The impacts of policies to meet the UK Climate Change Act target on air quality – an explicit modelling study

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King’s College London
LAQN conference
June 2016
Air pollution is a major public health issue

• Mainly due to fine particles – the effects of PM$_{2.5}$ on premature mortality

• But there is increasing evidence of the independent effects of NO$_2$
Across the UK poor air quality......

- equivalent of 29,000 premature deaths due to breathing tiny particles released into the air (in 2008 data)

- the average loss of life was 6 months, (although the actual amount varies between individuals, from a few days to many years)

- ‘...air pollution may have made some contribution to the earlier deaths of up to 200,000 people in 2008, with an average loss of life of about 2 years per death affected...’

- Economic cost of the order of £8-20 billion per year (from IGCB)

Published December 2010
But estimates of the impact of air pollution on health are increasing as evidence on NO$_2$ strengthens.

RCP estimate ~ 40,000 deaths
UK Climate Change Act 2008

• The UK has set a target of **80% reduction in CO₂ 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
AQ benefit

Energy efficiency
- Demand management
  - Nuclear
- Wind, solar and tidal
- Nitrogen efficiency
- Hybrids, LZEVs
- CCS

CC benefit

Increase in 'uncontrolled' diesel
- Biofuels
- Biomass
- Combined heat and power?
- Buying credits overseas

Flue gas desulfurization
Three-way catalysts – petrol
Particulate filters – diesel

Uncontrolled coal and oil fossil fuels in stationary and mobile sources
NIHR funded project

Energy Scenarios → Emission Inventories → Air Quality Model (CMAQ) → Health Impacts

Working with UCL who provided energy scenarios

Economic costs of health impacts

Social Deprivation
NIHR project
Linking UK Times outputs to UK and European Emissions

We have ‘soft linked’ the UK Times energy systems model (outputs provided by UCL, Mellissa Lott) 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.
<table>
<thead>
<tr>
<th>Scenario</th>
<th>Description</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>DECC Baseline</td>
<td>DECC Baseline (no further carbon mitigation)</td>
<td>Nuclear phasing out</td>
</tr>
<tr>
<td>Reference</td>
<td>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</td>
<td>Nuclear expansion</td>
</tr>
<tr>
<td>Low GHG</td>
<td>80% reduction by 2050 + interim carbon budgets (through the 4th budget); no damage costs included for non-GHG air pollutants</td>
<td>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</td>
</tr>
<tr>
<td>Nuclear – replacement only</td>
<td>LowGHG scenario + constraint on nuclear so that it can only maintain its current capacity levels.</td>
<td>Nuclear capacity capped at 10 GW (i.e. current levels)</td>
</tr>
<tr>
<td>Modal shift – active transport</td>
<td>In UKTM, this is the same as the lowGHG scenario, but we will replace enough car demand with active transport to maintain 2020 PM levels</td>
<td>To show benefits of a cultural shifts to reduce road transport/car use in London. EVs will not be enough.</td>
</tr>
</tbody>
</table>
Low GHG Scenario
Primary energy consumption (PJ)

- Nuclear
- Renewables
- Oil and oil products
- Natural Gas
- Natural Gas
- Electricity import
- Coal and coke
- Biomass and biofuels

MRC-PHE
Centre for Environment & Health

Kings College London
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
- VOC and NH3 are taken from Eclipse 5a
Comparison with NAEI 2030 (Low GHG)

Snap 1 – Energy comb
Snap 2 – Non-Ind comb
Snap 3 – Manufac comb
Snap 4 – Prod processes
Snap 5 – Extract/Distribution
Snap 6 – Solvent use
Snap 7 – Roads
Snap 8 – Other mobile
Snap 9 – Waste
Snap 10 – Agriculture
Snap 11 – Other
Comparison with NAEI 2030 (Low GHG)

Emission factor (Category)

- pm10
- pm25
- so2

Emission 2030
PredEm 2030

factor (Category)

- Emission 2030
- PredEm 2030
Bvehkm- Modal shift Active Travel (MS_AT) - Roads (snap 7)

<table>
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<tr>
<th>UKTimesSector</th>
<th>FuelType</th>
<th>2010</th>
<th>2050</th>
<th>UKTimesSector</th>
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<tr>
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<td>Van</td>
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<td>E85</td>
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<tr>
<td>Bus</td>
<td>HEV</td>
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<tr>
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<td>Van</td>
<td>HEV</td>
<td>0.0</td>
<td>28.2</td>
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<td><strong>Total</strong></td>
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<td><strong>4.6</strong></td>
<td><strong>Van</strong></td>
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<td><strong>HGV</strong></td>
<td><strong>Total</strong></td>
<td><strong>27.3</strong></td>
<td><strong>35.9</strong></td>
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</table>
### Emissions - snap 2 - includes Domestic Biomass

<table>
<thead>
<tr>
<th>Pollutant</th>
<th>Scenario</th>
<th>2011 NAEI (domestic wood burning)</th>
<th>2030 NAEI*</th>
<th>Pred 2030** (domestic wood burning)</th>
<th>Pred 2050**</th>
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</thead>
<tbody>
<tr>
<td>PM$_{10}$</td>
<td>LGHG</td>
<td>23.7 (10)</td>
<td>26.7</td>
<td>49.9 (35)</td>
<td>25.2 (14)</td>
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<tr>
<td>PM$_{2.5}$</td>
<td>LGHG</td>
<td>22.7 (9)</td>
<td>26.2</td>
<td>47.3 (33)</td>
<td>24.1 (13)</td>
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</table>

### UK Emissions reductions 2011 to 2050 (%) - Low GHG

<table>
<thead>
<tr>
<th>Pollutant</th>
<th>%</th>
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<tbody>
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<td>co</td>
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<tr>
<td>nh3</td>
<td>6</td>
</tr>
<tr>
<td>nox</td>
<td>-64</td>
</tr>
<tr>
<td>pm10</td>
<td>8</td>
</tr>
<tr>
<td>pm25</td>
<td>-9</td>
</tr>
<tr>
<td>so2</td>
<td>-62</td>
</tr>
<tr>
<td>voc</td>
<td>11</td>
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</table>

* UEP48 DECC energy forecast and NAEI 2012
** Low GHG
PM$_{2.5}$ and NO$_x$ emissions

2011 Surface PM$_{2.5}$ Emissions

2050 Surface PM$_{2.5}$ Emissions

Delta surface PM$_{2.5}$ emissions 2050-2011

2011 Surface NO$_x$ Emissions

2050 Surface NO$_x$ Emissions

Delta Surface NO$_x$ Emissions 2050-2011
O₃ in 2050-simulations performed for every hour over the year.
The change in annual mean UK concentration of \( \text{NO}_2 \) and \( \text{O}_3 \)
Changes in PM?
NO\textsubscript{X} reducing strongly, as is SO\textsubscript{2}, NH\textsubscript{3} not reducing and local PM sources changing, e.g. currently PM from wood burning ~ 1 \mu g m\textsuperscript{-3}

Secondary aerosols – ammonium sulphate and ammonium nitrate, organic aerosol – these have LONG lifetimes and can travel 100s of kilometres
Annual mean UK concentrations of PM$_{2.5}$

2011 annual mean PM$_{2.5}$

- Biomass inventory
- Other sources
  - Cooking
  - Diesel IVOC ($C_{10+}$) – VBS pm model

2030 annual mean PM$_{2.5}$

2051 annual mean PM$_{2.5}$
Increase in biomass use peaks in 2030-2035
Cooking emissions in London

pm ~ 0.5 μg m⁻³
Finer resolution modelling will follow (CMAQ-urban*)

Weather Research and Forecasting (WRF) meteorological model, the USEPA’s CMAQ model and ADMS-roads

Six road categories are included in the calculation

Model outputs: Hourly/Daily/Annual – nitrogen oxides (NO\textsubscript{X}), nitrogen dioxide (NO\textsubscript{2}), ozone (O\textsubscript{3}), particle matter (PM) components by source type (PM\textsubscript{10/2.5})

Emissions inventories
UK National Atmospheric Emissions Inventory (NAEI)
King’s Great Britain road traffic emissions
European Monitoring and Evaluation Programme (EMEP, http://www.ceip.at/)
European Pollutant Release and Transfer Register (EPRTR)
Biogenic Emission Inventory System (BEIS v3.14) VOC and soil NO

Boundary conditions: Met. and air quality

CMAQ-urban ref - Beevers SD, Kitwiroom N, Williams ML, Carslaw DC. 2012. One way coupling of CMAQ and a road source dispersion model for fine scale air pollution predictions. Atmospheric Environment 59, pp 47-58

* CMAQ-urban is the Community Multi-scale Air Quality (CMAQ) + Atmospheric Dispersion Modelling System (ADMS) roads model
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

Recent example of scenario testing in London for NO$_2$
Messages from the Low GHG (nuclear replacement only) scenario

• Urban levels of NO$_2$ and PM$_{2.5}$ should decrease significantly with corresponding improvements for public health

• **BUT** the incentivisation of biomass will lead to an increase in exposure to primary PM combustion products, including potentially to carcinogens peaking in 2030-2035

• Close to roads PM$_{10}$ may increase (non-exhaust pm)

• Long-term ozone exposure will increase – health effect evidence is needed
Acknowledgements:

Martin Williams and Nutthida Kitwiroon (KCL)
Melissa Lott, Steve Pye (UCL)
Project funded by NIHR

Thank you!
Comparison of CMAQ and EMEP4UK SIA composition

2011 PM2.5 ammonium

NH$_4^+$

Average range of concentrations over south east of UK

SO$_4^{2-}$

NO$_3^-$

http://www.emep4uk.ceh.ac.uk/2011