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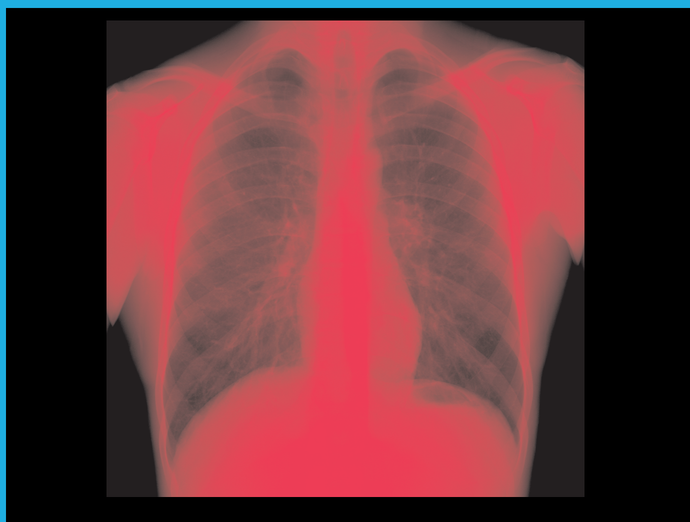
Air Pollution: Action in a Changing Climate



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The Scottish Government

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Ministerial Foreword

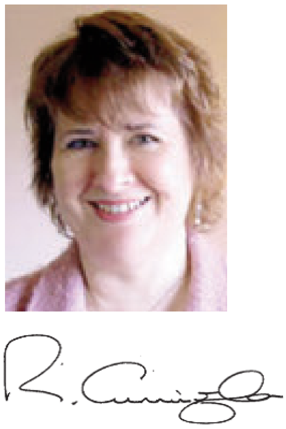
Over the last 50 years air quality has improved beyond all recognition. The choking smogs of the 1950s are a thing of the past, driven by concerted action especially on energy use and transport.

But air pollution still significantly reduces average life expectancy, causes many extra admissions to hospitals, and damages the natural environment. Surveys repeatedly show that people care strongly about air pollution, predominantly in urban and industrial areas but also in other surroundings. So, in common with other countries, we have to take further steps.

Taking action to reduce the effects of climate change provides an excellent opportunity to deliver further benefits to both air pollution and greenhouse gas emissions. Both arise from broadly the same sources and will therefore benefit from many of the same measures; so the combined benefits are substantially greater, when we compare them with the costs, rather than if we look at each group of benefits in isolation.

Now is the right time to consider how we can achieve these additional benefits, particularly from improving public health, through a closer integration of air quality and climate change policies. In the much shorter term we face challenges in meeting our current air quality targets, especially in relation to nitrogen dioxide and also particulate matter. This document summarises the main issues concerning air pollution and outlines the ways in which we can make the most of the interconnections between measures to address air pollution and climate change. It does not replace the more detailed strategy on air quality for the UK which we published in 2007; but it is intended to outline a wider vision for how we can link the two drivers for action more closely together. It also sets out the progress we are making on delivering our short-term air quality targets.

Jim Fitzpatrick
Minister for Food, Farming and the Environment
(Defra)



Roseanna Cunningham
Minister for Environment
(Scotland)

Jane Davidson
Minister for Environment, Sustainability and Housing
(Wales)

Edwin Poots
Minister of the Environment
(Northern Ireland)

Key messages

- Air pollution causes annual health costs of roughly £15 billion to UK citizens. This is comparable to the growing annual health costs of obesity, estimated at £10 billion (although the basis of the cost calculation differs). Many of our activities, especially transport and energy generation, contribute to both local air pollution and global climate change, so it makes sense to consider how the linkages between these policy areas can be managed to best effect.
- Our commitments to building a low carbon economy as set out in the UK and Scottish Climate Change Acts will reduce air pollution, but choices about the route we take to 2050 will affect the scale of improvements to air quality. Factoring air quality into decisions about how to reach climate change targets results in policy solutions with even greater benefits to society. Optimising climate change policies for air pollution can yield additional benefits of some £24 billion (net present value) by 2050.
- These air quality/climate change co-benefits will be realised through actions such as promoting ultra low-carbon vehicles, renewable sources of electricity which do not involve combustion, energy efficiency measures, and reducing agricultural demand for nitrogen. At the same time, we need to avoid as far as possible policies which tackle climate change but damage air quality, and vice versa. The science is complex and the evidence base is developing.
- Action at international, EU, national, regional and local levels will be needed to ensure policies are integrated to maximise these co-benefits and ensure ambitious but realistic targets for air pollution are set for the future. Some local authorities are leading by example now and actions in place demonstrate how synergies can be achieved. At the national level we intend to align future reviews of the Air Quality Strategy with the statutory carbon budget cycle, so we can evaluate the extent to which expected air quality benefits are being delivered.
- Further action is needed in the much shorter term to meet outstanding EU air quality obligations, including for nitrogen dioxide (NO_2), in the most cost-effective way.

Contents

Why do we care about air pollution?

1.1 Air quality in the UK and across the EU has improved significantly in the last couple of decades. However, we are still seeing evidence of negative health effects and environmental damage caused by emissions of air pollutants such as particulate matter (PM), ammonia (NH_3), oxides of nitrogen (NO_X) and sulphur dioxide (SO_2). The air pollutants of greatest concern in the UK now are PM, NO_X, ozone (O_3) and NH_3. Meanwhile, climate change has emerged as a major global challenge with achievement of legally binding targets by 2050 a key priority for the UK Government and the devolved administrations (DAs). Across Government, work is now underway through the 2009 Low Carbon Transition Plan (LCTP)[1] to meet our carbon budget commitments from 2008 through to 2022.

1.2 The reductions in emissions of air pollutants (**Figure 1**) have been largely due to policies targeted at cleaner technologies and fuels. There have also been improvements in ambient concentrations although for some key pollutants, this trend has slowed (**Figure 2**). Furthermore, we have seen a shift in the dominant sources of air pollutants. Twenty or thirty years ago these were mainly industry and domestic heating, today they are dominated by large combustion plants, particularly those used for power generation, and by transport. An overview of key air pollutants, their sources and emission trends can be found in **Annex A**.

Figure 1: Emission trends of key pollutants (total UK)

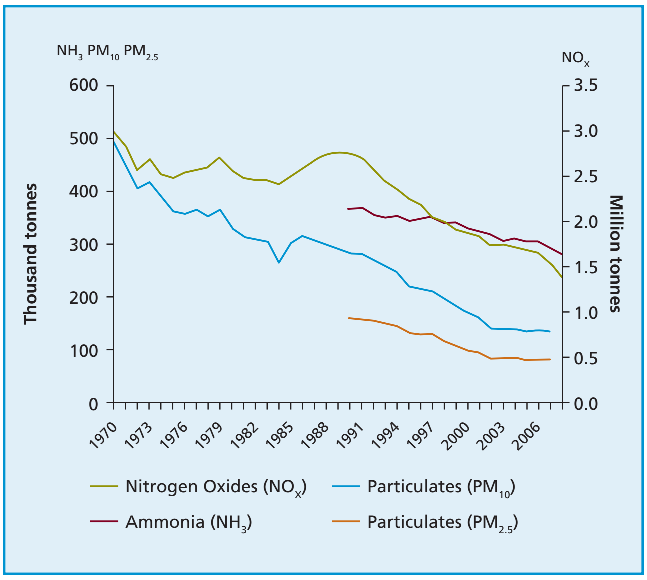
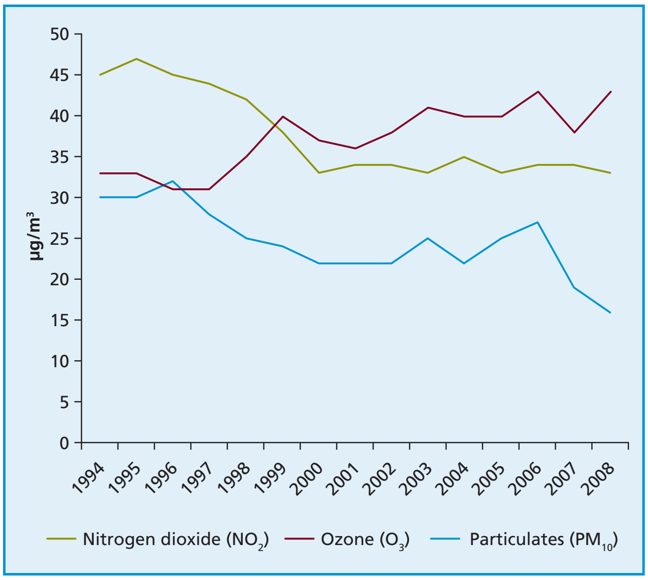


Figure 2: Annual mean concentrations at Birmingham Centre (AURN Station)



Air pollution damages human health

1.3 Adverse health effects from short and long term exposure to air pollution range from premature deaths caused by heart and lung disease to worsening of asthmatic conditions and can lead to reduced quality of life and increased costs of hospital admissions. Current evidence suggests that there is no "safe" limit for exposure to fine particulate matter ($PM_{2.5}$). The 2007 Air Quality Strategy[2] (AQS) estimated that based on air quality data from 2005, manmade $PM_{2.5}$ alone reduced the average life expectancy of people living in the UK by 7-8 months and imposed an annual cost of £18 billion, within the range of £9-20 billion.

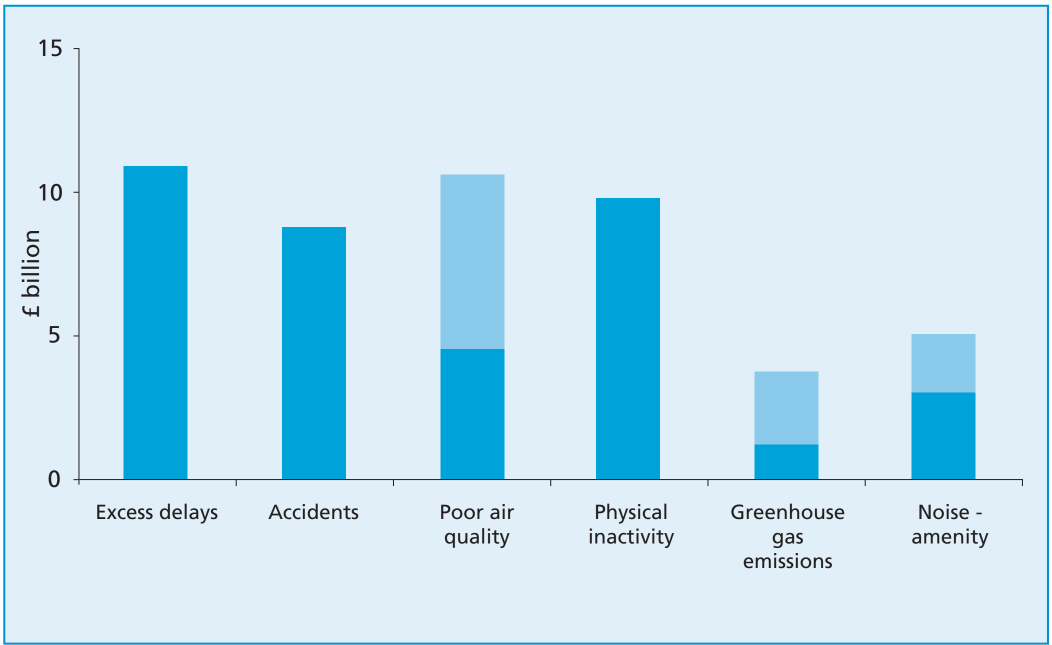
[1] http://www.decc.gov.uk/en/content/cms/publications/lc_trans_plan/lc_trans_plan.aspx

[2] http://www.defra.gov.uk/environment/quality/air/airquality/strategy/index.htm

An updated assessment, based on 2008 data, shows that improvements in pollutant levels since 2005 mean that the average reduction in life expectancy is now 6 months and the annual cost £15 billion, within the range of £8-17 billion. Though this demonstrates that improvements are still being made, analysis in the 2007 AQS showed that further air quality benefits are increasingly costly to achieve, making action difficult to justify on this basis alone. To put this in perspective, though direct comparisons are difficult due to the methodologies used, the economic cost of physical inactivity and obesity in urban areas has been estimated as in excess of £10 billion per annum[3]. A report from the Institute of Occupational Medicine[4] estimates that the gains in life expectancy that could be had from eliminating man-made fine particles (7-8 months based on 2005 levels) is larger than those possible from eliminating motor vehicle traffic accidents (1-3 months) or second-hand cigarette smoke (2-3 months).

1.4 A recent comparison of the wider costs of transport in urban areas in England also reveals that poor air quality may be responsible for up to one quarter, or £5 – 11 billion per annum, of these (**Figure 3**)[5]. Statements from the Committee on the Medical Effects of Air Pollutants (COMEAP) suggest that the impact is likely to be towards the higher end of this range[6].

Figure 3: Comparison of the wider cost of transport in English urban areas (£ billion per annum, 2009 prices and values).



Note: The air quality estimate is based on the 2005 estimate of the harm to human health from manmade $PM_{2.5}$. The pale blue colour represents the uncertainty of the figures, i.e. the range of £5-11 billion in the case of air quality.

[3] The Future of Urban Transport. DfT, 2009. Available from http://www.dft.gov.uk/pgr/regional/policy/urbantransport/

[4] Comparing estimated risks for air pollution with risks for other health effects. IOM, 2006. Available from http://www.iom-world.org/pubs/IOM_TM0601.pdf (published March 2006)

[5] The wider costs of transport in English urban areas in 2009. Cabinet Office.

[6] Long term exposure to air pollution: effect on mortality. COMEAP, 2009. Available from http://www.dh.gov.uk/ab/COMEAP

Box 1: Particulate matter

The health effects of particulate matter are more significant than those of other air pollutants. PM is made up of a complex mixture of solid and liquid particles, including carbon, complex organic chemicals, sulphate, nitrates, ammonium, sodium chloride, mineral dust, water and a series of metals, which is suspended in the air. PM_{10} refers to particles with a diameter smaller than 10μm and $PM_{2.5}$ to particles with a diameter smaller than 2.5μm. They may be produced directly from a source such as an engine – or formed from reactions between other pollutants (e.g. NO_2, SO_2, NH_3) in the air (secondary PM). Chronic exposure contributes to the risk of developing cardiovascular diseases and lung cancer. Particulate matter can have an either cooling or a warming effect on climate, depending on its properties, and also has a key role in the ecosystem impacts of air pollution.

Box 2: Ground level ozone

This is formed when pollutants such as nitrogen oxides and volatile organic compounds (VOCs) react in sunlight and is one of the major constituents of summer smog. High levels can cause breathing problems, reduce lung function and trigger asthma symptoms. Ground level ozone can also seriously damage crops and vegetation, and caused loss of EU arable crop production worth an estimated €6.7 billion in 2000[7]. Ozone is a powerful greenhouse gas and contributes to global warming both directly and by reducing carbon uptake by vegetation.

Air pollution damages sensitive ecosystems

1.5 Compared with human health effects, the damage caused by air pollution on ecosystems may be less obvious and more difficult to quantify and monetise, but it remains important. Air pollution can cause damage to plants and animals, to aquatic and terrestrial ecosystems, impacting on biodiversity and damaging valued habitats. Deposition of sulphur and/or nitrogen can cause increased acidity, and when critical loads[8] for acidity levels are exceeded, ecosystem damage may occur. This was the case in 58% of the area of terrestrial habitats assessed between 2004 and 2006 – though this is a big improvement since 'acid rain' was identified in the 1970s[9].

Box 3: Valuation of ecosystem services

These are the services that natural systems provide. Benefits include basic resources such as clean air and water and raw materials through to services such as climate regulation and personal wellbeing. Air pollution may enhance or reduce the services ecosystems can deliver. For example, deposition of the plant nutrient nitrogen can increase forest and crop production. However, this enrichment of nutrients (eutrophication) can also lead to a reduction in species diversity and therefore the pollination and aesthetic services of some ecosystems. Further research will assist in making a more comprehensive assessment of the impact of air pollution on ecosystems and the services they provide.

[7] Royal Society, 2008. Ground level ozone in the 21st century: future trends, impacts and policy implications.

[8] The critical load is the level of deposition of a pollutant over an extended period of time above which an ecosystem is at risk of significant damage.

[9] http://www.defra.gov.uk/environment/quality/air/airquality/strategy/index.htm

1.6 Eutrophication is caused by deposition of nitrogen oxides and NH_3. Emissions of both pollutants have decreased considerably since the 1970s, but changes in atmospheric chemistry mean that the main result has been reduced exports of emissions to mainland Europe, rather than deposition reductions in the UK. Currently, critical loads are exceeded in 60% of habitats sensitive to eutrophication from nitrogen deposition[9].

We have legal ambient air quality limits and emission ceilings to achieve

1.7 Current legal limits on **ambient air quality** are now met across most of the UK's land area. However, the remaining 'hotspots' where limits for PM_{10} and NO_2 are not yet met are in densely populated urban areas, so human exposure is significant. The recent Ambient Air Quality Directive provides for additional time to meet these limit values, subject to satisfying the European Commission that compliance will be achieved by the extended deadlines (2011 for PM_{10} and 2015 for NO_2).

1.8 Even where legal limits have been achieved, effort is needed to maintain air quality given pressures from increasing population and demands on transport and land use. A new control framework for $PM_{2.5}$ means that we must continue to reduce exposure of those living in urban areas to this pollutant with a view to attaining a 2020 exposure reduction target across the UK. Defra and the devolved administrations are working with the Department for Transport and other delivery partners to meet our targets as soon as possible, and **Section 4** sets out the work in progress.

1.9 Some air pollutants are transported great distances and cause harmful effects far from their source, so **national ceilings for emissions** of key pollutants are agreed at EU level and under the auspices of the United Nations Economic Commission for Europe (UNECE). This legislation complements that on ambient air quality and includes ceilings for SO_2, VOCs, NH_3 and NO_X, to be achieved by 2010. In relation to ozone, EU legislation sets targets and long-term objectives for concentrations in ambient air. This also recognises that the principle means of control of ozone lies in reducing emissions of precursors such as VOCs and NO_X. The UK is on track to achieve the 2010 ceilings, with the exception of that for NO_X which we expect to meet by 2012. Negotiations for revised ceilings for 2020, which are likely to include $PM_{2.5}$, are expected to commence soon, so levels of ambition will need to be considered.

[9] http://www.defra.gov.uk/environment/quality/air/airquality/strategy/index.htm

Climate change and air pollution – what's the connection?

2.1 Climate change and air pollutants share common sources. Greenhouse gases are most active high up in the atmosphere, whereas the most important factor for air quality is the concentration of pollutants nearer the earth's surface. This picture is complicated by the fact that some 'traditional' air pollutants act as greenhouse gases too, (ozone, for example) or are involved in their formation (NO_X, for example). The United Nations Environment Programme (UNEP) has recently launched an Integrated Assessment of Black Carbon and Tropospheric (ground level) Ozone to evaluate their roles in air pollution and climate change. Against this, whilst reducing emissions of SO_2 has been important to reducing damage to public health and the environment (acid rains), the sulphate or "white" aerosols (secondary PM) which it helps to form acts to cool the earth's atmosphere. This illustrates the complex relationships and trade-offs that need to be managed.

2.2 Electricity generation and road transport are two of the most significant sources of both air quality and climate pollutants. Other sources include shipping (NO_X and CO_2), agriculture (NH_3, nitrous oxide (N_2O) and methane (CH_4)), and biomass burning (PM, NO_X and N_2O).

2.3 Changes in the climate will impact on air quality; increases in temperature may affect the formation of ozone, increasing the frequency and severity of summer smogs. During the UK heat-wave of August 2003, between 420 and 770 (depending on the method of calculation) deaths brought forward were attributable to air pollution in a 15-day period[10].

2.4 Though separate policy frameworks have evolved for managing air pollution and climate change, it will be important to develop strong linkages between these if we are to deliver our policy goals in the most cost-effective way. Delivery of air quality and climate change goals requires public engagement to encourage more sustainable behaviours in relation to, for example, transport choices. In recognition of how strongly people engage with the quality of their local environment, the local public health benefits resulting from many climate change mitigating actions should inform future communications activities at national and local level.

Box 4: Black carbon

Black carbon is a fraction of **particulate matter**, comprising of particles resulting from inefficient burning. Sources include diesel engines, biomass burning and coal power stations. In the atmosphere this pollutant contributes to climate change by absorbing heat and by depositing on snow and ice thereby reducing the reflectivity of those areas, possibly speeding up the melting of glaciers and altering weather patterns. Emerging evidence suggests that black carbon may contribute 20-50% of the warming effect of CO_2 to near-term climate change[11].

[10] Stedman, J.R. 2004. The predicted number of air pollution related deaths in the UK during the August 2003 heatwave. Atmospheric Environment 38. 1087–1090

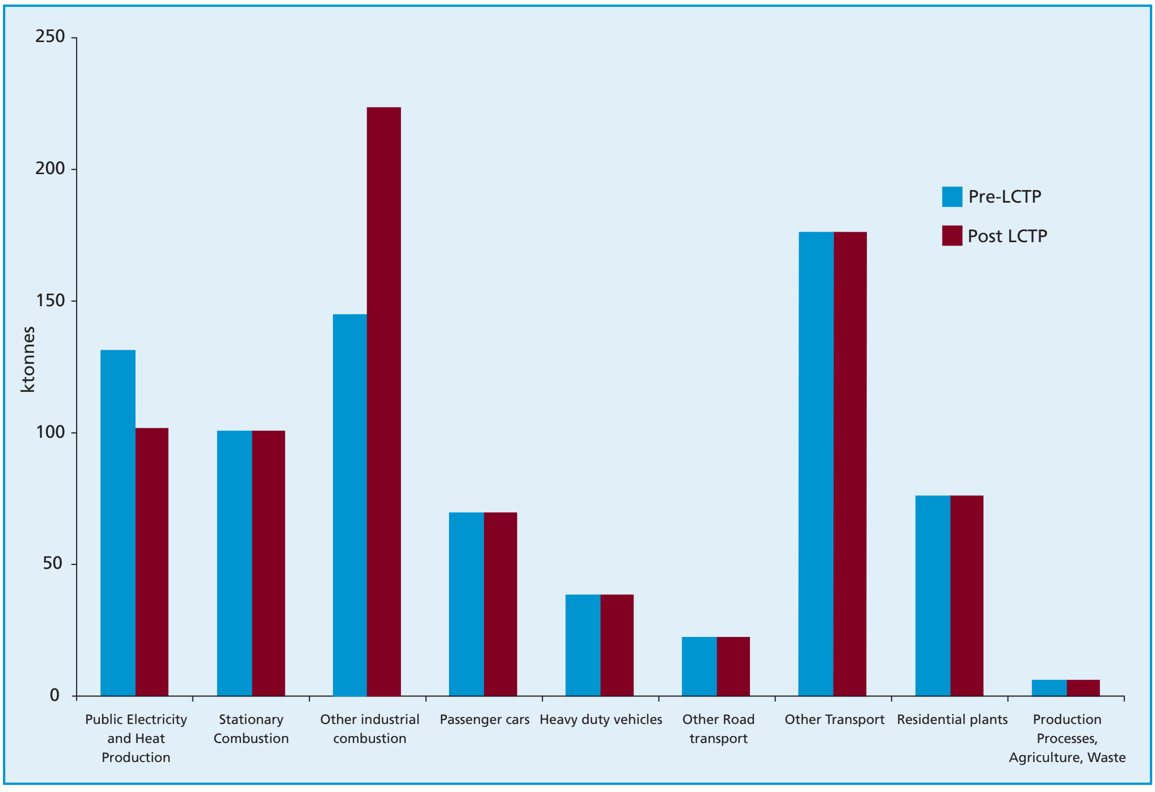
[11] V. Ramanathan & G. Carmichael, 2008. Global and regional climate changes due to black carbon. Nature Geoscience 1, 221 – 227 and www.unep.org

The legal framework and the Low Carbon Transition Plan

3.1 The UK Climate Change Act, developed by the UK Government in partnership with the devolved administrations, has introduced the world's first legally binding framework to tackle climate change, including a target to reduce emissions by at least 80% below 1990 levels by 2050. Progress will be supported by a series of five-year carbon budgets. The UK Low Carbon Transition Plan (LCTP), published in 2009, sets out how the first three budgets will be delivered, towards emission cuts of 34% on 1990 levels over the third budget period (2018-2022).

3.2 Becoming a low-carbon economy will require a large reduction in combustion processes, which will also bring about improvements for air quality. However, in the shorter term some measures suggested in the LCTP may slow down improvements in air pollution. This is illustrated in **Figure 4** below, where the projected impacts of the LCTP[12] (red columns) on UK emissions of NO_X are compared to energy projections based on policies that pre-date the LCTP[13] (blue columns). Though projections are sensitive to assumptions on the method of electricity generation and therefore uncertain, the additional LCTP measures can be seen to further decrease emissions of air pollutants from the public energy and heat production sector (due to reductions in coal use, changes to gas use and increased use of renewables). These are however outweighed by increased emissions from electricity generated by companies primarily for their own consumption, including combined heat and power (labelled as 'Other industrial combustion'). The net effect of the additional measures in the LCTP will be the emission of an extra 53 ktonnes of NO_X (816 ktonnes of total NO_X emitted in 2020 with LCTP compared to 763 ktonnes without).

Figure 4: Impact on UK NO_X Emissions (ktonnes) of the Low Carbon Transition Plan in 2020



12 Based on Updated Energy Projection UEP 38

13 Based on UEP 37

3.3 This initial result reflects the limited options available for reducing CO_2 emissions in the timeframe of the LCTP, but also highlights the risks for local air quality. In light of this, the Department of Energy and Climate Change (DECC) and Defra, in consultation with the devolved administrations, are working closely together to ensure that the relationship between air quality and climate change is well understood and reflected in future policy decisions. Accordingly, DECC have included guidance consistent with the Interdepartmental Group on Costs and Benefits (IGCB) on air quality into their toolkit for evaluation of climate change impacts. This is a major contribution to DECC's wider aim to deliver climate change objectives at the lowest social cost.

Box 5: Local case study: Biomass

The use of solid biomass (wood) as a fuel has benefits over fossil fuels in terms of carbon emissions; wood fuel is generally regarded as a low or zero carbon fuel. But depending on the fuel it is replacing, burning of wood can have positive or negative impacts on air quality. Wood fuel tends to emit a lower mass of particles than coal and often less than fuel oil but in comparison with natural gas, PM_{10} emissions from wood can be 10 – 100 times higher, based on emissions from current low emission boiler plants. Future technological developments could greatly improve the emission performance of wood burning appliances.

Camden Council plans to move away from reliance on the national grid for energy generation and adopt gas fired combined heat and power (CHP) generation in the medium term, to reduce CO_2 emissions. However, recognising that wider use of local power and heat generation might increase emissions of NO_X and PM_{10}, particularly if biomass is used as fuel, it has included in its air quality action plan a measure to review the long term use of combined heat and power generation to ensure air quality impacts are considered in the design of CHP plants especially during the introduction of new development in Camden.

3.4 Defra will continue to work across government to ensure that measures to facilitate climate change mitigation, such as promoting biomass through easing planning restrictions, or providing encouragement such as the renewable heat incentive[14], take account of air quality impacts.

Benefits of integrating policy

3.5 The 2007 AQS showed that after many years of significant improvement, air quality benefits are increasingly costly to achieve, making action difficult to justify on this basis alone. Subsequent evaluation of a measure to increase uptake of low emission vehicles (LEV) showed that when viewed from an air quality perspective the benefits were marginal, with a cost of £61 million and benefits of around £72 million on an annual basis. However, the measure was also estimated to realise climate change benefits valued at £91 million, thus bringing the total annual benefits to around £163 million for the same cost of £61 million. Low emission vehicles now form a key part of future planning for delivery of climate change targets and feature in the LCTP.

[14] Policy measures agreed with DECC under the Renewable Energy Strategy and draft Renewable Heat Incentive will mean that the uptake of biomass heat will have only a small impact on air quality, at the very least up to 2020.

Box 6: The Office for Low Emission Vehicles (OLEV)

OLEV is taking forward an ambitious programme towards a sustainable lower carbon vehicle fleet. In April 2009, the Secretaries of State for Transport and Business jointly announced the UK's strategy for Ultra Low Carbon Vehicles. This sets out Government's activity over the next five years including reference to £250 million of consumer incentives to stimulate the take up of electric and plug-in hybrid vehicles. Further details are at www.dft.gov.uk/olev/.

3.6 In the long term, take-up of ultra low emission vehicles in urban areas where air quality is a priority would be likely to result in significant public health benefits. We will therefore work with local authorities to highlight the opportunities available to promote low emission vehicles and encourage especially urban authorities to take a strategic approach to tackling both carbon and air polluting emissions.

3.7 The calculations used to assess the costs and benefits of air quality measures in the 2007 AQS did not consider the cost of abatement required to meet legal limits, which would better reflect our need to attain and then maintain compliance. Defra has now developed a new method of analysing the economic risk of exceeding targets (Box 7) which will help planning for future compliance. This methodology is similar to that used to assess climate change actions.

Box 7: Integrating costs of exceeding legal limits into policy evaluation

The Government's Interdepartmental Group on Costs and Benefits (IGCB) has published a new methodology to assess the costs and benefits of measures that impact on air quality. This builds on existing approaches, and will only apply when a policy is expected to result in limit values being exceeded. In such cases, the new methodology involves estimating the costs of abatement action required to keep within the air quality limit values, so that these can be factored into the economic appraisal of the policy. This helps to ensure that the costs of exceeding limit values are properly reflected in the analysis. It will also help prevent future exceedences as any abatement required will have been considered in the policy appraisal.

As a first stage, the IGCB has published the document outlining the new methodology to be applied where appropriate and proportionate. As the second stage, further work is being taken forward: (a) to test out its application and to seek views from expert practitioners on the practicalities of applying this methodology; and (b) to develop guidance and appraisal tools to enable practitioners to apply the new methodology in a proportionate and transparent way. More details on valuing air quality can be found at the IGCB website:
http://www.defra.gov.uk/evidence/economics/igcb/index.htm

3.8 Looking beyond the published LCTP, towards 2050, there are major benefits to be gained from integrating climate change and air quality policies. The UK MARKAL-ED model is used within Government to generate the optimal mix of emission-generating technologies and project the lowest-cost basket of technologies across five sectors (transport, electricity generation, residential use, road transport and industry – it does not include waste or agriculture). A study in 2008[15] examined the air quality impacts of two hypothetical 2050 scenarios:

A. The optimal technology mix based on the Climate Change Act reduction targets for 2020 and 2050;

B. As Scenario A, except that the air quality impacts are also taken into account when selecting the optimal technology mix.

[15] Optimising delivery of Carbon reduction targets: integrating air quality benefits using the UK MARKAL model. 2008. Available from http://www.defra.gov.uk/environment/quality/air/airquality/panels/igcb/publications.htm

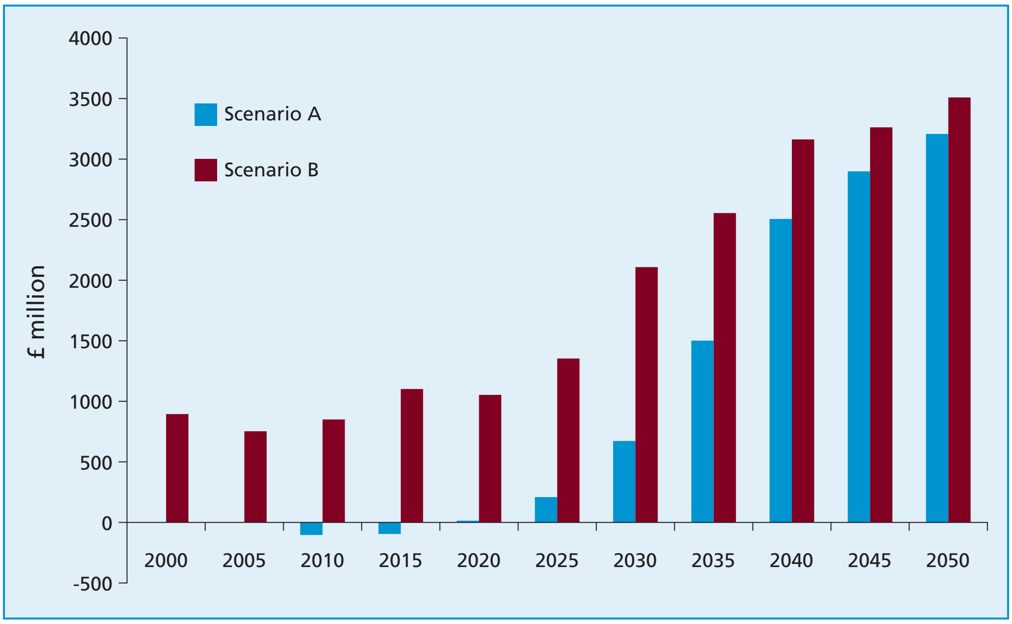
3.9 The results (shown in **Figure 5**) demonstrate that under both scenarios, mitigating climate change leads to reductions in air pollutant emissions. In Scenario A, this reduction delivers a value of £15 billion by 2050. However, when the technology is optimised to take into account air quality, additional benefits worth £24 billion can be achieved, bringing the total to nearly £40 billion (all figures are net present value). The additional benefits in Scenario B arise from:

NO_X: switching from diesel to hydrogen-powered vehicles and reducing carbon capture and storage (CCS) coal use and replacing it with CCS gas or nuclear power for producing electricity.

SO_2: quicker phase-out of solid fuels. In electricity generation, increased reliance on flue gas desulphurisation (FGD) plants. The industry sector would switch to gas, phasing out coal.

PM_{10}: shift in the transport sector from diesel to petrol, and a move away from biomass for residential heating (potentially the most significant shift between scenarios A and B).

Figure 5: MARKAL modelling of the benefits of integrating air quality and climate change policies



3.10 Individual choices in relation to how we travel, heat our homes and offices and what products we buy will also influence air quality and climate change. An illustration of a possible trade-off between air quality and climate change is shown in **Table 1**, where the average emissions[16] of three types of car fuelled by either petrol, diesel (Euro 4 vehicle emission standards) or a petrol hybrid engine, are monetised.

Table 1: Typical annual environment and health cost of car travel (UK)

Costs with regards to	Petrol car	Diesel car	Petrol Hybrid
Climate change[1]	£166	£146	£98
Air quality[2]	£1[3]	£21	£1
Total	£167	£167	£99

1 Based on the non-traded shadow price of carbon
2 Primarily based on health effects of particulate matter (IGCB). Euro 5 standards, which will apply to all new cars from January 2011, will introduce PM emission standards for diesel cars which are similar to those for petrol cars.
3 The difference in scale between these costs reflects the extensive emission control already introduced for cars in terms of air quality pollutants

16 The CO_2 reduction for hybridisation is based on the Honda Civic range. Specifically, the petrol variant 1.8i VTEC SE, the diesel 2.2i CDTI SE-T, and the hybrid 1.4 IMA ES CVT.

3.11 Considering only the benefits to climate change, switching from petrol to diesel appears to be a good option, reducing climate change costs by 12%. Looking at the impacts on air quality in isolation, a move from petrol to diesel would currently increase health costs by 20 times. By taking both sets of costs into account, there is no overall benefit in moving from petrol to diesel and on balance, the petrol hybrid car looks preferable, as this incurs the lowest cost overall. Note that the climate change impacts of black carbon (see Box 4), of which there will be significantly more from the diesel car, have not been taken into account, nor have a range of non-monetised air quality impacts (additional aspects of ill-health, ecosystem impacts). This highlights further the potential additional value to society when impacts of both air quality and climate change are considered together.

Mapping the road to 2050

3.12 Since the 2008 MARKAL analysis the key economic sectors and likely policy choices for delivering the significant additional reductions needed beyond the current LCTP to meet the 80% 2050 target are emerging more clearly. These, and a qualitative assessment of their likely impacts, are set out in **Table 2**. The extent to which some of these options will be available will depend on technological development and costs, so consideration of the optimal mix is at this stage hypothetical. However, it is useful to illustrate the sorts of policy choices that would likely result in additional air quality benefits or costs in the 2020 – 2050 timeframe.

Table 2: Policy choices for delivering climate change targets for 2020-2050

	Option	Likely impact on air pollution[17]	Commentary
Transport	Electric cars		Highly beneficial for urban air quality. Benefits for UK emissions (including of greenhouse gases (GHGs)) is dependent on the energy source used to generate the electricity but it is assumed that low carbon sources are used.
Transport	Hydrogen fuel-cell cars		Highly beneficial for urban air quality. The benefit for UK emissions (including GHGs) is dependent on the energy source used for creating the hydrogen fuel but it is assumed that low carbon sources are used.
Transport	Biofuels		Higher blends (>15%) of some conventional biofuels could increase NO_X and VOC emissions, with PM emissions likely to decrease. Certain biofuels such as biomethane can deliver considerable air quality benefits relative to diesel if fuelling and emissions control systems are well engineered.
Heating	Ground- and air source heat pumps		Produces no air pollution emissions and therefore beneficial for urban air quality and, subject to the energy source used to operate the pump, for UK emissions.
Heating	Combined Heat and Power		Large scale uptake would tend to require CHP in urban centres, with a negative impact. In terms of national emissions, CHP uptake will make heat and electricity generation more efficient, with the likely result that total emissions will reduce.

17 Green = measure is positive for air quality. Amber = measure can be positive and negative, or is uncertain. Red = measure is likely to be negative. Two colours indicates a likely impact between two classifications.

Energy	Nuclear		Produces limited air pollution emissions and therefore beneficial for both urban air quality and UK emissions.
Energy	Carbon capture and storage (coal)		CCS is not yet demonstrated at commercial scale but impacts are expected to vary across the different types of technology used and could be strongly beneficial, neutral or possibly negative for national air pollution emissions. Little impact on urban air quality.
Energy	Renewables (non-combustion)		This technology produces no air pollution emissions and is therefore beneficial for both urban air quality and UK emissions.
Biomass	Biomass (heat)		Higher rates of uptake than the already substantial levels set out in the Renewable Energy Strategy[18] and use in other sectors post 2020 is likely to mean that deployment will be increasingly in urban areas and replace natural gas use. Impacts are therefore likely to be increasingly negative on urban air quality. However, "red" status could be avoided through future planning or other controls, and improvements to (and dependent on cost of) abatement technology such as installation of effective abatement equipment for district heating.
Biomass	Biomass (energy generation)		Where biomass is used as a fuel in large scale power generation, any adverse impacts could be greatly reduced through the use of existing emissions control technologies, especially where coal fired generation is replaced. Potential block to the greater deployment of non-combustion based generation.
Biomass	Carbon capture and storage (biomass)		CCS has not yet been demonstrated at commercial scale, but has the potential to mitigate some of the negative impacts of biomass.
Remaining hydrocarbon use			Current hydrocarbon use is negative for air quality and climate change. Depending on amount and location of use, continuing impacts could be neutral (business as usual) or negative.
Agriculture	Small N_2O reduction		Small scale reductions in N_2O emissions could be achieved through practice and management changes in agriculture. Selection of appropriate measures could have a neutral or negative impact on ammonia emissions.
Agriculture	High N_2O reduction		Large scale reductions in N_2O emissions from agriculture are likely to require reductions in input of nitrogen to agricultural systems, with benefits on NH_3 emissions.

3.13 Building on these policy choices, we can construct 'best case' and 'worst case' scenarios to illustrate how decisions on how to achieve 2050 climate change targets could deliver additional air quality benefits (Scenario 1), or costs (Scenario 2). The first scenario is wholly beneficial for air quality and national emissions and reflects policy choices which optimise air quality and climate change benefits. The second is generally damaging for air quality and emissions of air pollutants or does not result in an optimal reduction in greenhouse gas and air pollutant emissions, and would reflect overall a less cost-effective means of delivering the UK's climate change commitments. These scenarios do not incorporate consideration of feasibility and are purely illustrative.

[18] http://www.decc.gov.uk/en/content/cms/what_we_do/uk_supply/energy_mix/renewable/res/res.aspx . Policies set out in the Renewable Energy Strategy and proposals for the Renewable Heat Incentive will result in air quality impacts from the substantial increase in biomass heat proposed up to 2020 being restricted to small and manageable levels.

Scenario 1: Climate change action brings additional benefits through air quality improvements.

Our cars and goods vehicles are powered either by electricity, hydrogen fuel cells or biomethane, with conventional biofuels used in the largest, inter-urban HGVs; our homes and businesses are heated by air and ground source heat pumps or electrical heating; lighting and electricity is provided through a mixture of nuclear, non-combustion renewable, and pre-combustion CCS equipped fossil fuel generators; remaining hydrocarbons are confined to chemical processes (plastics, pharmaceuticals, process chemicals, etc.); agricultural demands for nitrogen are greatly reduced and a high level of ambition is set for N_2O emissions reduction. This is likely to result in additional co-benefits from air pollution reduction running to many billions of pounds per year. There will also be important, but uncosted, benefits for human and ecosystem health.

Scenario 2: Climate change action brings further costs through the deterioration of air quality

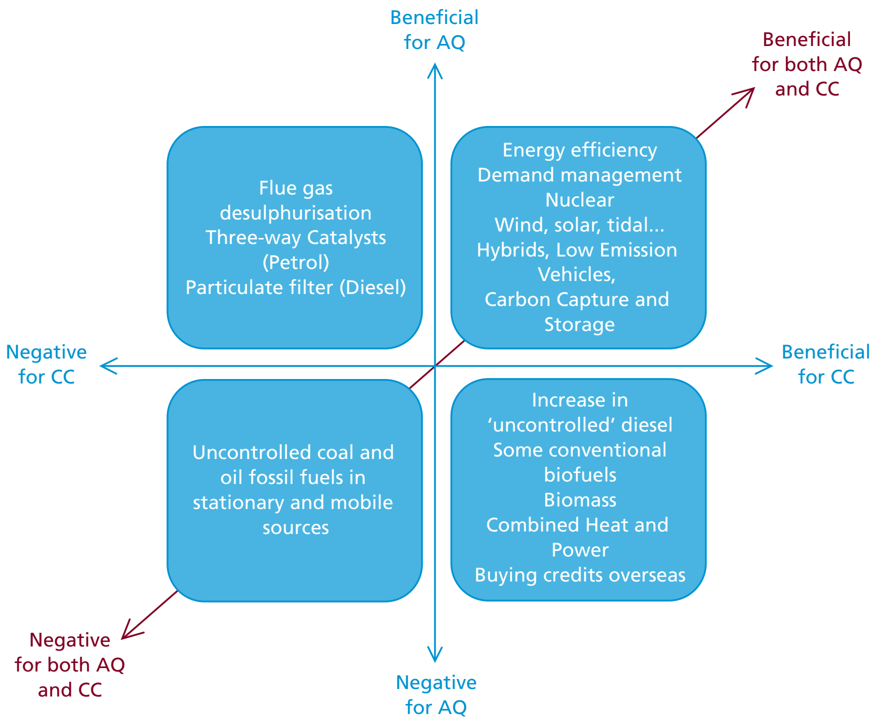
Conventional biodiesel or bioethanol is the fuel of choice for road transport; our homes and businesses get their heat and power from localised CHP plants, fuelled by gas or biomass; coal fired electricity generation provides the UK base load, with post-combustion CCS fitted; biomass is widely used in homes and as a heating fuel of choice in small boilers; N_2O from agriculture is controlled through manure management practices only.

This is likely to result in large costs in terms of additional air pollution damage, bringing new emissions sources into our urban areas. National emissions will still be reduced but by far less than for Scenario 1.

3.14 An important area requiring decisions on the trade-offs between air quality and climate change is the use of after-treatment technologies to clean up air pollutant emissions from road vehicles and power stations. One example is the fitting of particle filters to light-and heavy-duty vehicles in recent EU legislation.

3.15 These devices are extremely efficient in removing the PM from diesel exhausts. As particles are probably the single most important air pollutant affecting human health this is a major advance, but it does come with a fuel consumption penalty and hence works against carbon reduction targets. However, the filters also reduce the emissions of black carbon, which is a powerful warming agent so they do bring some climate change benefits too. Better scientific understanding of the links and alignment of air quality targets with those for climate change should help inform future decisions around trade-offs. **Figure 6** is a simple illustration of key synergies and tradeoffs.

Figure 6: Policy map displaying air quality/climate change interactions



Realising the benefits

3.16 The challenge in addressing air pollution and climate change over the coming decades will be to maximise synergistic policies at international, national, regional and local level, while striving to minimise conflict between policies and to manage any residual negative impacts.

3.17 The UK will be informed by these links in EU and international negotiations of future air quality targets so as to avoid forcing actions which lead to disbenefits for climate change.

3.18 Discussions of new national emission ceilings for 2020 have started within the UNECE and in considering ambitions levels, the UK will review analysis on what climate change actions can be expected to deliver in terms of reductions in emissions of key pollutants. The European Commission is also committed to a review of the Ambient Air Quality Directive in 2013 and Defra will be gathering evidence to inform the UK's input. In the review, we will be considering the extent to which current and planned actions under the LCTP will deliver the reductions in $PM_{2.5}$ that we will be aiming for by 2020. We will also be looking to ensure that the limit values and their application reflect the best health evidence available.

3.19 Domestically, we will aim to align future reviews of the Air Quality Strategy with those of the LCTP and the carbon budget cycle. The Air Quality Strategy is a requirement under the 1995 Environment Act and the Environment (Northern Ireland) Order 2002 and is an important vehicle for describing progress and reviewing measures to further improve air quality. Aligning reviews of the strategy with the carbon budget cycle will enable us to track improvements in air pollution alongside reductions in greenhouse gases and evaluate the extent to which we are realising the optimum benefits. Defra and the devolved administrations will be giving further consideration to the details and timing of this process and views of stakeholders will be invited.

3.20 Local authorities have an important role to play in delivering improvements to air quality and in combating climate change and we will be looking to encourage this further. The two case studies below demonstrate good examples of how the links are being made at a local level.

Box 8: Local case study: Perth and Kinross Air Quality Action Plan

Recognising the linkages between air quality and climate change, Perth and Kinross Council assessed the impact of its draft Air Quality Action Plan on greenhouse gas emissions. The draft Plan had primarily focused on reducing road traffic and the climate change assessment showed that most measures, such as the Cross Tay Link combined with city centre traffic management, would help reduce both air pollution and greenhouse gas emissions.

However, a few measures, such as moving new housing or business developments out of town, though reducing population exposure to air pollutants risked increasing greenhouse gas emissions through longer commuting distances. As a result, such measures are not taken further in the final version of the Action Plan, published in 2009.

Box 9: Local case study: Greenwich Peninsula Low Emission Zone, London

With air quality in parts of Greenwich above target levels, Greenwich Council recognised that innovative solutions were needed. Using Section 130 of the Town and Country Planning Act 1990, the Council granted planning permission for the redevelopment of the Millennium Dome site and its surroundings in 2003 on condition that the UK's first Low Emission Zone (LEZ) was implemented as part of the scheme.

Following the initial controls, focused on Euro 4 vehicle emission standards, development of the sustainable Greenwich Millennium Village presented an opportunity to evolve the LEZ concept in 2005 to include CO_2 reduction criteria. Since then, the LEZ has not only delivered a co-benefit for air quality and climate change by accelerating the uptake of cleaner fuels and technologies but has also raised awareness of pollution issues and of the cost-effective measures to tackle them.

3.21 Defra and the devolved administrations are now considering the recommendations of a recent report reviewing local air quality management across the UK and discussing with stakeholders how to take them forward. The review includes recommendations to build on synergies between climate change and air quality policies and action at local level.

Meeting our international, EU and domestic targets for air quality

4.1 As set out in Section 1, before we are likely to realise the expected benefits of greater optimisation of air quality and climate change actions, further action is needed to meet current air quality limits for PM_{10} and NO_2. Defra is working with the Department of Transport (DfT), the devolved administrations, the Mayor of London and local authorities to secure the necessary improvements. Key deadlines are shown in Annex B.

Box 10: Meeting NO_2 limits

The UK has a significant number of mainly urban locations that exceed the EU limit values for NO_2 and without additional action will continue to do so in 2015. In some areas, particularly London, there are widespread exceedences, which call for strong coordinated measures at national, regional and local level. Defra and the DAs are, with assistance from DfT, the Greater London Authority (GLA), local authorities and others, reviewing a large number of options for measures that could help achieve the limit values by 2015. These fall into four broad categories:

- Accelerating clean technologies – including retrofitment, low emission vehicles, buildings efficiency, euro emission standards etc.;
- Encouraging further behavioural changes – including modal shift, traffic management, safer driving, cycling, walking;
- Local measures and delivery including parking controls, bus management arrangements, strengthening local air quality delivery;
- Strategic options such as Low Emission Zones, local transport planning and very low carbon vehicles.

We are likely to need to accelerate relevant climate change actions or focus them in areas where air quality improvements are most needed. Applications setting out how limits will be achieved by 2015 need to be submitted to the European Commission by September 2011.

Box 11: Meeting PM_{10} limits

In 2009 the UK along with most other EU Member States applied for an exemption from the 2005 PM_{10} compliance obligation until 2011, as projections suggested that we would then have reached compliance. Since this submission, the 2008 national assessment[19] has shown that compliance has now been reached in all zones except London. An immediate priority is to ensure that limit values will be met across Greater London by 2011. "Hotspots" around a few major roads are the outstanding challenge, with local transport measures being key for compliance. The UK Government is working with the Mayor of London to provide the necessary assurances to the European Commission. Given there is no safe level of exposure to $PM_{2.5}$ and the legal framework to address this, it will be important to continue to deliver further reductions in levels of this pollutant.

Box 12: Air quality in London

The Mayor of London's revised air quality strategy is expected to be finalised later in 2010 following public consultation. It is anticipated that this will set out ambitions for further improvements to air quality including the introduction of a third phase to the London Low Emission Zone for light vehicles and in due course extending the zone to cover NO_X emissions from vehicles. The GLA believes that the measures in the strategy will reduce NO_X emissions by up to 40% by 2015 and, coupled with natural turnover, PM_{10} emissions by up to 30% by 2012. These actions will make important contributions to our application for additional time to meet the NO_2 limit values, and to the maintenance and further improvement of particulate matter pollution in London.

Around Heathrow airport, NO_2 is the air pollutant of concern. In its decision about airport expansion, the UK Government has committed to not releasing additional capacity until air quality limits are met. Support for the expansion is also contingent on putting in place a new regulatory mechanism to ensure that limits are not exceeded. DfT is working on this with Defra, the Environment Agency and the Civil Aviation Authority, and proposals will be subject to public consultation.

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[19] http://cdr.eionet.europa.eu/gb/eu/annualair

- We will be working across the UK Government and with the devolved administrations to ensure that agreed methodologies for assessing the costs and benefits to air quality are built into the evaluation of climate change impacts of policies. This will help deliver climate change objectives at the lowest social costs, and reflect the need to attain and then maintain compliance with ambient air quality limits;
- In future EU and international negotiations on air pollution emissions and air quality the UK Government will aim to align ambition levels with what climate change measures can be expected to deliver; where there are trade-offs to be made, we will continue to work to manage these to deliver optimal social benefits;
- The UK Government will continue to work to develop improved understanding of the complex linkages between air quality and climate change pollutants to ensure well targeted and cost-effective policies and a coherent policy framework. In particular, further work is needed to facilitate comparison of air quality and climate change impacts;
- On health effects of air pollution, Defra will be working with Department of Health and the Health Protection Agency, through the Committee on the Medical Effects of Air Pollutants (COMEAP) to help reduce uncertainties around the health evidence on PM toxicity, ozone and NO_2;
- We will aim to align future reviews of the Air Quality Strategy with reviews of progress against carbon budgets and will consider further how this is best achieved, possibly within the context of taking forward the review of local air quality management;
- An immediate priority is to work towards compliance with current EU air quality limits. Where the impact of possible policy interventions is uncertain, new tools or evidence gathering approaches may need to be developed, potentially in collaboration with other institutions or EU Member States.

Annex A: Key air pollutants

Pollutant	**Health effects**	**Environmental effects**	**Trend**
Particulate matter ($PM_{2.5}$ and PM_{10} secondary PM) See Box 1 and 4	Short and long term exposure can worsen respiratory and cardiovascular illness and increase mortality.	Secondary PM includes sulphate, nitrate and ammonium, formed from SO_2, NO_X and NH_3 which are the main drivers for acidification and eutrophication (see below). Black carbon, a potent short lived climate forcing agent, is a key part of the particulate matter mix, resulting from combustion process emissions.	Concentrations in urban areas have largely levelled off since around 2000 although a dip in concentrations has been observed in the last two years.
Nitrogen oxides (NO_X – made up of NO and NO_2)	Can cause inflammation of the airways, affect lung function and respiratory symptoms. Involved in the formation of PM and ozone. The effects of long-term exposure are less certain than the effects of short-term exposure.	Contribute to acidification and eutrophication of terrestrial and aquatic ecosystems, damaging habitats and leading to biodiversity loss.	Initial reduction in concentrations in line with emission controls, but concentrations have levelled off since the early 2000s and remain largely flat. There are some indications that emission controls on diesel vehicles may not have delivered the expected reductions in NO_2 concentrations.
Ozone (O_3) See box 2	Can damage airways and reduce lung function. Increases incidence of respiratory symptoms.	Can cause damage to plants, leading to yield loss and impact on biodiversity. Ozone is also a greenhouse gas.	Severity of peak episodes (summer smog) greatly reduced, but background urban levels are rising
Sulphur dioxide (SO_2)	Causes constriction of the airways of the lung. Involved in the formation of PM.	Contributes to acidification of terrestrial and aquatic ecosystems, damaging habitats and leading to biodiversity loss.	Industrial emission controls and removal of sulphur from road fuels has meant that concentrations have gone down dramatically since the 1970s and are continuing to do so.
Ammonia (NH_3)	Involved in the formation of PM.	Can lead to damage of terrestrial and aquatic ecosystems through eutrophication and acidification.	Emissions are dominated by agriculture and are on a slow downward trend. Concentrations are significant only close to emission point.

Annex B: Short to medium term milestones for air quality and emission reduction policies

		2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
1	Nitrogen dioxide (NO_2) limit values set out in the air quality directive (1999/30/EC) enter into force.	Jan										
2	Deadline for transposing the requirements of the new ambient air quality directive (2008/50/EC) into national law.	June										
3	National emission ceilings for SO_2, NO_X, VOCs and NH_3 must be met.	Dec										
4	Extended deadline to comply with the existing particulate matter (PM_{10}) limit value for zones approved by the European Commission under the new ambient air quality directive.		June									
5	Latest date for submitting an NO_2 time extension notification for assessment by the European Commission.		Sept									
6	Expected agreement on a revised UNECE Gothenburg Protocol setting 2020 emission ceilings for SO_2, NO_X, VOCs and NH_3, and a new 2020 emission ceiling for $PM_{2.5}$.		Dec									
7	European Commission review of the requirements in the ambient air quality directive (2008/50/EC).				2013							
8	New limit value (25µg/m³) for particulate matter ($PM_{2.5}$) must be met and exposure concentration obligation (20µg/m³) for particulate matter ($PM_{2.5}$) takes effect.						Jan					
9	Extended deadline to comply with the existing NO_2 limit values for zones approved by the European Commission under the new ambient air quality directive.						Jan					
10	National exposure reduction target for $PM_{2.5}$ should also be achieved.											Jan
11	Expected date for compliance with tighter national emission ceilings for SO_2, NO_X, VOCs and NH_3, and a new emission ceiling for $PM_{2.5}$.											Dec

Key:

Ambient air quality deadlines
EC review of ambient air quality directive
Emissions reduction targets

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