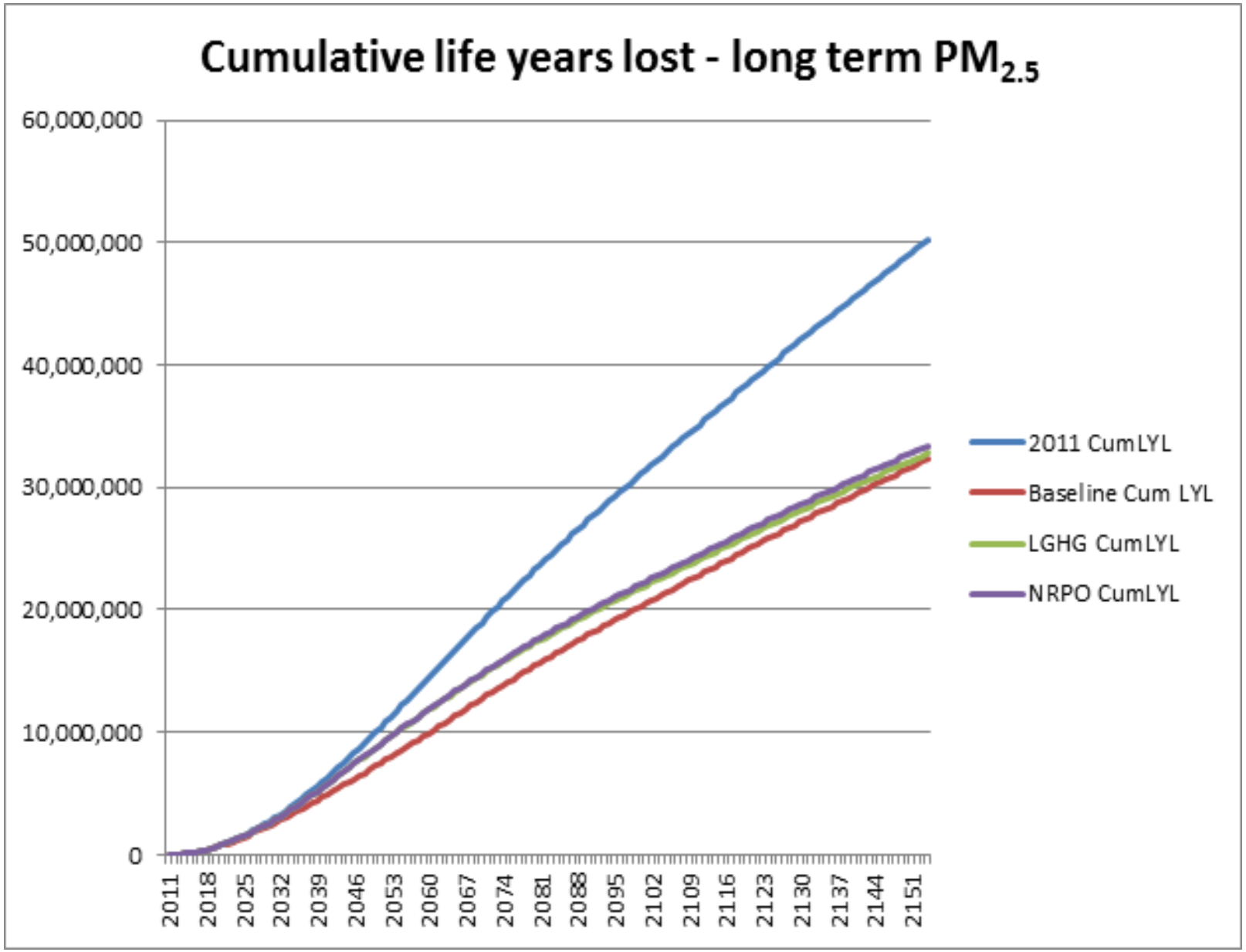


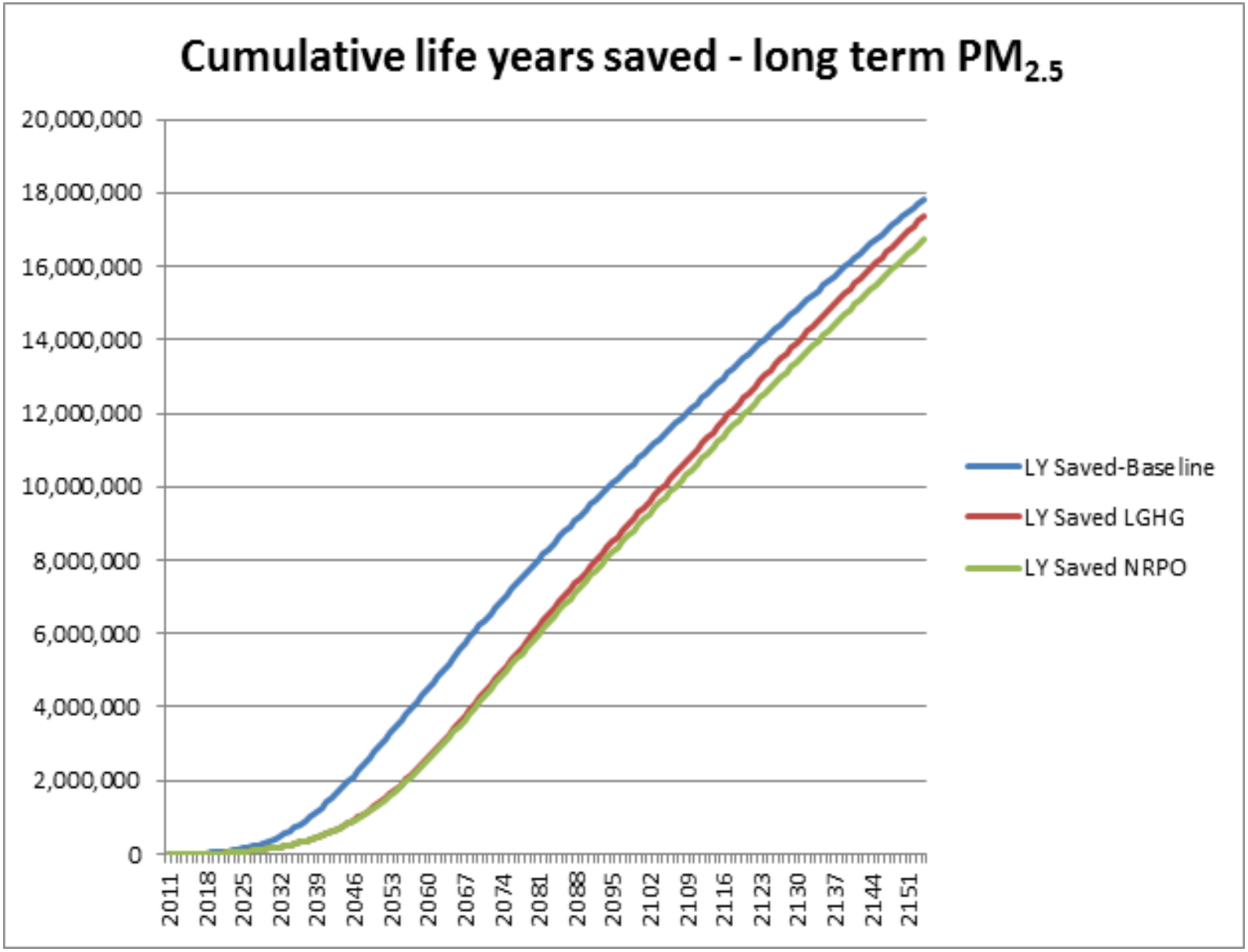


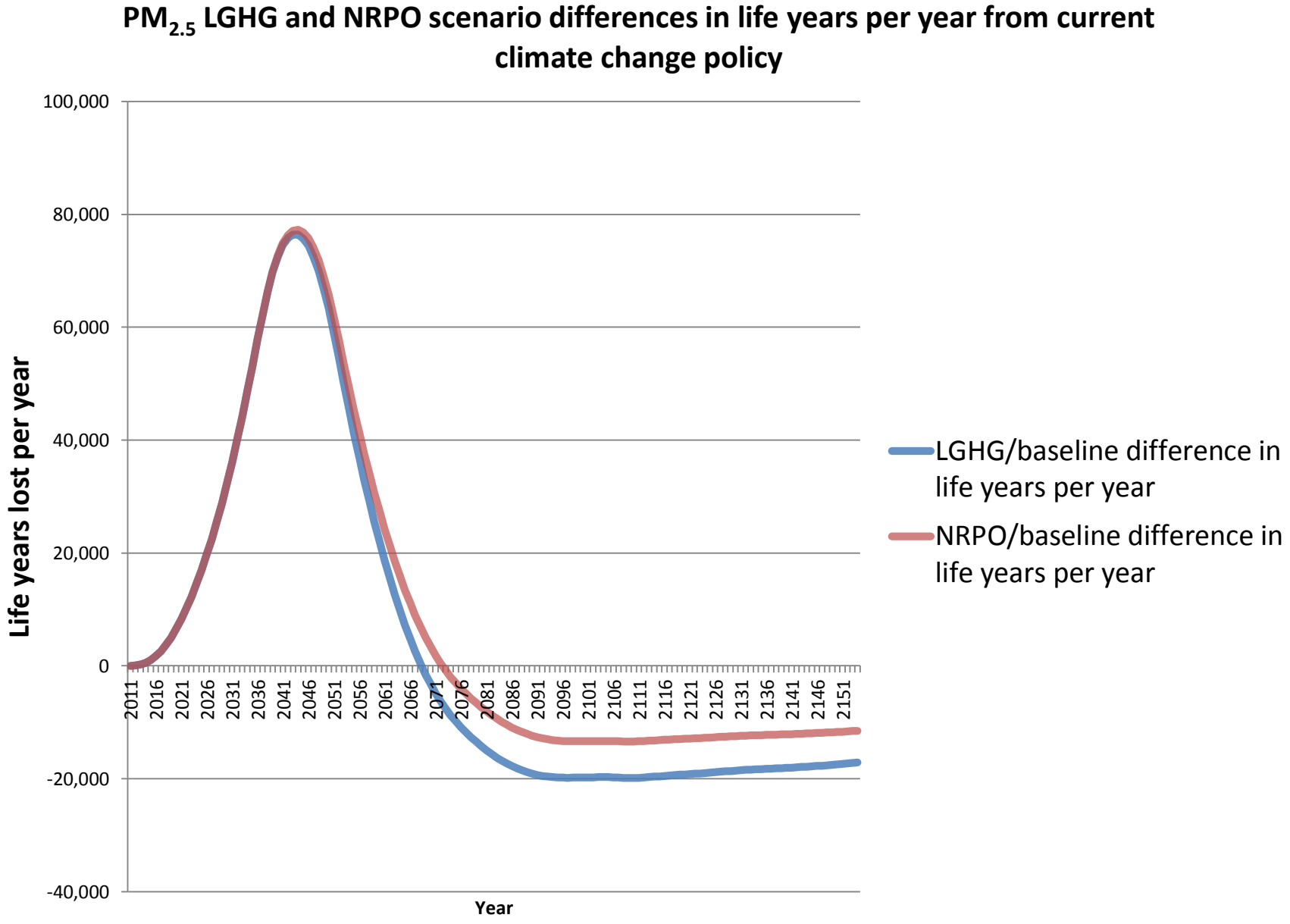
Health Impact Assessment method for long term exposure to $PM_{2.5}$ and NO_2

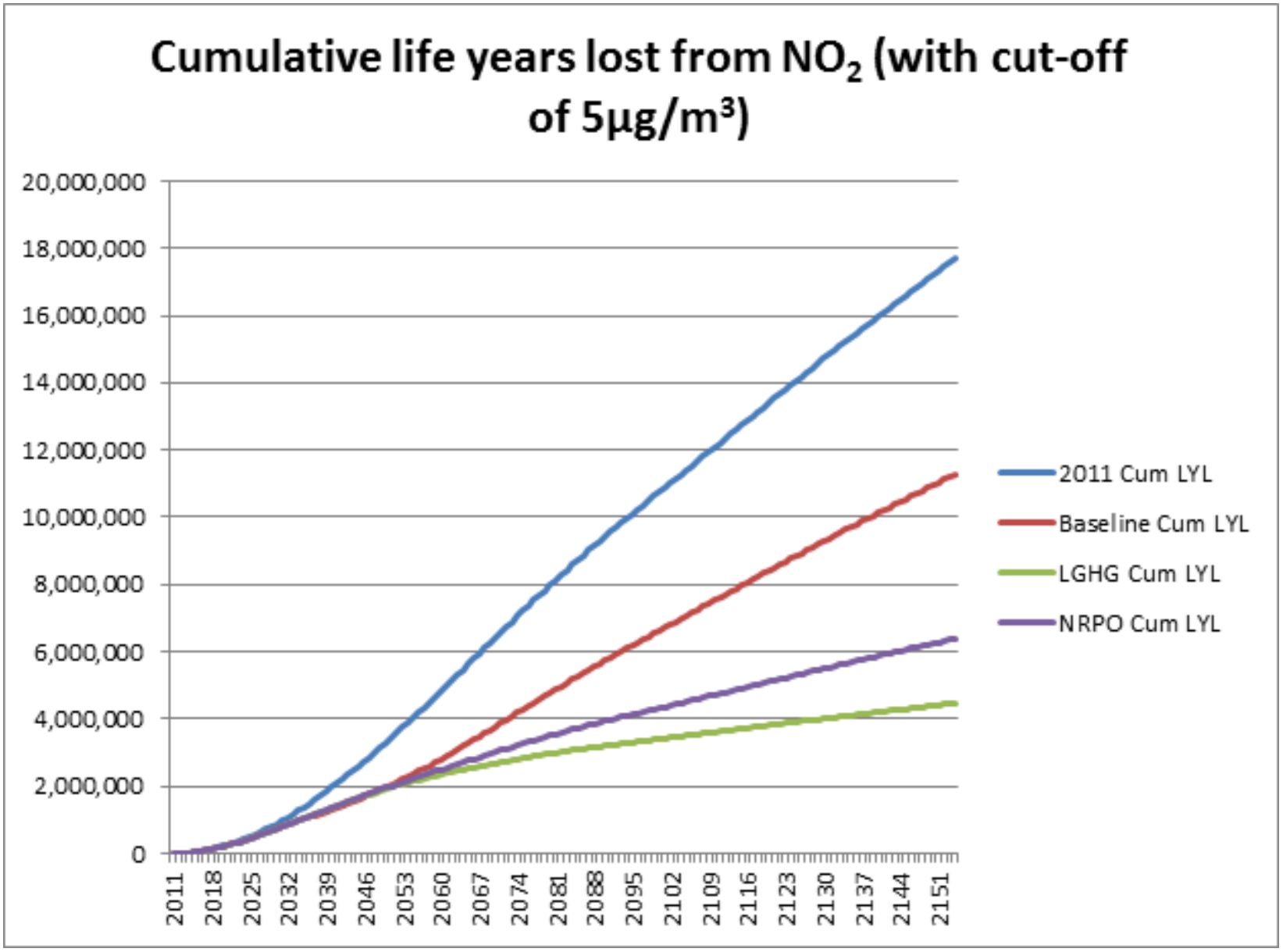
Full Impact methodology

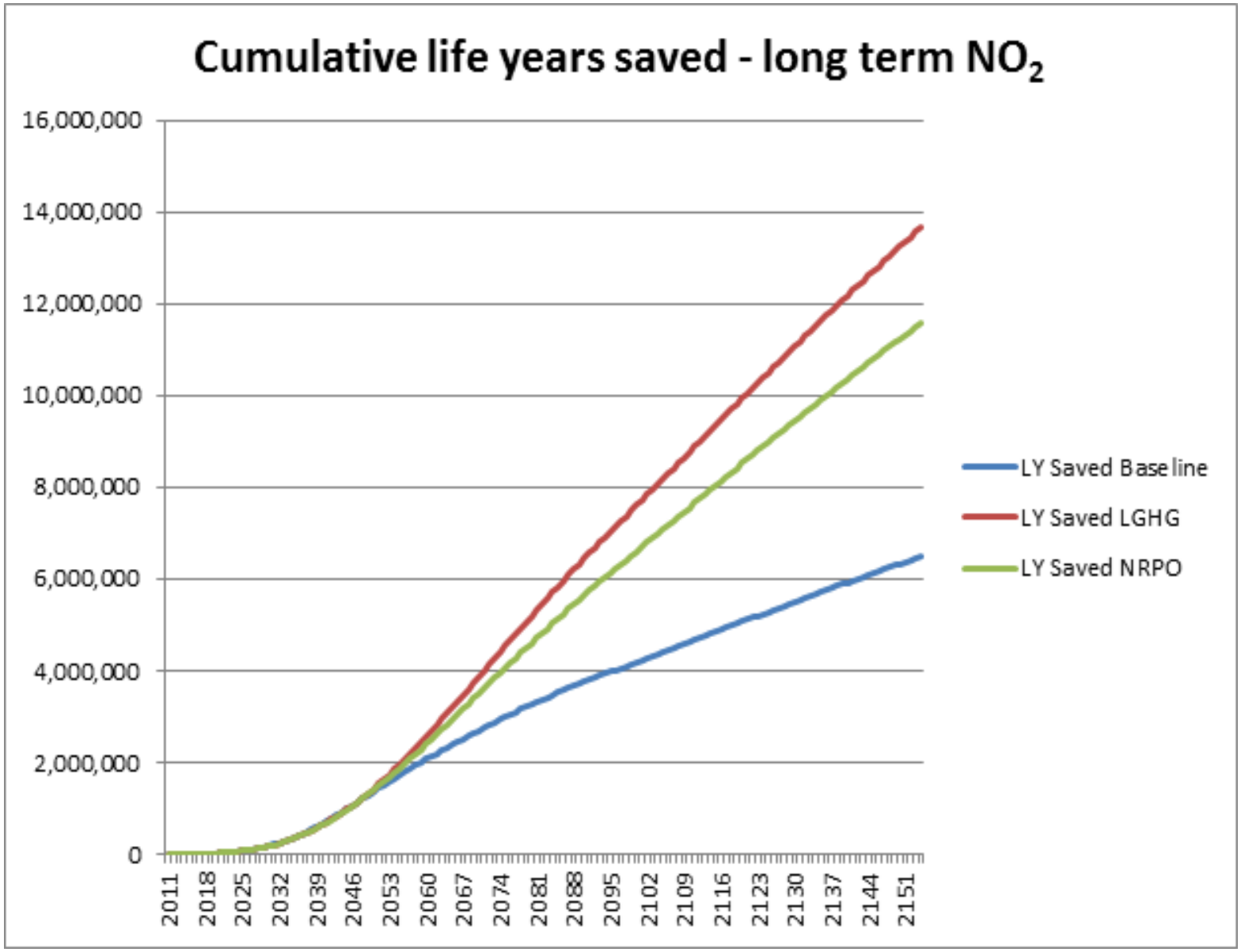
- Uses life tables of pop. and death in 2010 by single year age group
- Follow life tables through for a lifetime 105 years to 2114, with new birth cohorts
- Use EPA lag 30% effect first year, 12.5% years 2-5, 20% years 5-20
- Results can be summarised as total Life Years and loss of Life Expectancy from birth
- Impact of future reduction scenarios on Life Years and life-expectancy


Cumulative life years lost - long term PM2.5
60,000,000
50,000,000
40,000,000
30,000,000
20,000,000
10,000,000
0
2011
2018
2025
2032
2039
2046
2053
2060
2067
2074
2081
2088
2095
2102
2109
2116
2123
2130
2137
2144
2151
2011 CumLYL
Baseline Cum LYL
LGHG CumLYL
NRPO CumLYL


Cumulative life years saved - long term PM2.5
20,000,000
18,000,000
16,000,000
14,000,000
12,000,000
10,000,000
8,000,000
6,000,000
4,000,000
2,000,000
0
2011
2018
2025
2032
2039
2046
2053
2060
2067
2074
2081
2088
2095
2102
2109
2116
2123
2130
2137
2144
2151
LY Saved-Baseline
LY Saved LGHG
LY Saved NRPO


PM2.5 LGHG and NRPO scenario differences in life years per year from current climate change policy
Life years lost per year
100,000
80,000
60,000
40,000
20,000
0
-20,000
-40,000
2011
2016
2021
2026
2031
2036
2041
2046
2051
2056
2061
2066
2071
2076
2081
2086
2091
2096
2101
2106
2111
2116
2121
2126
2131
2136
2141
2146
2151
Year
LGHG/baseline difference in life years per year
NRPO/baseline difference in life years per year

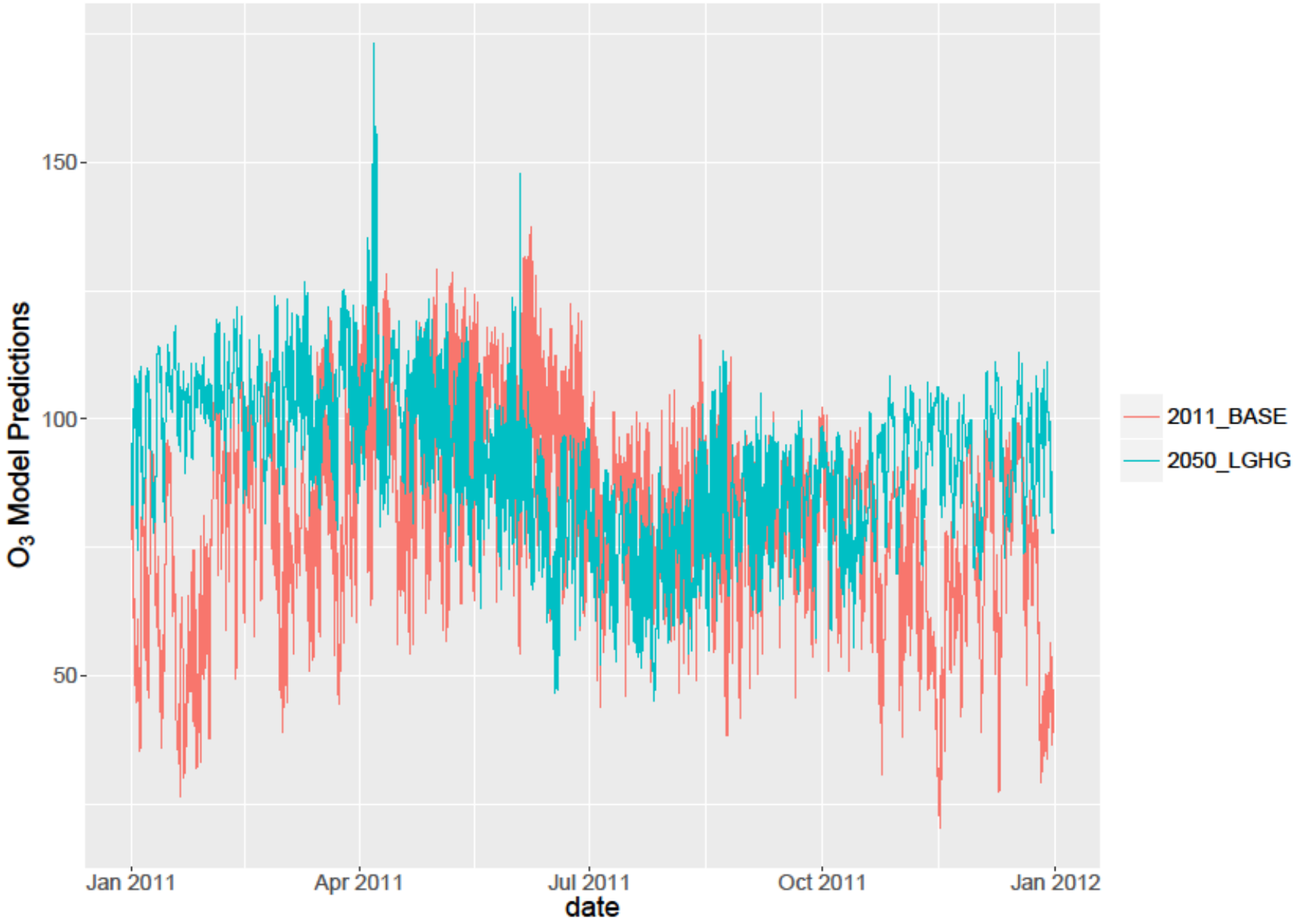

Cumulative life years lost from NO2 (with cut-off of 5µg/m3)
20,000,000
18,000,000
16,000,000
14,000,000
12,000,000
10,000,000
8,000,000
6,000,000
4,000,000
2,000,000
0
2011
2018
2025
2032
2039
2046
2053
2060
2067
2074
2081
2088
2095
2102
2109
2116
2123
2130
2137
2144
2151
2011 Cum LYL
Baseline Cum LYL
LGHG Cum LYL
NRPO Cum LYL

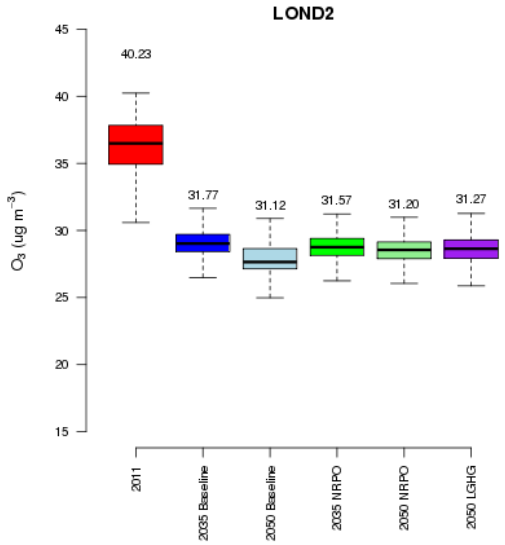

Cumulative life years saved - long term NO2
16,000,000
14,000,000
12,000,000
10,000,000
8,000,000
6,000,000
4,000,000
2,000,000
0
2011
2018
2025
2032
2039
2046
2053
2060
2067
2074
2081
2088
2095
2102
2109
2116
2123
2130
2137
2144
2151
LY Saved Baseline
LY Saved LGHG
LY Saved NRPO

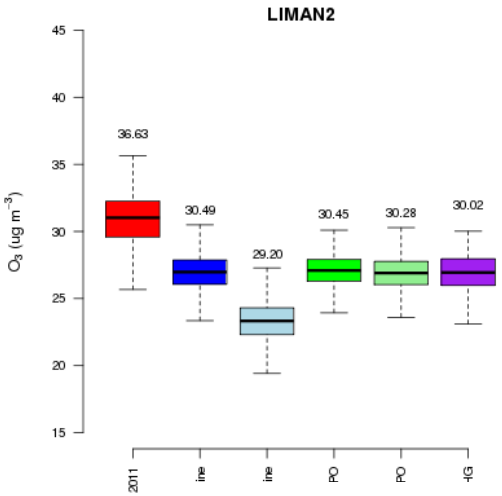
Health impacts of ozone

- Depend crucially on the issue of a threshold or cut-off
- Long-term exposure impact (WHO-HRAPIE 2013) has CRF with cut-off at 70µg/m^3
- UK COMEAP has short-term exposure CRF with cut-off at ***zero***
- Large differences in ***size*** and ***sign*** as ozone concentrations change.

Hourly ozone concentrations

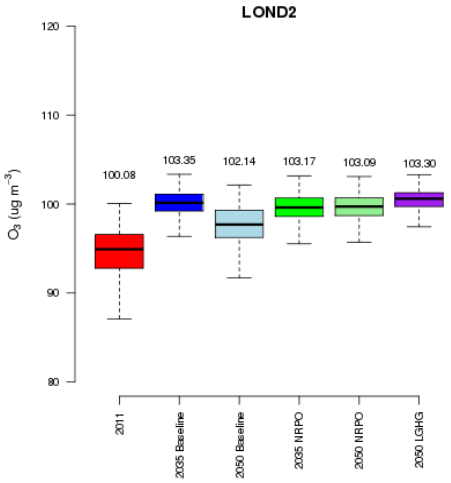


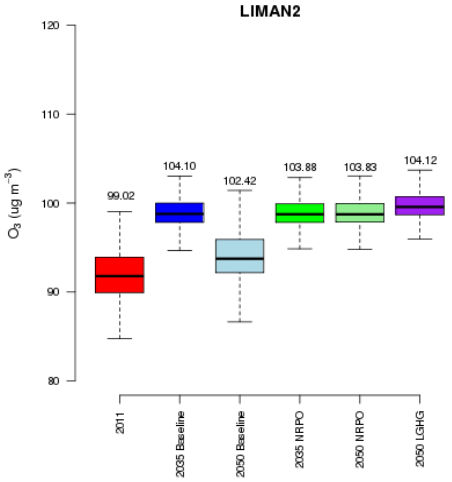




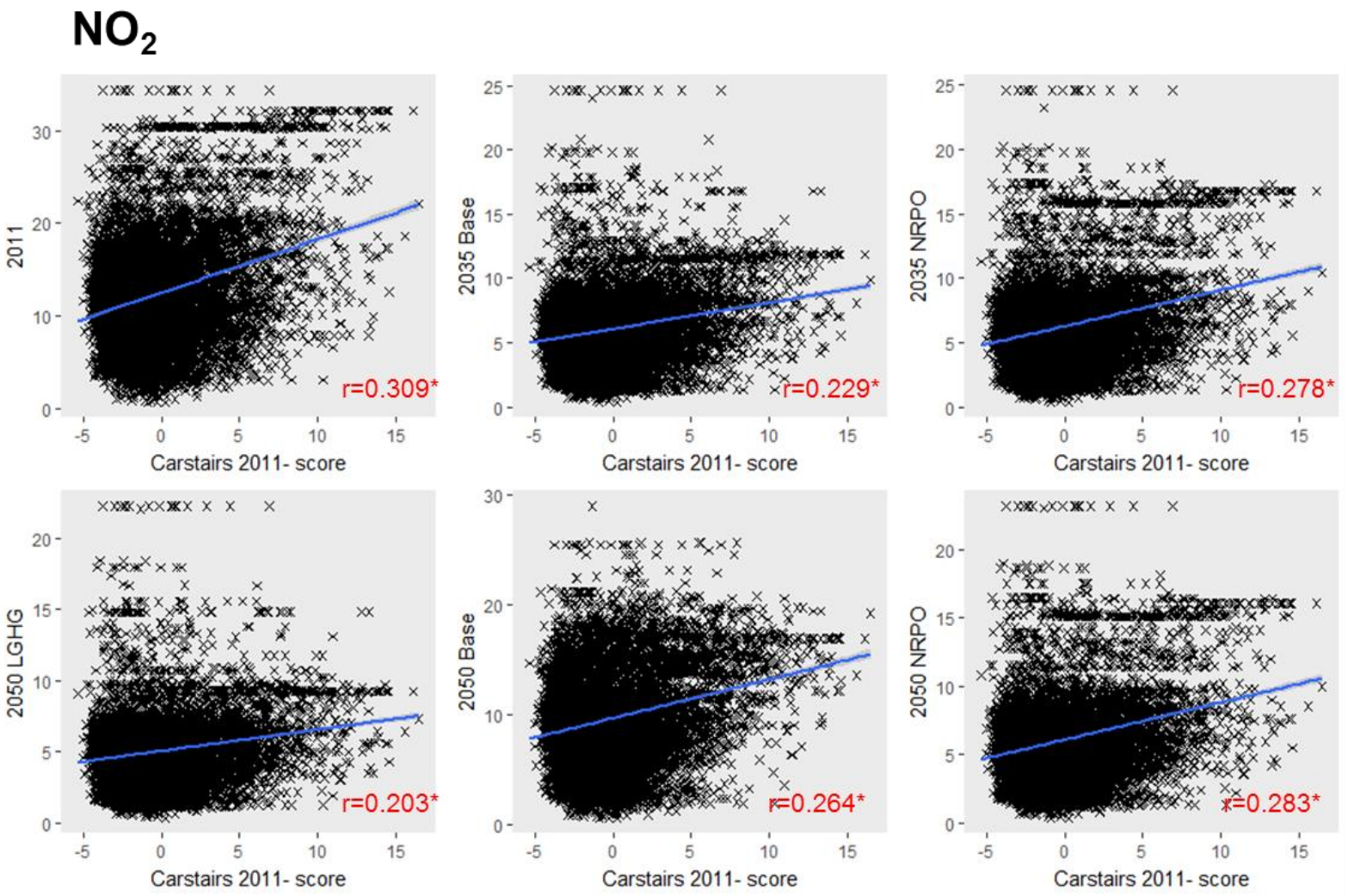
Long-term exposure metric

Short-term exposure metric

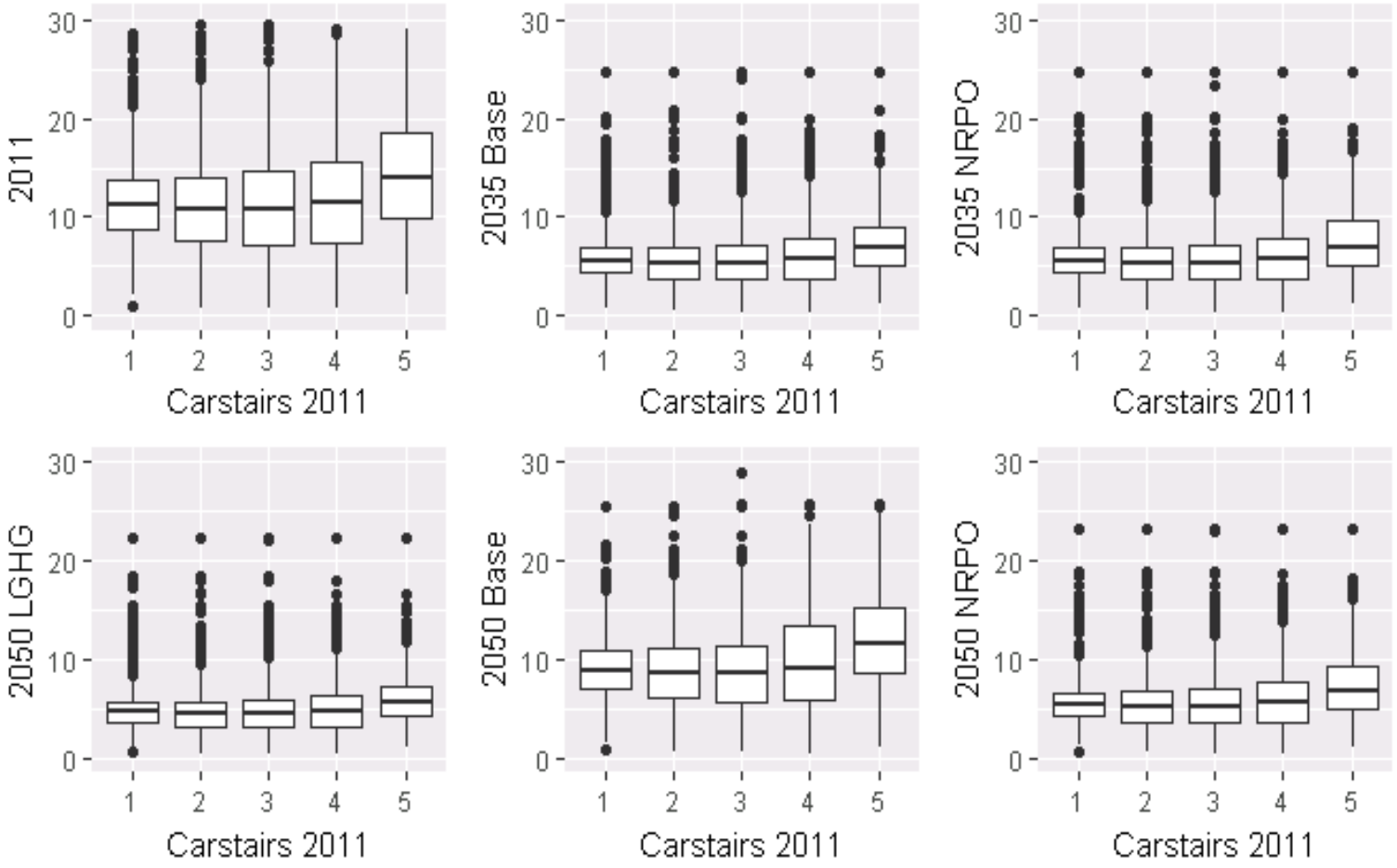




Exposure to NO_2 by deprivation index



Exposure to NO_2/deprivation stratified by Ward



Conclusions and Policy Messages

- Urban levels of NO_2 should decrease significantly with corresponding improvements for public health and legal compliance
- PM concentrations should also decrease
- ***BUT*** further policies to attain the CCA 2050 target will not give any additional public health benefit beyond policies already in place

- The incentivisation of biomass could lead to an increase in exposure to *primary PM combustion products*, including carcinogens in the period 2030-2035
- Non-exhaust PM concentrations will probably increase – how toxic are they?
- Currently accepted metrics for long- and short-term ozone exposure change in *different directions* in future – more health effect evidence on a possible threshold is needed