Issue 1

Policy Evaluation: measures to reduce air pollution from road traffic

A report produced for the Department for Environment, Food and Rural Affairs, the Scottish Executive, the National Assembly for Wales and the Department of the Environment in Northern Ireland

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Customer	Department for Environment, Food and Rural Affairs, Scottish Executive, National Assembly for Wales and the Department of the Environment in Northern Ireland
Customer reference	EPG 1/3/146
Confidentiality, copyright and reproduction	
File reference	ED 47014225; j:\…\policy_evaluation\policy_evaluation_1e.doc
Report number	AEAT/ENV/R/0838
Report status	Issue 1 - final

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Executive Summary

The Air Quality Strategy for England, Wales, Scotland and Northern Ireland (AQS, DETR et al 2000) embraces a range of UK and European policy measures and regulations for the abatement of air pollution. It is widely recognised that road traffic is a major contributor to air pollution in urban areas in the UK. The reduction in emissions from road traffic arising from the introduction of catalytic converters, related vehicle technology and fuel standards are the policy measures expected to have had the largest impact on air pollution concentrations in UK cities over the last ten years.

There is considerable interest within DEFRA over the retrospective evaluation of policy initiatives. One initiative identified for scrutiny was the Air Quality Strategy. Recognising, however, that this was a collection of individual instruments, each of which had effects on pollutant emissions and air quality, it was decided initially, to evaluate what would probably have been the most important of them in terms of urban air quality, namely the measures taken to reduce emissions from road vehicles. DEFRA (previously DETR) therefore commissioned AEA Technology to evaluate the impact of measures to reduce vehicle emissions on air quality since the early 1990s.

This report provides an analysis of the impacts of policy measures to reduce NO_x, PM10 and CO emissions from road traffic. The analyses utilise modelling approaches developed in the site-specific analysis of pollutant concentrations (Stedman,1999 and DETR et al, 2000) and high resolution pollutant mapping techniques. Modelled concentrations have been projected both backwards and forwards according to emission projections derived from the National Atmospheric Emissions Inventory (NAEI).

In order to assess the impact upon air pollution of the technological abatement policies implemented throughout the 1990s and early 21st century, projections have been calculated for the current baseline road traffic emissions estimates defined by the NAEI and a 'no abatement' road traffic emissions scenario. Under this second scenario any reduction in emissions that would have arisen from the technical measures through European Directives or Government policies are excluded. Both emissions scenarios incorporate impacts of traffic demand policy measures, such as the 10-Year Plan for Transport and current policies on non-traffic sources.

It has been shown that policy measures have reduced concentrations of NO_2, PM10 and CO relative to estimates of concentrations had abatement policies not been introduced. On average, in 1999, annual average NO_2 and PM10 were reduced by 9 and 4 μgm^{-3} respectively and 8-hour maximum CO concentrations by 1.0 mgm^{-3} at urban background locations relative to estimates for the no abatement scenario. At roadside locations, reductions are more pronounced as might be expected from policy measures effecting road traffic emissions; annual average NO_2 and PM10 reduced by 10 μgm^{-3} and 12 μgm^{-3} respectively and 8-hour maximum CO concentrations by 2.1 mgm^{-3}.

By 2010, it is predicted that policy measures will have resulted in further significant reductions in pollutant concentrations. Annual average NO_2 and PM10 are predicted to be 22 and 10 μgm^{-3} lower respectively and 8-hour maximum CO concentrations 2.1 mgm^{-3} lower at

urban background locations. At the roadside, reductions relative to the no abatement scenario are estimated at 38 and 25 μgm^{-3} lower for the NO_2 and PM10 annual average respectively and 4.4 mgm^{-3} for the CO maximum 8-hour average.

It has also been identified that current policy measures will have an important part in reducing the number roads exceeding the AQS annual mean objective for NO_2 in 2005. By 2005, abatement measures are predicted to have reduced the number of roads exceeding the AQS objective by 75% relative to the no abatement scenario. Of the roads exceeding the objective by 2005, 65% are located in inner and outer London, and a further 32% in other areas of England. In addition, it has been shown that the policies measures up to and including the introduction of the Euro IV standard are unlikely to be sufficient to reduce concentrations at all roadsides to below the EU Daughter Directive Limit Value of 40 μgm^{-3} by 2010. Of those roads predicted to exceed this Limit Value in 2010 78% are located in inner London.

It has been established that, the single largest contributor to reductions in NO_x emission from road transport in 2010 was the introduction of three-way catalysts for petrol vehicles under Euro I. This measure is predicted to account for 46% of the total reduction in NO_x emission, arising from all policy measures, for this year (relative to the no abatement scenario). Cleaner diesel combustion systems introduced under the same Euro standard accounted for a further 18% of the total NO_x reduction in 2010 and all other policies (Euros II to IV plus cleaner fuels) the remaining 36% of NO_x emission reduction.

In terms ambient NO_2 concentrations, the introduction of the 3-way catalyst is likely to accounted for largest proportional reduction in concentrations in areas outside of London (46% of reductions arising from all policies in 2010). In London, however, the largest contributor to reductions at in ambient NO_2 by 2010 is predicted to be the Euro II fuel standard, which is predicted to account for 39% of the total reduction in ambient NO_2 concentrations arising from all measures by 2010 (14% more than Euro I). The discrepancy in contribution from abatement measures to concentration reductions within London and the rest of the UK is likely to be linked to the effect of cold start emission characteristics of petrol vehicles with catalysts and variations in the diesel/petrol vehicle emission split in these location types.

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1 Introduction

1.1 POLICY CONTEXT

The Air Quality Strategy for England, Wales, Scotland and Northern Ireland (AQS, DETR et al 2000) embraces a range of UK and European policy measures and regulations for the abatement of air pollution. It is widely recognised that road traffic is a major contributor to air pollution in urban areas in the UK. The reduction in emissions from road traffic arising from the introduction of catalytic converters, related vehicle technology and fuel standards are the policy measures expected to have had the largest impact on air pollution concentrations in UK cities over the last ten years.

There is considerable interest within DEFRA over the retrospective evaluation of policy initiatives. One initiative identified for scrutiny was the Air Quality Strategy. Recognising, however, that this was a collection of individual instruments, each of which had effects on pollutant emissions and air quality, it was decided initially, to evaluate what would probably have been the most important of them in terms of urban air quality, namely the measures taken to reduce emissions from road vehicles. DEFRA (previously DETR) therefore commissioned AEA Technology to evaluate the impact of measures to reduce vehicle emissions on air quality since the early 1990s.

1.2 THIS REPORT

This report provides an analysis of the impacts of policy measures to reduce NO_x, PM10 and CO emissions from road traffic. The analyses utilise modelling approaches developed in the site-specific analysis of pollutant concentrations (Stedman, 1999 and DETR et al, 2000). Using these techniques, empirical models are employed to predict concentrations in a base year and assign the measured concentrations to a range of source sectors. Modelled concentrations are then projected both backwards and forwards according to emission projections derived from the National Atmospheric Emissions Inventory (NAEI).

By projecting pollutant concentrations both forwards and backwards, it has been demonstrated that agreement with measured concentrations in the early 1990s is good. It also shows that the emission inventory and modelling method have both successfully characterised the sources contributing to measured air pollutant concentrations and the way emissions have changed during the 1990s.

Site specific projections have been updated with the latest pollutant models and NAEI road traffic emissions estimates. Projections are calculated using the 1999 base year for all years between 1990 and 2010. In order to assess the impact of technological abatement policies implemented throughout the 1990s and early 21st century, projections have been calculated with both the current baseline road traffic emissions estimates and a 'no abatement' road traffic emissions scenario. The 'no abatement' scenario excludes from the NAEI any reduction in emissions that would have arisen from the technical measures through European Directives or Government policies, although incorporates the impact traffic demand policy measures, such as the 10-Year Plan for Transport and current policies on non-traffic sources, such as those relating to large combustion plant.

In this way measured concentrations in recent years can be compared with those that would have been likely in the absence of any technical measures to reduce pollution from road traffic. It is also possible to compare predictions of air quality in 2010 for our baseline scenario with what might have happened in the absence of any historical (since 1990) and future technical measures.

2 Baseline emissions projections

Emission inventory maps for 1998 at a 1 km x 1 km from the NAEI have been used throughout the work presented here (Goodwin et al, 2000). Maps of area emissions for the following sectors have been calculated:

- Domestic
- Services (emissions from heating plant in commercial and public buildings etc.)
- Industry
- Road Transport
- Off road vehicles
- Shipping
- Rail
- Other

Emissions maps for 1999 and 2010 have been calculated by scaling the 1998 emissions according to projections of emissions available from the NAEI by the changes in UK total emissions for each sector. The emissions projections for road traffic and non-road traffic sources are described in this section. Projections of secondary PM_{10} concentrations are also described.

2.1 ROAD TRAFFIC EMISSIONS

The emissions from road transport are calculated by combining vehicle emission factors with traffic and fleet composition data. The emission factors are based on measured data from past and current vehicles on the road and how they have recently changed and will continue to change with new vehicle technologies and cleaner fuels. The traffic data are from surveys of past and current levels of traffic flow on the UK road network and projections of their change in different area and road types in the country. Changes in the composition of the fleet refer to the past and predicted numbers of new vehicle sales combined with average vehicle survival rates. These define the penetration rates of new vehicle technologies associated with the tighter European Directives on emissions and factors like the increase in the number of diesel powered cars entering the fleet. They also reflect Government policies and incentives influencing consumer preference and market availability. The influence of the introduction of tighter emissions standards and how the penetration of new vehicles through the car fleet impacts upon road traffic emissions is demonstrated in Figures 1 and 2 for NO_x emissions.

The following sections summarise the information used and main assumptions made in calculating the baseline emission projections.

Figure 1 Emissions of NO_x from road traffic by vehicle type (kT as NO_2 per year)

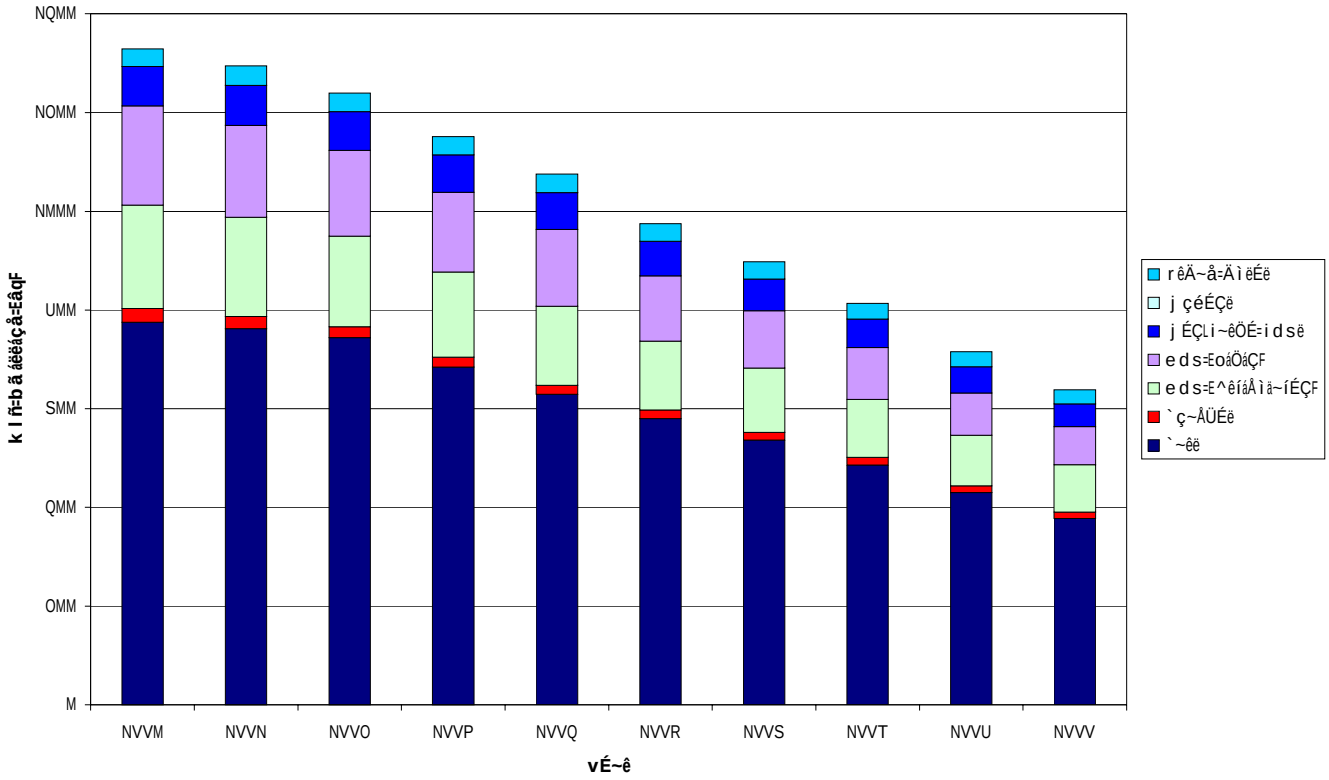
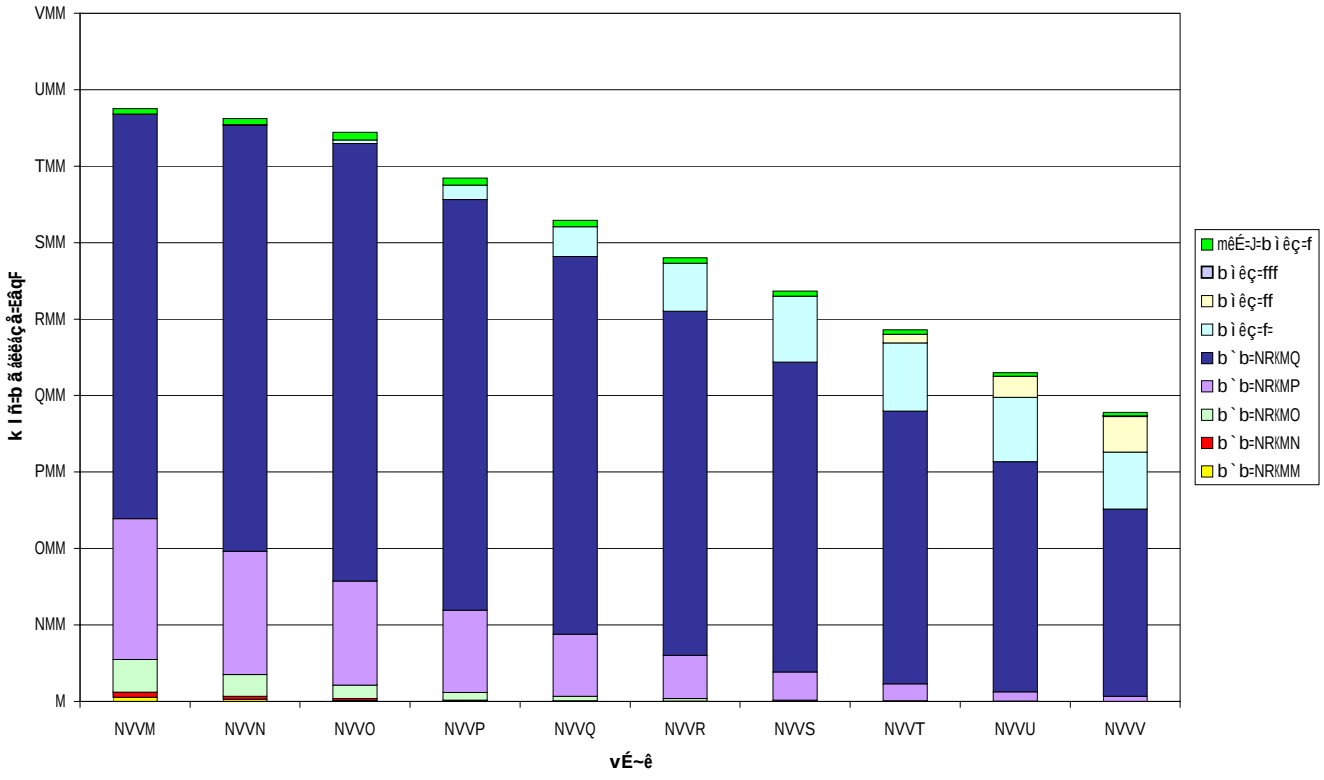


Figure 2 Contribution to total road traffic NO_x emission from cars by vehicle emission standard (kT as NO_2 per year)



2.1.1 Emission Factors

The emission factors and related assumptions used in this study are the same as those used in the AQS consultation document on the revision of the PM10 objective (DEFRA et al, 2001).

- Emission factors for different vehicle types registered up to 1996/1997 and running with their engines fully warmed up were derived from speed-emission factor functions provided by TRL (1998) and the COPERT II database (EEA, 1997). These are based on emissions measured over different drive cycles and average speeds.

- The measured data cover vehicles manufactured to emission regulations up to Euro I:
  Cars 70/220/EEC (ECE 15.00 to 15.04) up to 91/441/EEC
  LGVs 93/59/EEC
  HDVs 88/77/EEC and 91/542/EEC

  For vehicles registered after 1996 (Euro II) and up to 2006 (Euro IV) the emission factors were scaled according to the ratios of the type-approval limit values, taking account of the differences in the regulatory drive cycles. The scaling factors are reported in Murrells (2000) and are based on values from the EU MEET Programme and figures quoted in other EU communications.

- Cold start emissions (the additional emissions which occur when the vehicle is started with its engine not at its normal operating temperature) were calculated for light duty vehicles using the methodology in COPERT II. In estimating emissions for future technologies (Euro III and IV), different scaling factors were used for emissions in the hot and cold start part of a drive cycle.

- The effect of improved fuel quality on emissions were represented by scaling factors based on empirical relationships between fuel properties and emissions taken from the report of the European EPEFE programme. Different scaling factors are used for different parts of the drive cycle (Murrells, 2000).

- It is assumed that 5% of cars fitted with three-way catalysts fail each year. 95% of failed catalyst vehicles are repaired after the vehicle is 3 years old.

- NOx, CO and VOC emissions from catalyst cars degrade linearly with age or mileage at rates based on information from the European Auto-Oil Programme. Particulate emissions from diesel cars and light duty vehicles (LGVs) also degrade linearly. It is assumed that rates of degradation are slower for Euro III and IV vehicles than for Euro I and II vehicles due to improved technologies and on-board diagnostic systems.

2.1.2 Fleet Composition

- The turnover of the vehicle fleet is based on survival rate functions implied by historic vehicle licensing statistics (number of new registrations and numbers still registered by age in each year).

- For the projections, growth in new car sales was taken from DETR's Vehicle Market Model. For other vehicle types, new sales and growth in the vehicle stock were related to

the growth in number of vehicle kilometres (see below)

The percentage of diesel cars sold new in 1999 was 14%. Based on information from DETR (2000), Table 1 presents the assumptions made about the future diesel penetration of the new car market.

Table 1 Assumed diesel penetration of the new car market

Year	2000	2001	2002	2003	2004	2005	2006	2007	2008+
Diesel penetration of new car market (%)	15	16	17	18	19	20	21	22	22

2.1.3 New Vehicle Emission Standards and Technologies

The following assumptions were made about the introduction of the new emission standards (as new registrations) and technologies that vehicle manufacturers and fleet operators have or are putting into the fleet:

Petrol cars:

Euro II (94/12/EC) – 100% from 1 January 1997
Euro III (98/69/EC) – 3.7% in 1998 to 10% in 2000 (balance are Euro II's)
Euro IV (98/69/EC) – early introduction from 2001, as defined by DETR (2000). Balance are as Euro III, see Table 2.

Table 2 Assumed early penetration of Euro IV cars into the new petrol car market

Year	2000	2001	2002	2003	2004	2005
Proportion of Euro IV cars in the new petrol car market	0%	20%	40%	60%	80%	100%

Diesel cars:

Euro II (94/12/EC) – 100 % from 1 January 1997
Euro III (98/69/EC) – 3.7% in 1998 to 10% in 2000 (balance are Euro II's). 100% from 1 January 2001 to 2005
Euro IV (98/69/EC) – 100% from 1 January 2006
In addition to this, the penetration of new diesel cars fitted with particle traps was assumed as follows (DETR, 2000), see Table 3.

Table 3 Assumed early penetration of new diesel cars with particle traps into the new car market

Year	2000	2001	2002	2003	2004	2005+
Proportion of new diesel cars with particulate traps	0%	5%	10%	15%	20%	25%

The balance of diesel car sales were as the appropriate Euro standard (Euro III or IV). It was assumed that PM_{10} emissions from a diesel car fitted with a particulate trap are reduced by 85%

relative to the Euro II level; emissions of other pollutants are unaffected and are assumed to be at levels appropriate to the Euro standard that applies.

LGVs (petrol and diesel):

Euro II (96/69/EC) – 100 % from 1 January 1998
Euro III (98/69/EC) – 100% from 1 January 2002 (2001 for small LGVs)
Euro IV (98/69/EC) – 100% from 1 January 2006

HGVs and buses:

Euro II (91/542/EEC) – 100 % from 1 October 1996
Euro III (1999/96/EC) – 100% from 1 October 2001
Euro IV (1999/96/EC) – 100% from 1 October 2006 (standards for NOx introduced in 2 stages, second stage from 1 October 2008)
In addition to this, the retrofitting of particulate traps on heavy duty vehicles was assumed from 2000 (DETR, 2000), see Table 4

Table 4 Assumed penetration of retrofitted particle traps into the HGV fleet

Year	2000	2001	2002	2003	2004	2005+
Cumulative number of heavy duty vehicles retrofitted with particulate traps	4000	6000	8000	10000	12000	14000
Proportion of these vehicles which would have meet Euro II standards (balance as Euro III)	100%	90%	75%	60%	45%	30%

- In terms of emission factors, it was assumed that a particulate trap reduces emissions from a heavy duty vehicle by 85% (PM_{10}) and 17% (NOx) relative to a Euro II vehicle running on 1996 standard diesel
- In the case of buses, account was also taken that a number of vehicles have been fitted with oxidation catalysts since 1997. The proportion fitted rose from 5% in 1997 to 15% in 1999, all as Euro II vehicles. The proportion in the Euro II fleet is assumed to remain constant thereafter. An oxidation catalyst (combined with running on ULS diesel) reduces PM_{10} emissions from a bus by 50% relative to the Euro II level (LT Buses, 1998).

Motorcycles:

- 97/24/EC - 100% from 1 January 2000

2.1.4 Penetration of Cleaner Fuel Standards and Specifications

- Consumption of leaded petrol has been gradually phasing out since the introduction of unleaded petrol in 1988. It is assumed to be completely phased out from 1 January 2000.

- The introduction of 500 ppm sulphur diesel from October 1996 is accounted for, reducing PM_{10} emissions from pre-Euro II diesel vehicles from this date.

- European Fuel Directives 98/70/EC set tighter standards on petrol and diesel fuels sold from 1 January 2000 (Fuel 2000) and 1 January 2005 (Fuel 2005). However, the early introduction of ultra-low sulphur petrol and diesel (ULSP and ULSD, maximum sulphur content of 50ppm) meeting the 2005 specifications started in 2000 and is assumed to reach 100% penetration in 2001 and onwards. Many bus fleets started using ULSD as early as 1997. Consumption of ULSD by buses is assumed to gradually rise from 10% in 1997 to 100% in 2000.

2.1.5 Traffic Data and Projections

Traffic activity is used in the form of vehicle kilometres by each type of vehicle on each type of road or area in the UK. Speed data are also used to calculate average emission factors from the speed-emission functions that are used.

- Annual vehicle kilometre figures for years up to 1999 are taken from DETR based on their traffic census of the national road network.

- Growth in vehicle kilometres are forecast from 1999 for each vehicle, road and urban area type. Vehicle kilometres in each road/area type are forecast separately for traffic in England, Scotland, Wales and N Ireland, as follows:

- ***England:***
  Traffic growth is based on a combination of vehicle kilometre (vkm) figures by area type from the 10-Year Plan for Transport and the 1997 NRTF. It is assumed that traffic grows at a rate defined by the NRTF from the base year to 2005 then linearly approaches the vehicle kilometre figures given in the 10 Year Plan for 2010. After 2010, traffic is assumed to continue to grow at a rate defined by the NRTF from this year.

- ***Scotland:***
  Traffic growth is based on a combination of base 1996 vehicle kilometre (vkm) figures for different road types in Scotland given by DETR and the rate of traffic growth from 1997 to 2011 defined by the Central Scotland Transport Model (CSTM3). It is assumed that traffic grows at a rate defined by the NRTF from the base year to 2005 then linearly approaches the vehicle kilometre figures given in the CSTM3 for 2011. After 2011, traffic is assumed to continue to grow at a rate defined by the NRTF from this year.

- ***Wales and N. Ireland:***
  In the absence of other information, it is assumed that traffic growth in Wales is based on figure by area type from the 10-Year Plan for Transport and the 1997 NRTF (see England above). In Northern Ireland, growth are defined by the 1997 NRTF from base 1996 vehicle km figures given by DoE N Ireland for road types in that region.

- Average traffic speeds on different urban area and road types, rural roads and motorways are used based on an analysis of data from a number of different DETR publications referring to results from different traffic speed surveys. It is assumed that average speeds on the road network do not change in the future.

For England and Wales the network model in the NRTF framework divides the country into 11 different 'area types' and these are listed in Table 5. Traffic data for road links in Scotland were also assigned to area types 4 to 11. In addition to projections of UK total emissions the NAEI can also provide projections of emissions for each individual area type in England, Scotland and Wales and these have been incorporated into the road link and area emissions maps for 2010.

Table 5 National Road Traffic Forecast area types for the Ten Year Plan for Tansport

Area Type	Description
1	Central London
2	Inner London
3	Outer London
4	Inner Conurbations
5	Outer Conurbations
6	Other urban areas > 25 km^2 area
7	Urban areas 15 - 25 km^2 area
8	Urban areas 10 - 15 km^2 area
9	Urban areas 5 - 10 km^2 area
10	Urban areas < 5 km^2 area
11	Rural areas

2.2 NON-ROAD TRAFFIC EMISSIONS

Projections of emissions from non-road traffic sources have been calculated by the NAEI based on the 1998 emissions estimates and activity drivers for the central growth / high fuel price scenario in Energy Paper 68 provided by the DTI (DTI, 2000). These estimates therefore incorporate an assumed growth in economic activity of about 2.5% per year and the continuation of current trends towards greater use of natural gas and cleaner technologies (DTI, 2000). Emissions from the railways sector have been recalculated to take into account the impact of the 10-Year Plan for Transport.

Projected emissions are directly available for 2010; emissions for 1999 have been calculated by linear interpolation between 1998 and 2000. Emissions for the years 2001 to 2004 and 2006 to 2009 have been calculated by linear interpolation between 2000, 2005 and 2010.

2.3 SECONDARY PARTICLES

Secondary particle concentrations for 2010 and other years have been predicted on the basis of a combination of measurements and modelling results. For simplicity secondary PM_{10} has been assumed to consist of sulphates and nitrates. Secondary organic aerosol has not been considered in the baseline projections. Measurements of sulphate at a network of eight rural sites have been made since 1987. Measurements of total inorganic nitrate (nitrate particles + nitric acid) were made at two rural sites between 1990 and 1999. The trend in total inorganic nitrate concentrations over this period has been assumed to be the same as the trend in nitrate particle concentrations.

Figure 3 shows the mean of annual mean sulphate particle concentrations for the years 1987 to 1999. The overall decline in concentrations is clear and there is also considerable year to year variation in concentrations due to variations in meteorological conditions form. A best fit line has been calculated and we have assumed that this fit line represents an average trend in concentrations due to changes in UK, European and other sources of SO_2 contributing to sulphate measured in the UK, with changes due to meteorological variability removed. Figure 4 shows a similar plot for nitrate.

Modelled sulphate and nitrate fields for the UK are available for 1997 and 2010 from both the EMEP model (at 150 x 150 km spatial resolution) and the HARM model (at 10 x 10 km spatial resolution) (Warren et al, 2000, Metcalfe et al, 2001). In both cases these models have been run using 10-year average meteorology for both 1997 and 2010. The calculated values for 2010 incorporate the emissions reductions set out within the 'Gothenburg Protocol' to Abate Acidification, Eutrophication and Ground-level Ozone and those proposed within the EU National Emission Ceilings Directive. Both of these models have been designed to predict acid deposition and are known to over-predict the absolute values of ambient sulphate and nitrate particle concentrations. We have therefore chosen to scale measured concentrations in the years 1996 to 1999 by the ratios of modelled concentrations in 1997 and 2010 in order to predict sulphate and nitrate concentrations in 2010. The EMEP model results indicate a reduction in UK average sulphate by 2010 to 53% of 1997 levels and a reduction in nitrate to 67% of 1997 levels.

There are a number of ways in which the measured and modelled concentrations could be combined to provide estimates for 2010, particularly because the year to year variability in measured concentrations caused by variations in meteorology has been excluded from the modelled values by the use of average meteorology. Figures 3 and 4 illustrate the approach that we have adopted. We have used the ratios of the modelled concentrations in 2010 to those in 1997 to calculate a prediction for concentrations in 2010 from the best-fit line value for 1997. This prediction for 2010 therefore represents our best estimate of concentration in 2010 for average meteorology. We have also assumed a linear decline in concentrations from 1997 to 2010. Predictions of secondary particle concentrations for individual base years were then calculated by scaling the measured concentrations in that year according the ratio of the best fit concentration in that year and the average meteorology prediction for 2010. In this way we have incorporated the individual base year meteorology into the prediction for 2010 for secondary particles. This is consistent with the method adopted for primary concentrations, where the incorporation of base year meteorology into the predictions for 2010 is implicit in the scaling of measured concentrations by changes in emissions.

Figure 3 Comparison of trends in annual mean sulphate particle concentrations

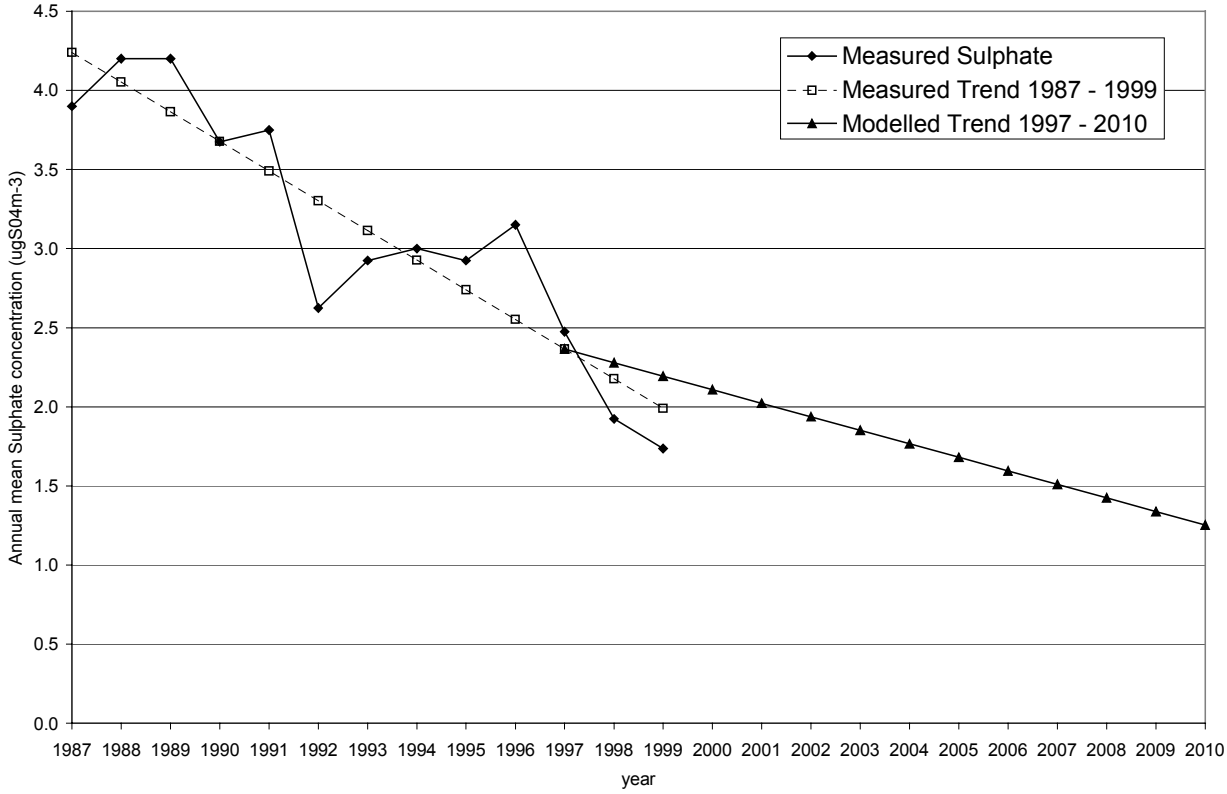
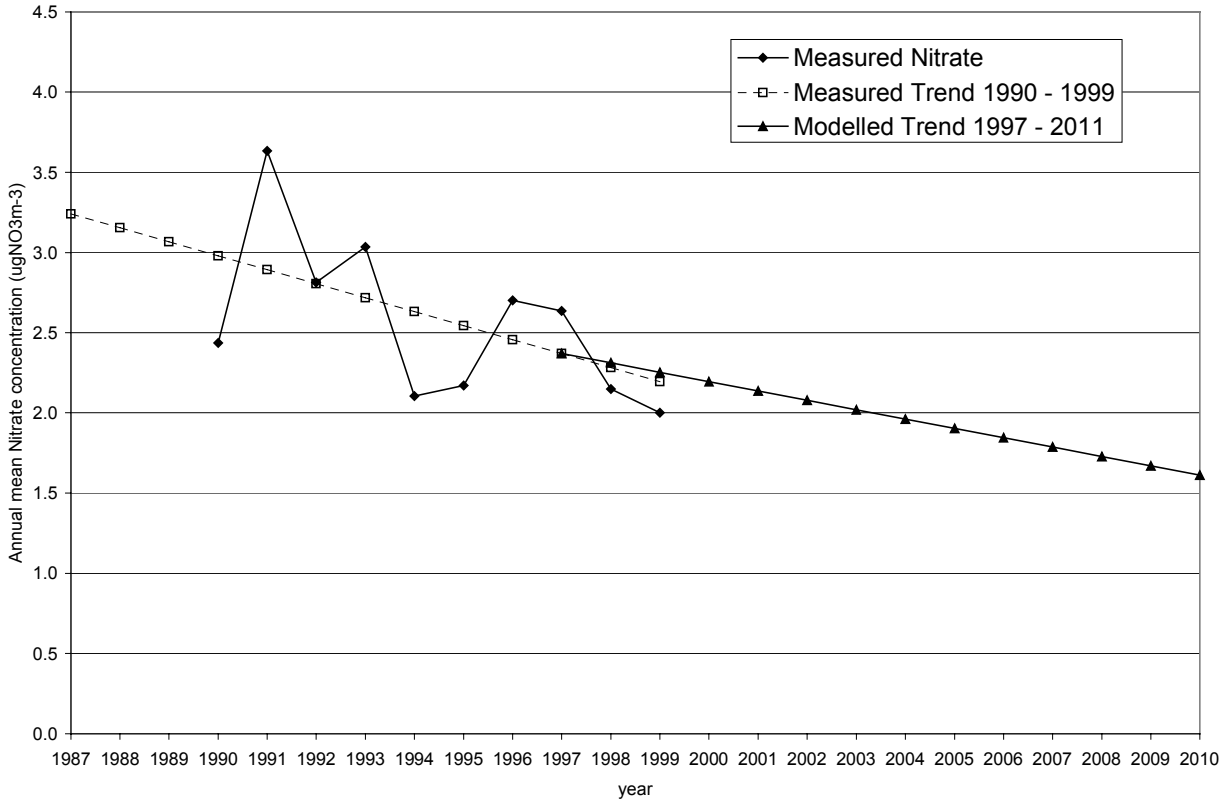


Figure 4 Comparison of trends in annual mean nitrate particle concentrations



3 No abatement emission projections

The policy evaluation analysis is based on a calculation of emissions from 1990 assuming that no technical measures had been or will be introduced to reduce vehicle emissions either through European Directives or Government policies.

In the analysis it is assumed that traffic growth and turnover in the fleet (based on new vehicle sales and survival rates) occur at the same rate as in the baseline. The future diesel penetration of the new car market was held the same as in the baseline. The main facts and assumptions that were omitted from the calculations are described as follows:

- All the European vehicle emission directives which have and will continue to be introduced since 1990 were omitted. That meant that the emission factors remained at their pre-Euro I values for all types of vehicles from 1990 into the future. In the case of petrol cars that would mean the ECE 15.04 standard prevailed, the implication being that no new cars were or will be fitted with three-way catalysts.

- No improvements in fuel quality occurred from the standards prevailing in 1990. This meant that all diesel vehicles continued to run on fuel with a 2000 ppm limit on the sulphur content since 1990. It also meant that in the projections no ultra-low sulphur fuels become available in the future, through Government policies of European Directives (e.g. Fuel 2005).

- The gradual phasing out of leaded petrol is assumed in the analysis. The reason for this assumption is that unleaded petrol started to become available from 1988 and it is assumed that the market penetration of unleaded petrol would continue to have occurred.

- No vehicle technologies would be introduced voluntarily by manufacturers to reduce emissions, for example by the fitting of particulate traps on new vehicles

- No vehicle would be retrofitted with equipment to reduce emissions, for example particulate traps and oxidation catalysts.

4 Site-specific projections of NO_x and NO_2 concentrations

4.1 METHOD

The method used to calculate site-specific projections of future annual mean NO_2 concentrations were first described in the AQS (DETR et al, 2000) and in some detail by Stedman et al (1998a) and Stedman (1999). The method has subsequently been revised and updated to incorporate:

1. More up-to-date monitoring information.
2. A considerably more detailed emission inventory for both the current *baseline* (1999) and the *no-road transport-abatement technology-scenario*.
3. Traffic activity information for the analyses carried out on the impact of the 10-Year Plan for Transport (Stedman et al, 2000).

The AQS sets the following provisional objectives for NO_2, to be achieved by 31 December 2005:

- Annual mean: 40 μgm^{-3}
- Hourly mean: 200 μgm^{-3}, not to be exceeded more than 18 times a year.

The first EU Air Quality Daughter Directive (AQDD1) sets the same concentrations as limit values, to be achieved by 1 January 2010. The annual mean objective and limit value are expected to be the more stringent of the two and our analysis is therefore focussed on predicting annual mean NO_2 concentrations.

The projections are based on measurements carried out at sites within the national automatic monitoring networks (see www.aeat.co.uk/netcen/airqual for details of the site locations and an archive of monitoring results). The following steps were required to project measured concentrations, and are carried out using both the current baseline and no road transport abatement technology emissions scenarios:

1. The measured NO_x concentration was divided into component parts. A map of rural concentrations was subtracted from the measured concentration to determine the local source contribution to annual mean NO_x concentration. Emission inventory maps (Goodwin et al, 2000) for 1998 were used to split the local source contribution into emissions sectors. Local sources were summed within a 35 km x 35 km area centred on the monitoring site location. An ADMS based dispersion matrix was applied to weight emissions from individual grid cell according to distance and direction from the site location. This dispersion matrix approach was also used to calculate the maps and is described in sections 6.
2. An additional contribution from emissions on the road adjacent to the monitoring site was included for roadside monitoring sites. An annual mean background concentration for each roadside site was derived from the maps described in section 6.

3. Each component was then projected forwards from the measurement year to 2010 according to the projected change in emissions from each sector and added together to give an estimate of annual mean NO_x for 2010. Rural concentrations were projected on the basis of changes in UK total NO_x emissions.
4. Ambient NO_2 concentrations vary according to the availability of both NO and oxidant. The following non-linear relationships between annual mean NO_2 and NO_x concentrations were used to calculate estimates of NO_2 concentration, (1 ppb NO_2 = 1.91 ugm^{-3} NO_2):

Central London Background: $NO_2\ (ppb) = 1.750.NO_x\ (ppb)^{0.7}$
Elsewhere Background: $NO_2\ (ppb) = 2.375.NO_x\ (ppb)^{0.6}$
Roadside: NO_2 (ppb) = $1.8767.NO_x\ (ppb)^{0.6}$

Figures 5 to 8 present examples of site-specific projections of NO_x and NO_2 concentrations for years between 1990 and 2010. Projected concentrations have been calculated from measured concentrations in 1999 using both the baseline and no abatement technology scenarios. There is good agreement between the projections for the years in the early 1990s and the measured concentrations. This gives us confidence that the split into different sectors and the emissions estimates are reasonable. The baseline scenario projections also clearly illustrate the impact of emissions reductions on ambient NO_x concentrations and the correspondingly smaller changes in annual mean NO_2.

The effect of the introduction of vehicle abatement technology measures throughout the 1990s is clearly shown in projected concentrations of NO_2. The initial decline in no-abatement concentrations in the early 1990s reflects the penetration of cleaner vehicle technology into the UK car fleet after their introduction in the late 1980s. The decline in concentrations from 2005 to 2010 at roadside sites represents the impact of the 10-Year Plan for Transport, which is much greater for the no abatement scenario because of the much higher emission rates per vehicle.

Figure 5 Projected NOx concentrations at Edinburgh Centre based on 1999 monitoring data plus baseline and no technology abatement emissions scenarios (µgm^{-3}, as NO_2)

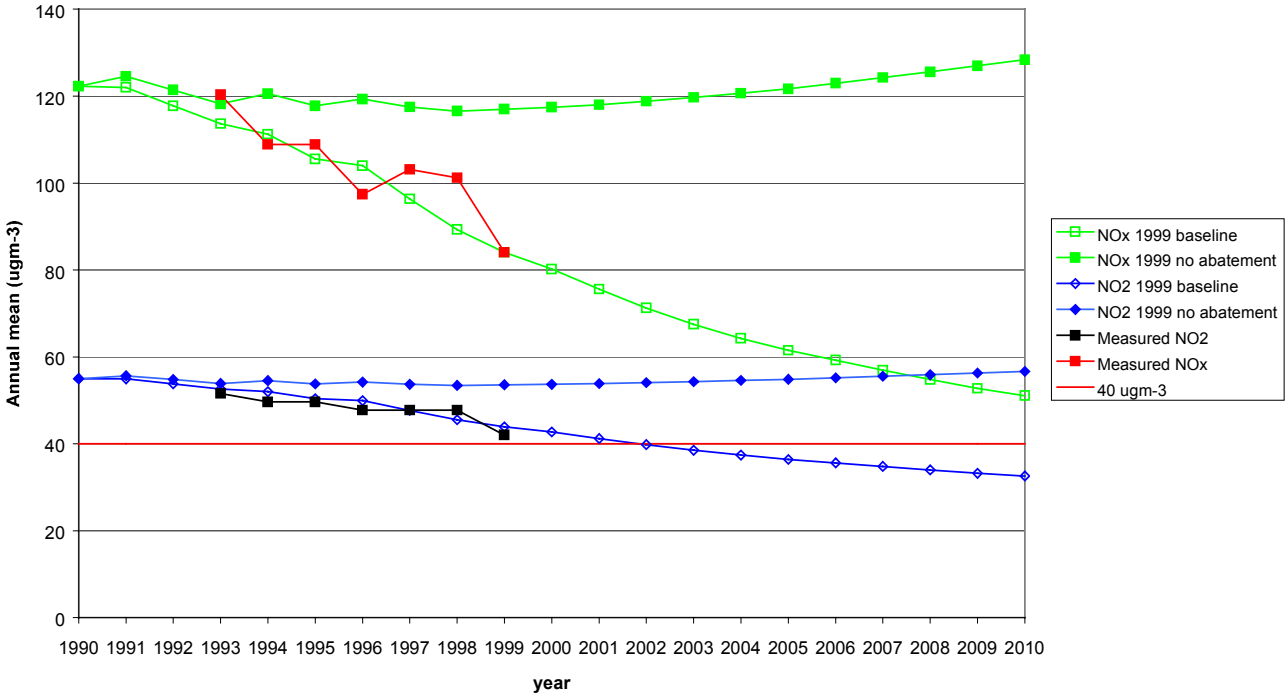


Figure 6 Projected NOx concentrations at Birmingham Centre based on 1999 monitoring data plus baseline and no technology abatement emissions scenarios (µgm^{-3}, as NO_2)

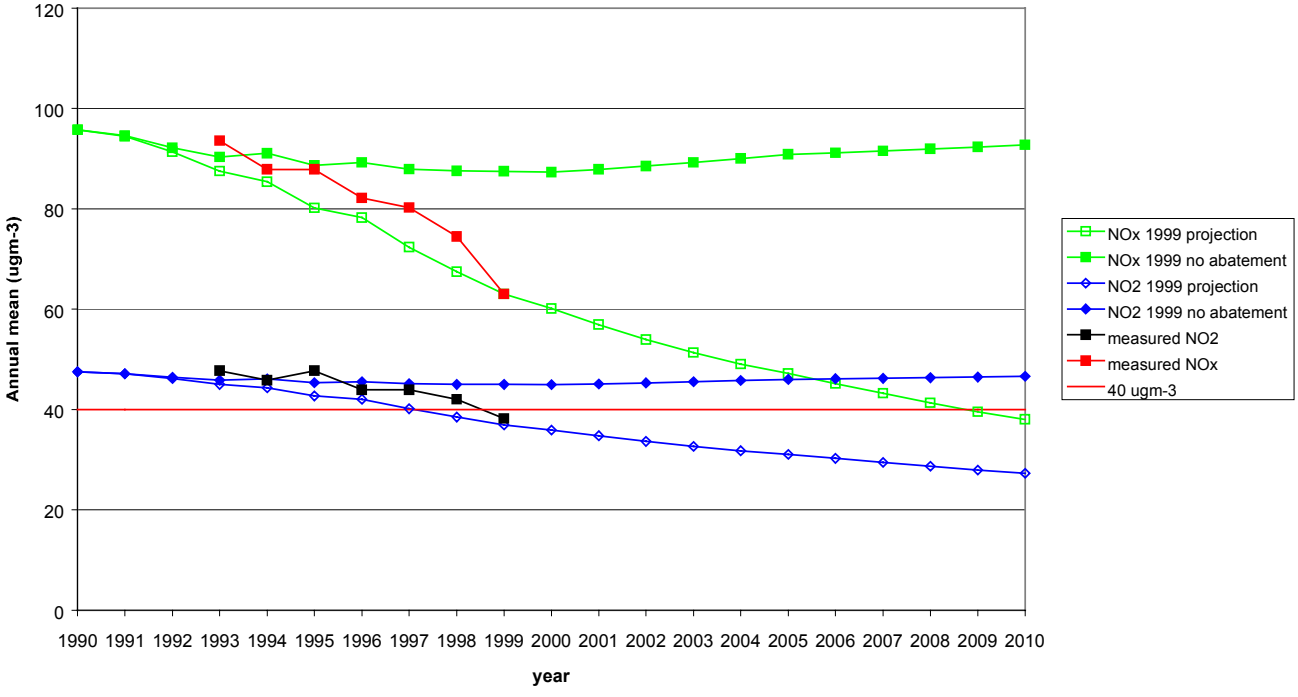


Figure 7 Projected NOx concentrations at Marylebone Road based on 1999 monitoring data plus baseline and no technology abatement emissions scenarios (µgm^{-3}, as NO_2)

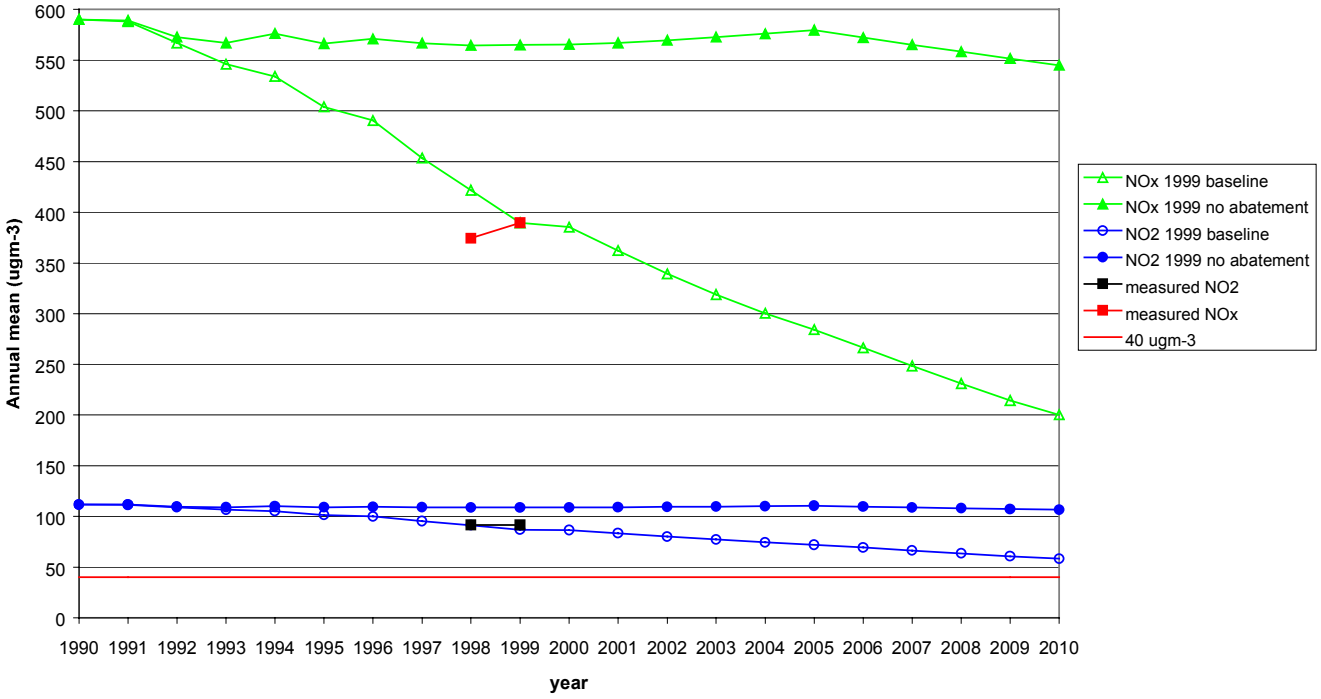
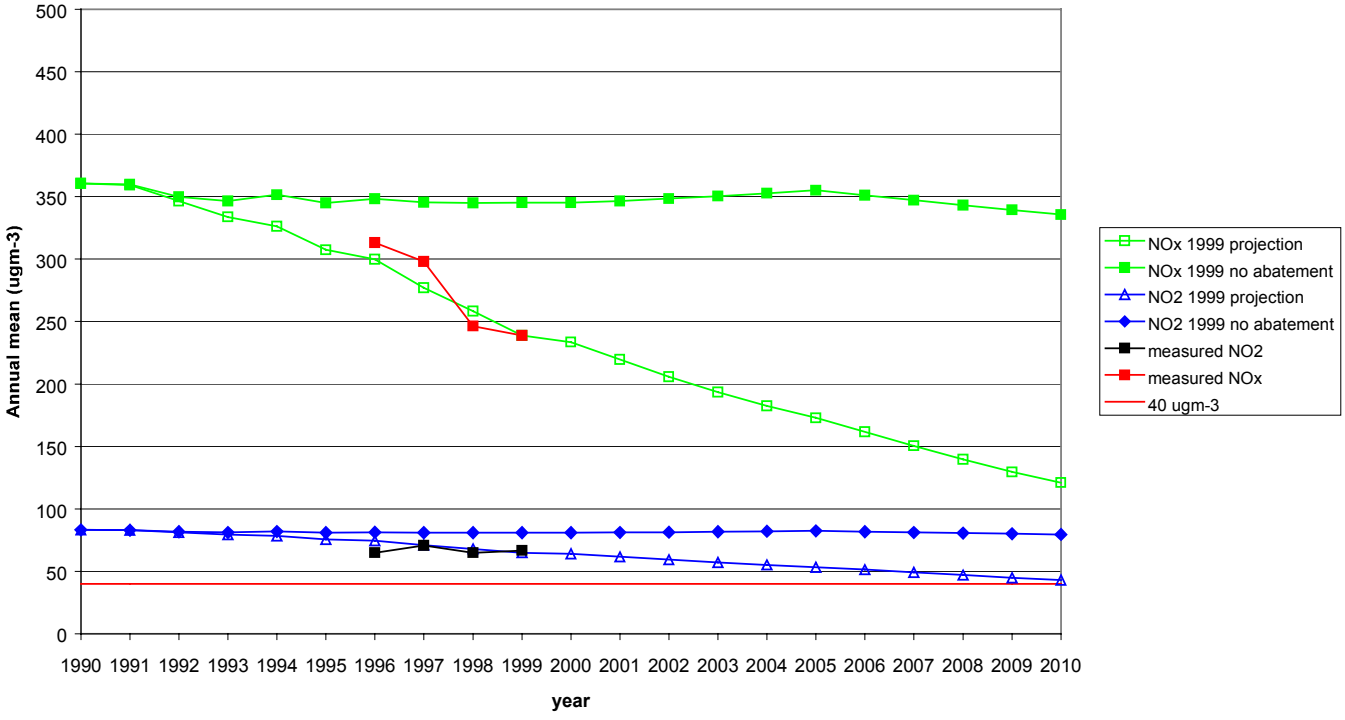


Figure 8 Projected NOx concentrations at Tower Hamlets Roadside based on 1997 and 1999 monitoring data plus baseline and no technology abatement emissions scenarios (µgm^{-3}, as NO_2)



Annual mean NO_2 concentrations for the 1999 base year are listed in Table 6 for the sites for which site-specific projections have been calculated. Measured annual average NO_2 concentrations are listed along with the NO_2 concentrations that have been estimated from the measured NO_x concentrations using the relationships described above. There are some differences between the measured and estimated NO_2 concentrations, particularly at Cromwell Road, but the non-linear empirical models provide a good representation of ambient NO_2 concentrations at the majority of monitoring sites.

Table 6 Measured annual mean NO_2 concentrations 1999 (μgm^{-3})

	Measured NO_2 1999	Projected (baseline) 1999	Projected (no abatement) 1999
London Bloomsbury	66.9	66.1	80.3
Birmingham Centre	38.2	37.0	45.0
Cardiff Centre	32.5	34.2	41.3
Edinburgh Centre	42.0	43.9	53.6
Belfast Centre	35.0	36.2	39.9
Liverpool Centre	42.0	48.0	56.6
Newcastle Centre	31.0	34.8	42.7
Manchester Piccadilly	43.0	44.5	54.6
Bristol Centre	38.2	42.7	52.1
West London	55.4	48.6	58.2
Bridge Place	63.0	55.2	60.0
Manchester Town Hall	42.0	41.5	50.5
Leeds Centre	43.9	45.1	55.4
Hull Centre	38.2	42.3	50.7
Haringey Roadside	47.8	45.1	55.3
Glasgow Roadside	68.8	67.1	85.3
Marylebone Road	91.7	87.1	108.9
Camden Roadside	66.0	59.8	74.7
Sutton Roadside	43.9	42.6	53.1
Bury Roadside	73.0	69.8	89.0
Tower Hamlets Roadside	66.9	64.9	81.0
Cromwell Road	91.7	67.7	84.1

4.1.1 Comparison of measured data with baseline and no-abatement projections

Baseline emissions scenario projections

- Measured annual mean NO_2 concentrations at most background monitoring sites were above or close to 40 μgm^{-3} during 1999.
- Annual mean concentrations at roadside sites were consistently above 40 μgm^{-3}.

No abatement emissions scenario projections

- For the same period, it is estimated that NO_2 concentrations would have been on average 9 μgm^{-3} higher at urban background sites and 10 μgm^{-3} higher at roadside site had vehicle abatement technologies not been introduced.

4.2 BASELINE AND NO ABATEMENT PROJECTIONS FOR 2010

Projected annual mean NO_x and NO_2 concentrations for 2010 (1999 base year) are listed in Table 7 for the baseline scenario for the sites for which site-specific projections have been calculated.

Table 7 Projected annual mean NO_x and NO_2 concentrations 2010 from base year 1999 (μgm^{-3}, as NO_2) for the baseline and no abatement scenario

	Projected NO_x 2010 (baseline scenario)	Projected NO_x 2010 (no abatement scenario)	Projected NO_2 2010 (baseline scenario)	Projected NO_2 2010 (no abatement scenario)
London Bloomsbury	88.8	179.7	49.1	80.4
Birmingham Centre	38.0	92.8	27.3	46.6
Cardiff Centre	33.9	82.4	25.5	43.4
Edinburgh Centre	51.1	128.4	32.6	56.6
Belfast Centre	39.5	76.4	27.9	41.5
Liverpool Centre	64.2	133.7	37.4	58.0
Newcastle Centre	33.2	85.3	25.2	44.3
Manchester Piccadilly	49.7	129.3	32.0	56.9
Bristol Centre	47.6	121.6	31.2	54.8
West London	61.5	136.0	36.4	58.6
Bridge Place	66.2	141.5	40.0	60.1
Manchester Town Hall	45.5	113.5	30.4	52.6
Leeds Centre	50.9	131.6	32.5	57.5
Hull Centre	43.19	116.09	29.47	53.33
Haringey Roadside	71.2	190.4	31.4	56.7
Glasgow Roadside	126.3	400.4	44.3	88.6
Marylebone Road	200.4	545.0	58.5	106.6
Camden Roadside	105.4	295.6	39.8	73.8
Sutton Roadside	59.48	180.16	28.21	54.85
Bury Roadside	122.0	442.5	43.4	94.0
Tower Hamlets Roadside	121.0	335.5	43.2	79.7
Cromwell Road	136.3	357.5	46.4	82.8

4.2.1 Comparison of baseline and no-abatement scenario projections for 2010

Baseline emissions scenario projections

- Of the background monitoring sites analysed using the baseline emissions scenario, only the projections for London Bloomsbury and London Bridge Place show concentrations of NO_2 above 40 μgm^{-3} in 2010.
- Projections for Liverpool Centre are close to 40 μgm^{-3}.
- The projections for the roadside sites at Glasgow, Bury, Tower Hamlets and London Cromwell Road are above 40 μgm^{-3}.
- Projected concentration at Marylebone Road are above 50 μgm^{-3}.
- Projected concentrations of NO_2 in 2010 at Haringey Roadside and Sutton Roadside are well below 40 μgm^{-3}.

No abatement emissions scenario projections

- NO_2 projections for 2010 are estimated to be in excess of 40 μgm^{-3} at all urban background sites.
- Projected concentrations for 2010 at London Bloomsbury are consistently above 80 μgm^{-3}.
- At roadside sites concentrations are consistently greater than 50 μgm^{-3} at all sites.
- NO_2 concentrations at Marylebone Road are projected to be greater than 100 μgm^{-3} by 2010.
- On average, it is estimated that annual mean NO_2 concentrations in 2010 at urban background sites would have been 22 μgm^{-3} higher at urban background sites and 38 μgm^{-3} higher at roadside sites had technological abatement policies not have been introduced.

4.3 INCREMENTAL IMPACT OF POLICY MEASURES

As a case study for NO_x and NO_2, the impact upon urban air quality of successive vehicle technology measures (Euros I to IV) and cleaner fuel technologies (lower sulphur fuels) have been investigated using the site-specific analysis tools. In carrying out this analysis emissions reductions arising from technology measures were successively added into the no abatement scenario to demonstrate the incremental impact of each measure. Figures 9a and 9b present the impact of technology abatement measures upon total UK and Urban UK NO_x emissions from road transport.

Figure 9a Reduction in UK NO_x road transport emissions arising from successive technology abatement measures (kT as NO_2 per year)

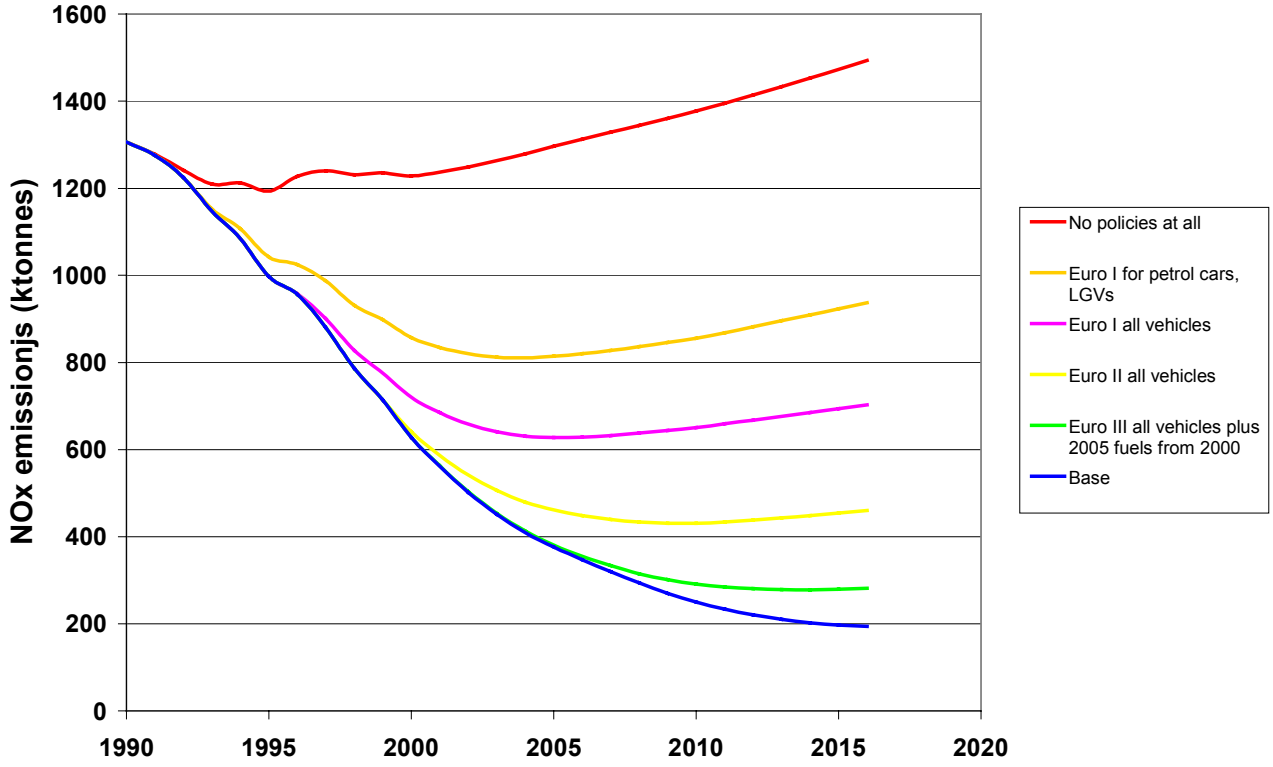


Figure 9b Reduction in UK Urban NO_x road transport emissions arising from successive technology abatement measures (kT as NO_2 per year)

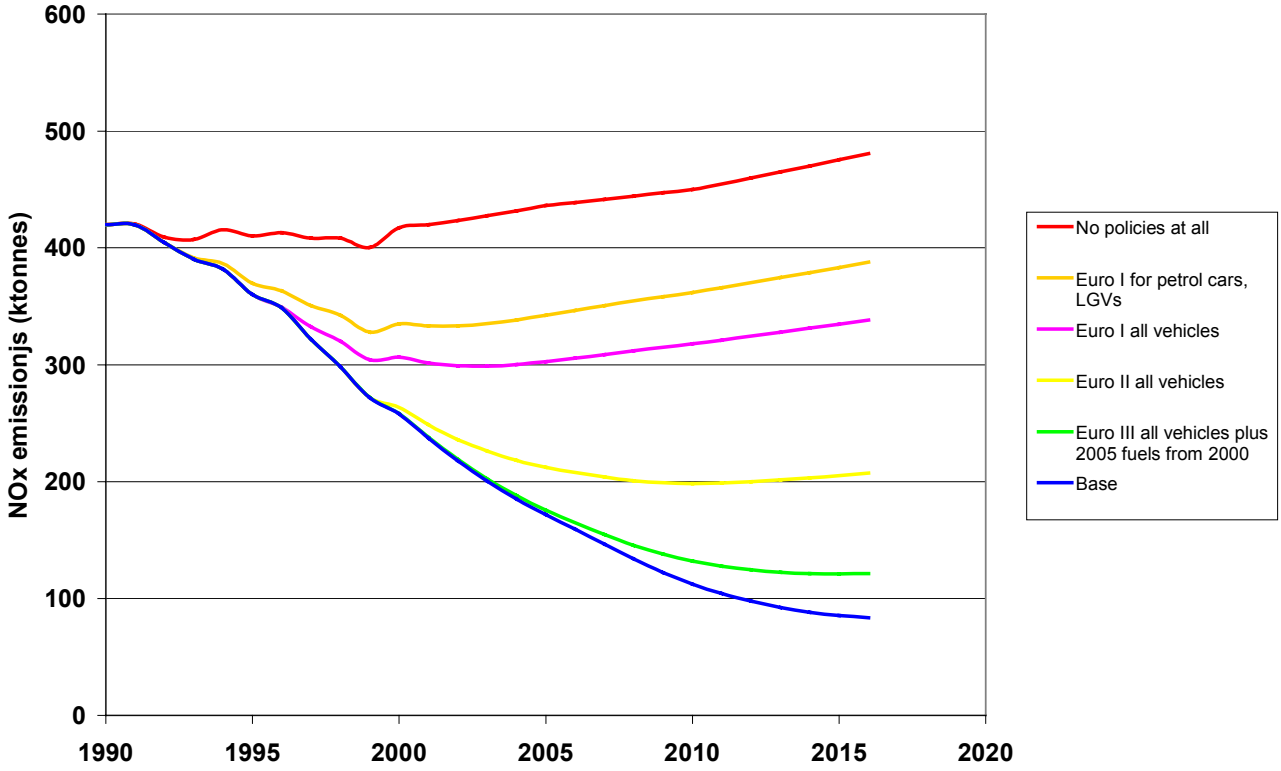


Figure 9a shows that the technology abatement measure accounting for the greatest reduction in total UK road transport NO_x emission was the introduction of the three-way catalyst for petrol vehicles under the Euro I vehicle standard. This technology measure is expected to account for approximately 46% of the total reduction in NO_x emission from road traffic arising from all policies in 2010. Improvements in engine management and fuel injection systems for diesels under the same standard and the introduction of Euro II for all vehicles brought about similar levels of reduction, accounting for 18% and 20% of the total reduction arising from all policies in 2010.

Figure 9b shows that the proportional effect of abatement measures in UK urban areas is different to that for total UK road transport emissions. By 2010, the Euro I standard in urban areas is expected to have only marginally greater impact upon Urban NO_x emissions than the Euro II standard, accounting for 39% of the total reduction in emissions from all policies, compared with the 35% reduction arising from Euro II standard. The increase in contribution to emission reduction from Euro II standard in urban areas may be explained by the cold start emission characteristics of vehicles with 3-way catalysts and the difference in the vehicle fleet composition for the UK and UK Urban areas. Within urban areas the effect of cold start emissions characteristics upon emissions from vehicles with 3-way catalysts is expected to have bigger influence as a result of the greater proportion of short journeys compared with the UK as a whole. In addition, Urban UK vehicle fleets are expected to have a greater proportion of buses than the UK as a whole, emissions from which are more effectively abated by Euro II standard. As a result of both these influences, the effectiveness of the Euro I standard is reduced in urban areas relative to Euro II.

Figures 10 to 13 present examples of site-specific projections of NO_x and NO_2 concentrations, under the baseline, no abatement technology scenarios and a selection of individual technology

abatement measures. The impact of successive technology abatement measures upon NO_x and NO_2 concentrations is clearly demonstrated.

Figures 10 to 13 show the impact of technology measures upon projected ambient air quality at the Manchester Piccadilly and Marylebone Road monitoring locations. Each successive measure results in a further reduction in emissions and therefore, ambient concentrations. In terms of policy measures with the greatest impact, Figure 9a has shown that the introduction of the 3-way catalyst and improved diesel engine injection and management systems under the Euro I standard are expected to have most effect upon total UK emissions of NOx from road transport. This observation is confirmed by the site-specific analyses of technology measures at Manchester Piccadilly presented in Figures 10 and 11. Figures 10 and 11 show that, the combined affect of the 3-way catalyst and improved diesel engine injection and management systems have the greatest impact upon NOx and NO_2 concentrations at this location. By 2010, Euro I measures are expected to account for 54% of the total reduction in annual mean NOx concentration arising from all policy measures and 46% of the total annual mean NO_2 concentration reduction. The next most effective policy measure by this date is expected to be the Euro II standard accounting for 28% of the total reduction NOx and NO_2 at Manchester Piccadilly. A summary table of the proportional affect of policy measures is presented in Table 8.

Figures 12 and 13 show similar analyses for the Marylebone Road monitoring location and present contrasting information. Figures 12 and 13 and analyses at other London background sites not presented here, suggest that in central London the Euro II standard has most effect upon NOx and NO_2 annual mean concentrations. By 2010, the Euro II standard is predicted to accounting for 41% the total reduction in annual mean concentrations arising from all measures for both pollutants. The Euro I standard for the same period accounted for a 35% and 32% reduction in NOx and NO_2 concentrations respectively. Table 8 presents a summary of the proportional affect of policy measures identified by the site-specific analyses at Marylebone Road.

The contrast in effectiveness of Euros I and II at these two sites illustrates the differences in behaviour of the UK total and UK urban emissions illustrated earlier. NO_x emissions influencing ambient concentrations at the Marylebone Road roadside site will be dominated by those from the road itself, with an additional contribution from traffic emissions from the rest of London. NO_x concentrations at the Manchester Piccadilly urban centre monitoring site will include a larger component from traffic emissions from outside the Manchester, from areas exhibiting a greater effectiveness of Euro I.

Figure 10 Predicted impact of successive technology abatement measures upon NOx concentrations at Manchester Piccadilly, using the 1999 base year (μgm^{-3}, as NO_2)

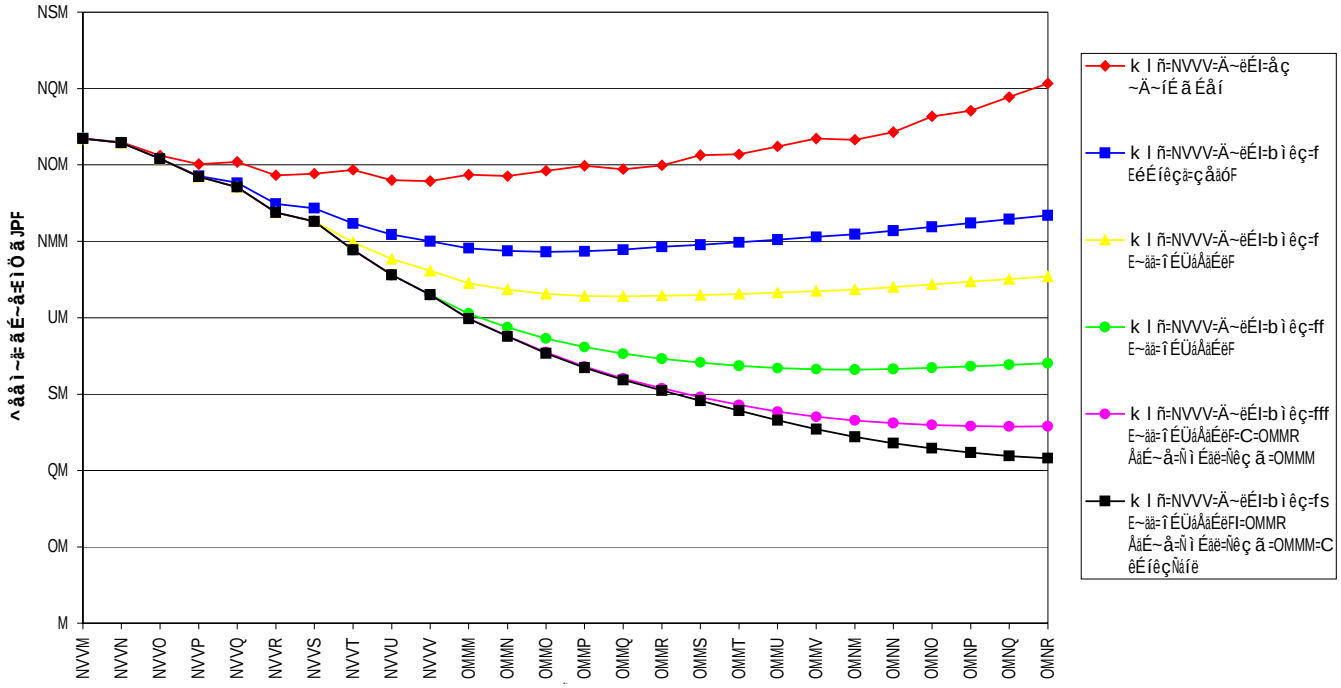


Figure 11 Predicted impact of successive technology abatement measures upon NO_2 concentrations at Manchester Piccadilly, using the 1999 base year

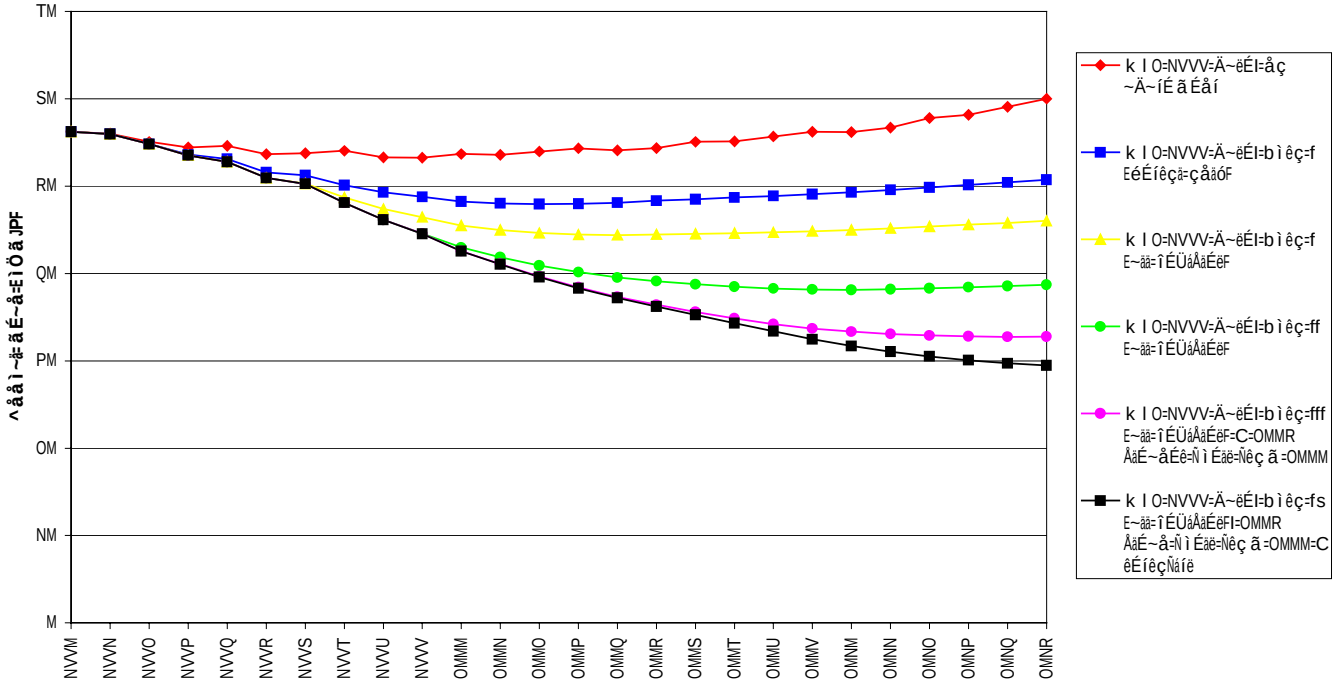


Figure 12 Predicted impact of successive technology abatement measures upon NOx concentrations at Marylebone Road, using the 1999 base year (μgm^{-3}, as NO_2)

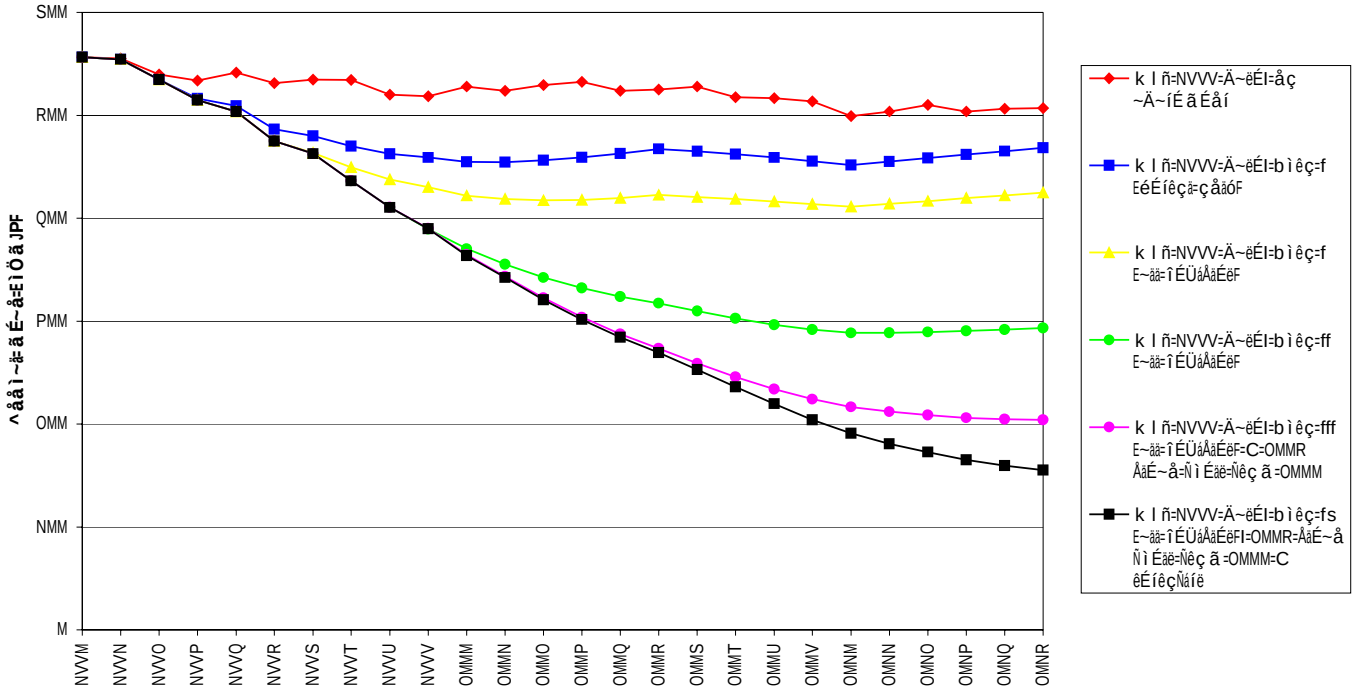


Figure 13 Predicted impact of successive technology abatement measures upon NO_2 concentrations at Marylebone Road, using the 1999 base year

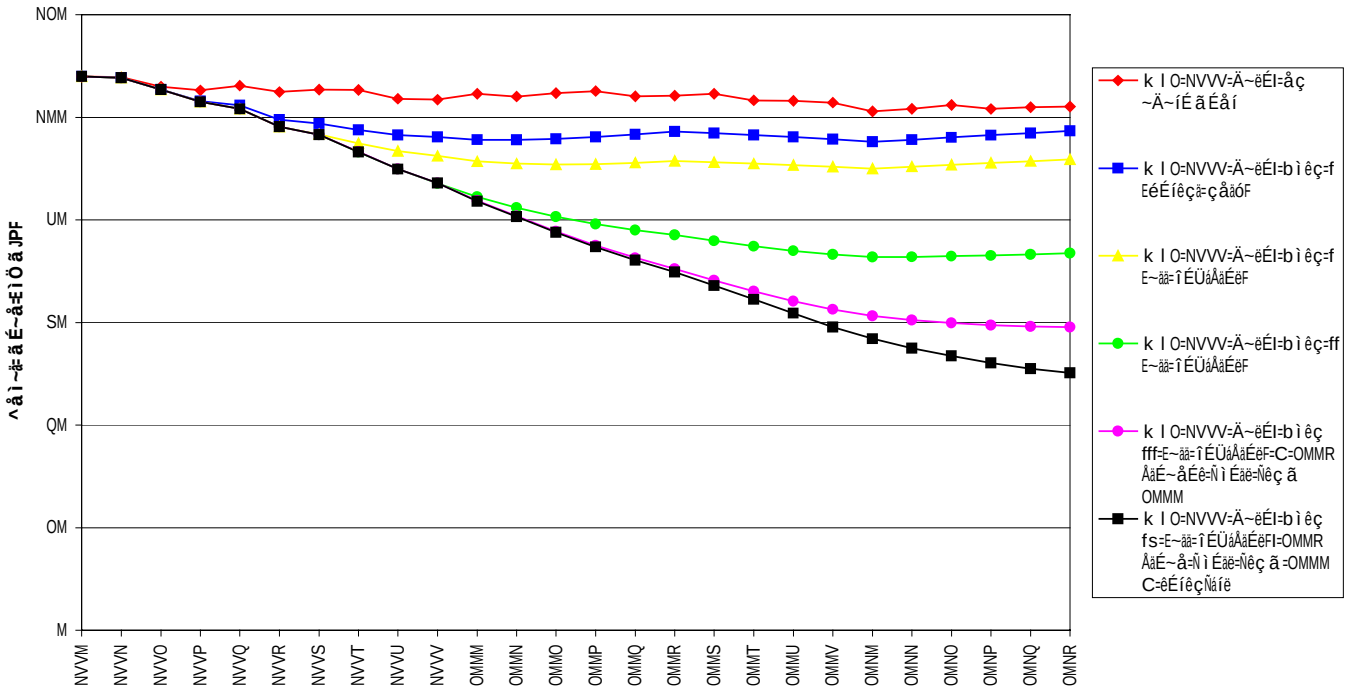


Table 8 Proportional effect of technology abatement measures upon annual mean NOx and NO_2 concentrations at Manchester Piccadilly and Marylebone Road monitoring sites in 2010 as identified by site-specific analyses

	Proportional effect of abatement measure in 2010 relative to baseline (%)			
	Manchester Piccadilly		Marylebone Road	
Abatement measure	NO_x	NO_2	NO_x	NO_2
Euro I	50%	46%	29%	25%
Euro II	27%	28%	40%	39%
Euro III	17%	20%	23%	26%
Euro IV	5%	7%	8%	10%
All policies (Baseline)	100%	100%	100%	100%

5 Site specific projections of PM_{10} concentrations

5.1 INTRODUCTION

The Air Quality Strategy for England, Wales, Scotland and Northern Ireland currently sets the following objectives for PM_{10} particles, to be achieved by 31 December 2004:

- 50 μgm^{-3} as a 24-hour mean, not to be exceeded more than 35 times a year
- 40 μgm^{-3} as an annual mean, not to be exceeded.

These objectives are consistent with the Stage 1 limit values for PM_{10} included in the first EU Daughter Directive (AQDD1), which are to be achieved by 1 January 2005. Indicative Stage 2 limit values for PM_{10} are also included in the first AQDD at 20 μgm^{-3} as an annual mean and 50 μgm^{-3} as a 24-hour mean, not to be exceeded more than 7 times a year, to be achieved by 1 January 2010.

5.2 TEOM AND GRAVIMETRIC MEASUREMENTS

The reference method for the AQDD1 limit values and AQS objectives for PM_{10} is the use of a gravimetric instrument. The analyses presented here are based on TEOM (Tapered Element Oscillating Microbalance) instruments, which are currently widely used with in the UK national monitoring networks. We have applied a scaling factor of 1.3 to all data before comparing with the limit value, as suggested by APEG (1999). All PM_{10} concentration data reported within this study are given in units of μgm^{-3}, gravimetric, meaning that TEOM data has been scaled to give a representation of concentrations as measured by a gravimetric, or equivalent instrument.

5.3 THE APEG RECEPTOR MODEL

The site-specific projections presented here were based on the receptor modelling methods that we developed within the framework of the APEG (APEG, 1999, Stedman et al, 1998b). A regression analysis has been carried out to divide measured daily average PM_{10} concentrations (as measured by TEOM or equivalent monitor) into three components:

- primary combustion PM_{10} (from co-located NO_x measurements)
- secondary PM_{10} (from rural sulphate measurements)
- 'other' PM_{10} (the residual)

The regression analysis was carried out for a calendar year of monitoring data for each site to determine the coefficients A and B:

$$[\text{measured } PM_{10} (\mu g\ m^{-3})] = A.[\text{measured } NO_x\ (\mu g\ m^{-3})] + B.[\text{measured sulphate } (\mu g\ m^{-3})] + \text{other } (\mu g\ m^{-3})$$

These coefficients can then be used to divide the measured concentration into the three components and the contributions from each component to the annual mean concentration can be calculated. This analysis has been completed for the base year1999 at a range of UK national network monitoring sites. Two key outputs from the model are an UK average concentration of 'other' particles and the coefficient, B, relating measured sulphate concentrations to secondary PM_{10} concentrations. Values of this coefficient are listed in Table 9 for the base years studied.

Table 9 Empirically derived factors relating measured sulphate to secondary PM_{10} concentrations

Year	Scaling factor
1999	2.91

5.4 PROJECTING CONCENTRATIONS

Each component of the annual mean PM_{10} concentration was projected from the measurements in 1999 to provide estimates of concentrations in 2010.

Maps of primary PM_{10} emissions for 1998 from the NAEI (Goodwin et al, 2000) were used to determine the sectors contributing to local primary combustion of PM_{10} at each monitoring site location. Local sources were summed within a 35 km x 35 km area centred on the monitoring site location. An ADMS based dispersion matrix was applied to weight emissions from individual grid cells according to distance and direction from the site location. This dispersion matrix approach was also used to calculate the maps and is described in section 6 on the mapping NO_x and NO_2.

Secondary particle concentrations in 1999 were derived from maps of rural measurements of sulphate (at 8 sites) using the factor listed in Table 9. Concentrations of sulphate and nitrate in future years were derived as described in section 2.3. Secondary nitrate concentrations were increased for the no abatement scenario to take account of the increase in UK NO_x emissions for this scenario relative to the baseline. Secondary nitrate from non-UK sources was maintained at baseline levels. The no abatement scenario therefore represents the absence of technical measures in the UK with emissions in European countries following the UK baseline.

We assumed that there will be no change in coarse ('other') particle concentrations.

Estimates of concentration were calculated using both the current baseline and the no abatement technology emissions scenarios.

Figures 14 to 17 show examples of site-specific projections of annual mean PM_{10} concentrations. It is clear that there is good agreement between the projections for the years 1993 to 1999 and the measured values for these years. The projections closely track changes in concentrations due to variations in emissions.

Figure 14 Projected PM10 concentrations at Bloomsbury based on 1999 monitoring data plus baseline and no technology abatement emissions scenarios

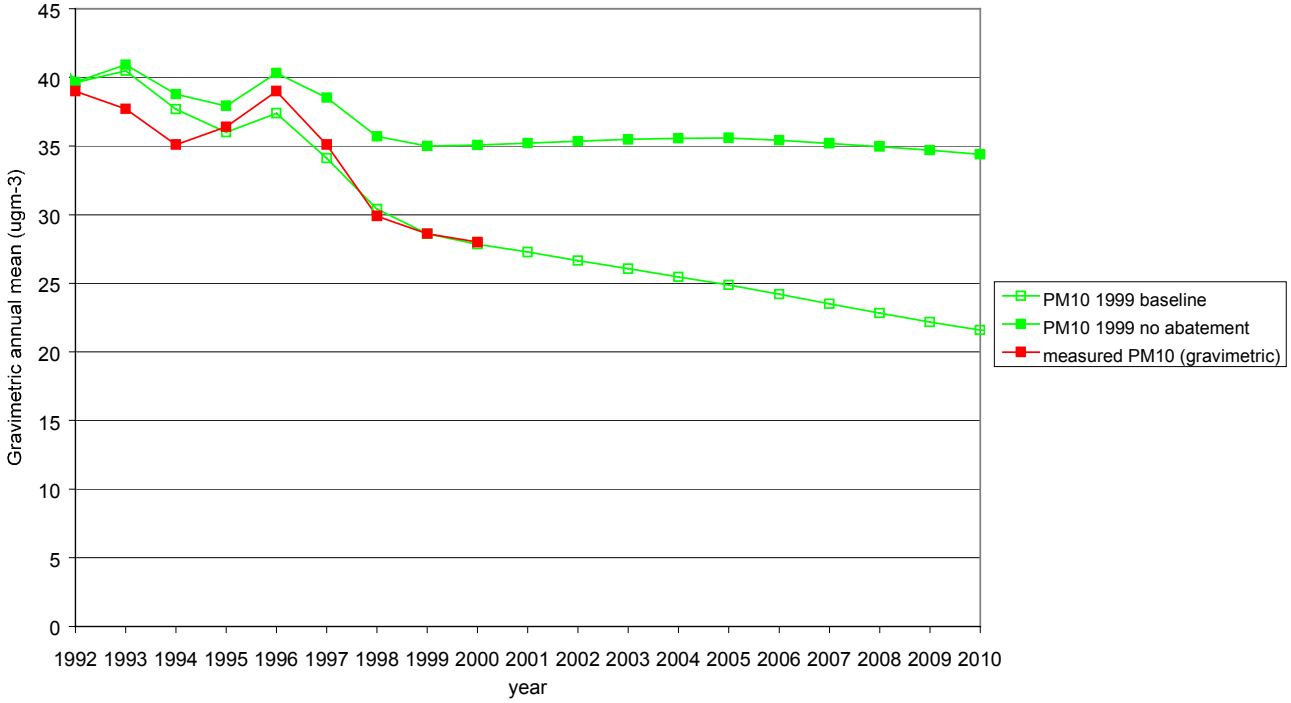


Figure 15 Projected PM10 concentrations at Belfast Centre based on 1999 monitoring data plus baseline and no technology abatement emissions scenarios

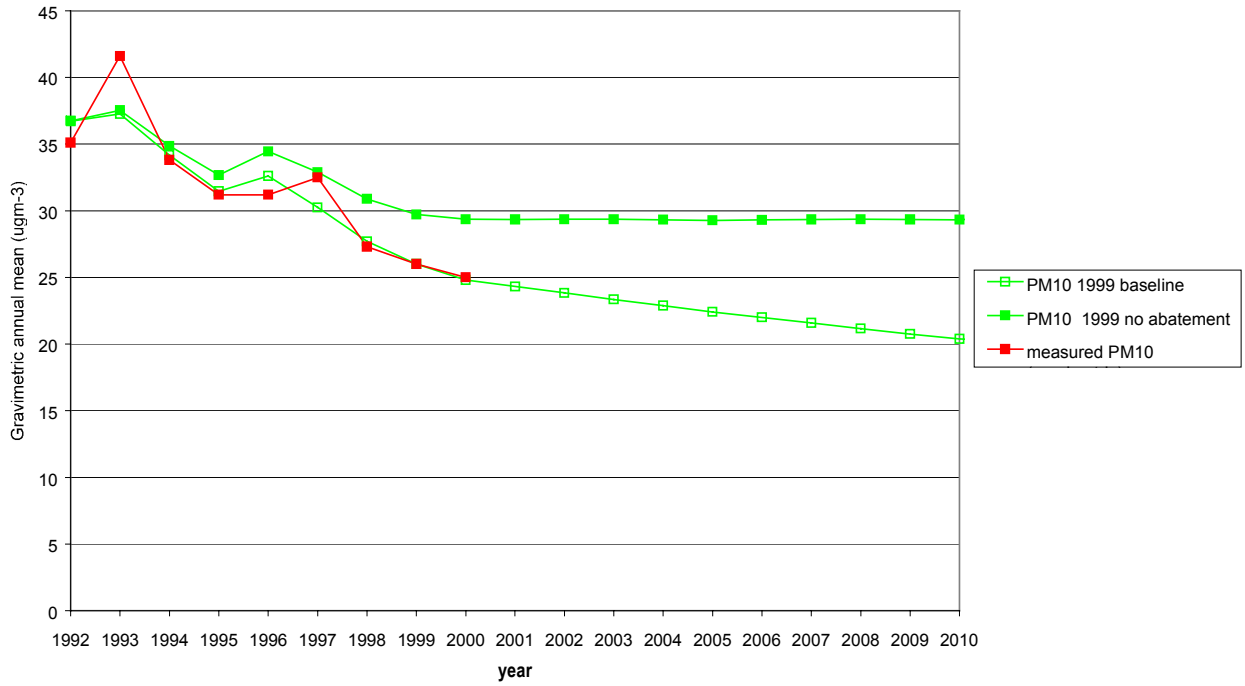


Figure 16 Projected PM10 concentrations at Sutton Roadside based on 1999 monitoring data plus baseline and no technology abatement emissions scenarios

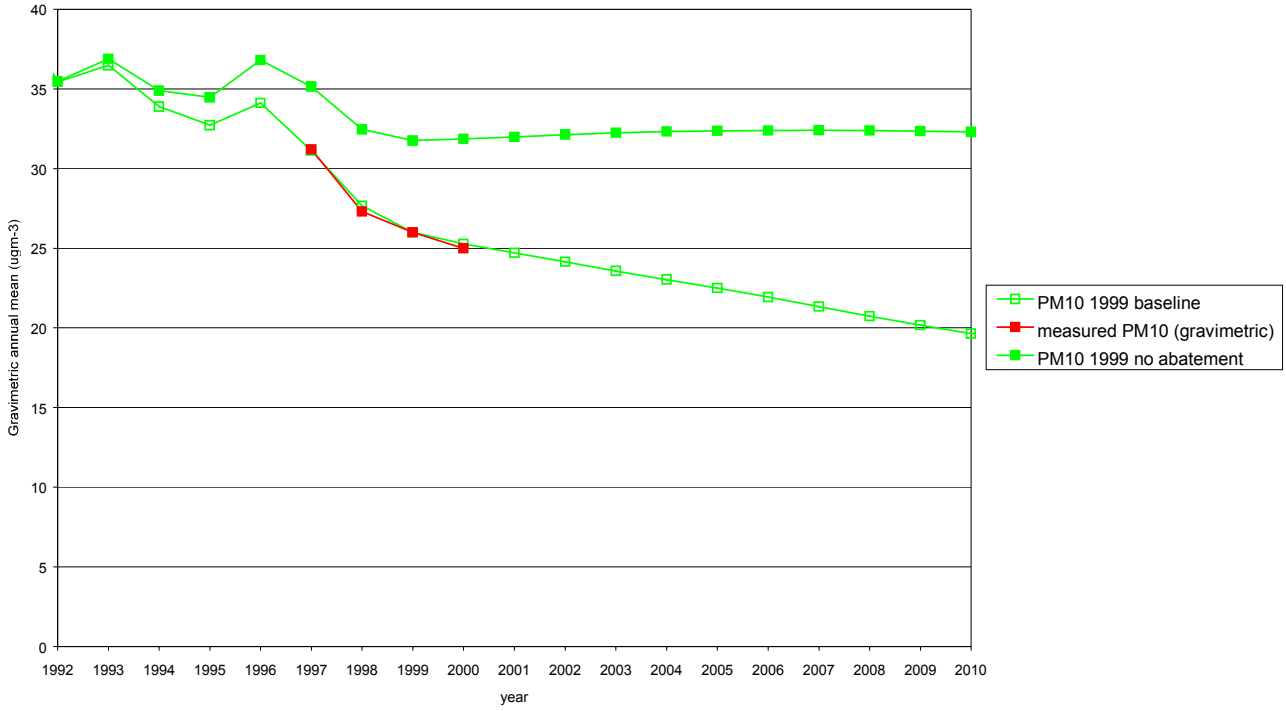
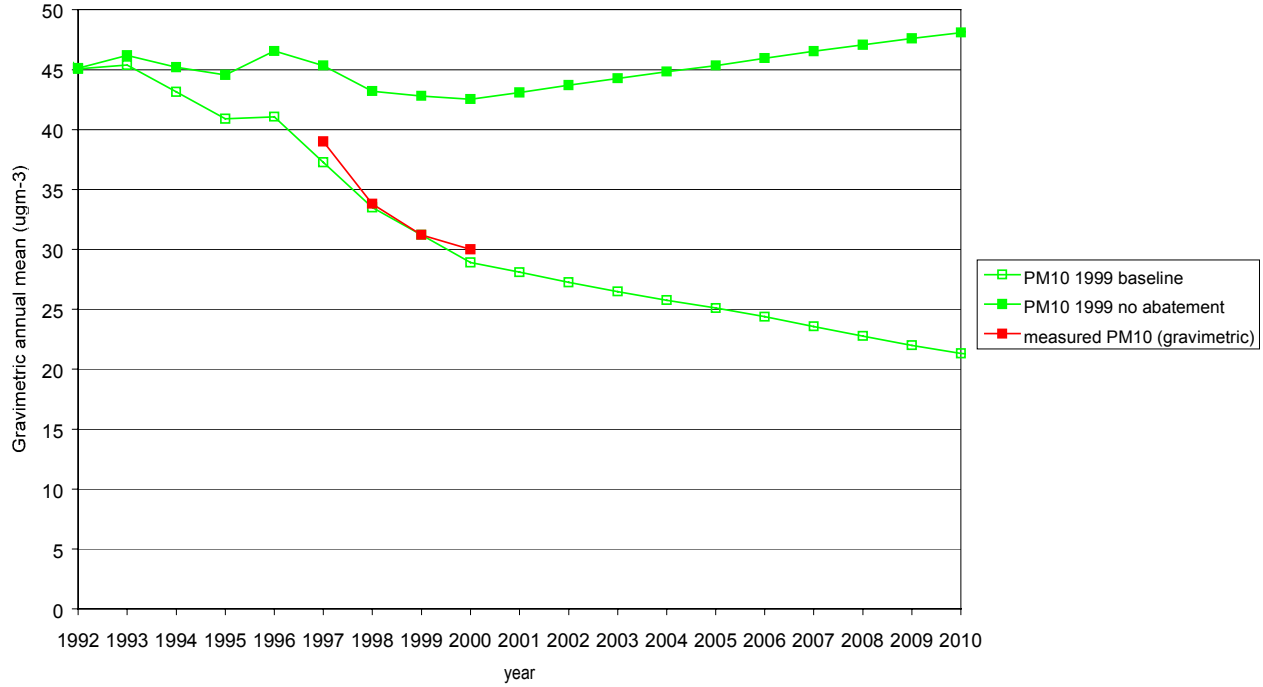


Figure 17 Projected PM10 concentrations at Bury Roadside based on 1999 monitoring data plus baseline and no technology abatement emissions scenarios



5.5 PROJECTIONS FOR ROADSIDE MONITORING SITES

Site-specific projections for roadside monitoring sites have also been calculated. Daily averages of measured PM_{10} at a nearby background monitoring site have been subtracted from the

concentrations measured at roadside monitoring sites in order to determine the roadside increment of daily PM_{10}. The annual mean of the roadside increment was then calculated from these daily values. It is not possible to determine the split of the roadside increment between traffic exhaust emissions and re-suspended dusts from current network measurements. Analyses of PM_{10} and $PM_{2.5}$ monitoring data presented in the APEG report (APEG 1999) suggested that re-suspended component could be 50% of the total. It is likely that this is an overestimate because exhaust emission may include some particles of diameter greater than 2.5 μm. We have assumed that re-suspended dust does not contribute to the roadside increment of PM_{10} concentrations in our projections

Projections for the industrially influenced sites at Port Talbot and Redcar have also been calculated. The industrial component of ambient annual mean PM_{10} at these sites was derived using the method described by Stedman et al (1998b). The industrial contribution was estimated on a daily basis as the residual remaining after the primary combustion (derived from co-located NO_x measurements, the secondary (derived from sulphate) and 'other' (calculated using the APEG receptor model at a nearby background site) components had been subtracted from the measured daily mean concentrations.

5.6 ANNUAL MEAN CONCENTRATIONS AND THE NUMBER OF DAYS WITH CONCENTRATIONS ABOVE 50 μgm^{-3}

Projections of annual mean PM_{10} concentrations have been calculated rather than projections of the number of days with concentrations greater than or equal to 50 μgm^{-3}. This is because an analysis of current monitoring data indicates that the EU AQDD Stage 2 annual mean limit value for 2010 of 20 μgm^{-3} is likely to be more stringent than the 24-hour limit value of 50 μgm^{-3}, not to be exceeded more than 7 times a year. The approximate annual mean equivalents of different numbers of days above 50 μgm^{-3} are listed in Table 10 along with the equivalent annual mean concentrations for raw TEOM measurement data. There is also a considerable computational advantage in restricting the projections to an analysis of annual means.

Table 10 The relationship between annual mean and number of days per year with concentrations greater than or equal to 50 μgm^{-3}, gravimetric

Annual mean equivalent μgm^{-3}, gravimetric	Annual mean equivalent μgm^{-3}, TEOM	Number of days with concentration greater than 50μgm^{-3}, gravimetric
31.6	24.3	35
28.0	21.5	23
25.0	19.2	14
23.0	17.7	9
⋆20.0	15.4	3

⋆ EU AQDD indicative stage 2 annual mean limit value for PM_{10}

5.7 MEASURED CONCENTRATIONS 1999

Measured annual mean PM_{10} concentrations for 1999 are listed in Table 11 for the sites for which site-specific projections have been calculated. Site specific projections using the no abatement emissions scenario are also presented. Projections for these years for the baseline

scenario are not shown, since these are constrained to be identical to the measured values. Data from TEOM instruments has been multiplied by a factor of 1.3, as discussed above.

Table 11 Measured annual mean PM_{10} concentrations 1999 (μgm^{-3}, gravimetric)

	Measured PM10 1999	Projected PM10 (no abatement scenario) 1999
London Bloomsbury	28.6	35.0
Birmingham Centre	23.4	27.6
Cardiff Centre	27.3	33.0
Edinburgh Centre	19.5	22.0
Belfast Centre	26.0	29.7
Liverpool Centre	26.0	31.2
Newcastle Centre	20.8	24.0
Bristol Centre	26.0	31.7
Rochester	20.8	22.1
Manchester Piccadilly	26.0	32.2
Haringey Roadside	28.6	36.5
Glasgow Roadside	27.3	39.4
Marylebone Road	45.5	68.2
Camden Roadside	33.8	45.8
Sutton Roadside	26.0	31.8
Bury Roadside	31.2	42.8
Port Talbot	33.8	37.5
Redcar	24.7	26.3

5.7.1 Comparison of measured data with baseline and no-abatement projections

Baseline emissions scenario projections

- Measured annual mean concentrations at all sites except Marylebone Road were below the AQS objective for 2004 (40 μgm^{-3}).
- Measured annual mean concentrations at Marylebone Road, Camden Roadside and Port Talbot were greater than the annual mean equivalent (31.6 μgm^{-3}) for the daily PM10 objective for 2004.
- No urban background monitoring sites exceeded the annual mean equivalent for the daily PM10 objective for 2004.

No abatement emissions scenario projections

- On average annual mean concentrations are predicted to have been 4 μgm^{-3} (gravimetric) higher at urban background sites and 12 μgm^{-3} higher at roadside sites had abatement technologies had not been introduced.
- Concentrations would have been at risk of exceeding the daily PM10 objective at 11 out of 18 sites in 1999 had policy measures not been introduced.

5.8 BASELINE AND NO ABATEMENT PROJECTIONS FOR 2010

Projected annual mean PM_{10} concentrations for 2010 (1999 base year) are listed in Table 12 for the baseline scenario for the sites for which site-specific projections have been calculated.

Table 12 Projected annual mean PM_{10} concentrations 2010 from base year 1999 (μgm^{-3}, gravimetric) for the baseline and no abatement technology scenarios

	Projected PM10 2010 (baseline scenario)	Projected PM10 2010 (no abatement scenario)
London Bloomsbury	21.6	34.4
Birmingham Centre	18.5	27.8
Cardiff Centre	21.4	34.2
Edinburgh Centre	16.1	22.0
Belfast Centre	20.4	29.3
Liverpool Centre	20.5	31.9
Newcastle Centre	16.8	23.9
Bristol Centre	20.3	32.9
Rochester	17.2	20.0
Manchester Piccadilly	19.7	33.6
Haringey Roadside	20.9	38.3
Glasgow Roadside	18.6	45.1
Marylebone Road	27.7	70.8
Camden Roadside	23.3	47.1
Sutton Roadside	19.6	32.3
Bury Roadside	21.3	48.1
Port Talbot	29.2	37.7
Redcar	21.6	25.1

5.8.1 Comparison of baseline and no-abatement scenario projections for 2010

- 20 μgm^{-3} (Stage 2 indicative AQDD1 Limit Value) is likely to be widely exceeded using both the baseline or no abatement emission scenarios.
- On average, it is estimated that concentrations at urban background sites will have been 10μgm^{-3} higher at urban background sites and 25 μgm^{-3} higher at roadside sites should technological abatement policy not have been introduced.

6 Site specific projection of CO concentrations

6.1 METHOD

The Air Quality Strategy for England, Wales, Scotland and Northern Ireland (DETR et al 2000) currently sets a specific objective for carbon monoxide to be achieved by 2003:

- 11.6 mgm^{-3} (10 ppm), measured as a running 8-hour mean

The recently adopted second European Daughter Directive on air quality, European Directive 2000/69/EC relating to limit values for benzene and carbon monoxide (AQDD2) prescribes the following limit value for carbon monoxide to be achieved by 2005:

- 10 mgm^{-3} (8.6 ppm), measured as a maximum 8-hour mean

Site-specific projections of future annual mean and 8-hour running mean CO concentrations were calculated in a similar fashion to NO_x and PM10, by factoring measurement data according to the projected changes in emissions for future years (Stedman and Linehan, 1999). At roadside locations, annual mean CO was estimated by projection of both the urban background and roadside increment components. The 8-hour mean projections at these locations contained contributions from the projected road traffic component only.

Figures 18 to 21 present examples of site-specific projections of CO concentrations for years between 1990 and 2010. Projected concentrations have been calculated from measured concentrations in 1999 using both the baseline and no abatement technology scenarios. The effect of the introduction of vehicle abatement technology measures throughout the 1990s is clearly shown in projected concentrations of CO. The initial decline in no abatement concentrations in the early 1990s reflects the penetration of cleaner vehicle technology into the UK car fleet after their introduction in the late 1980s.

Figure 18 Projected annual mean CO concentrations at Bridge Place based on 1999 monitoring data plus baseline and no technology abatement emissions scenarios

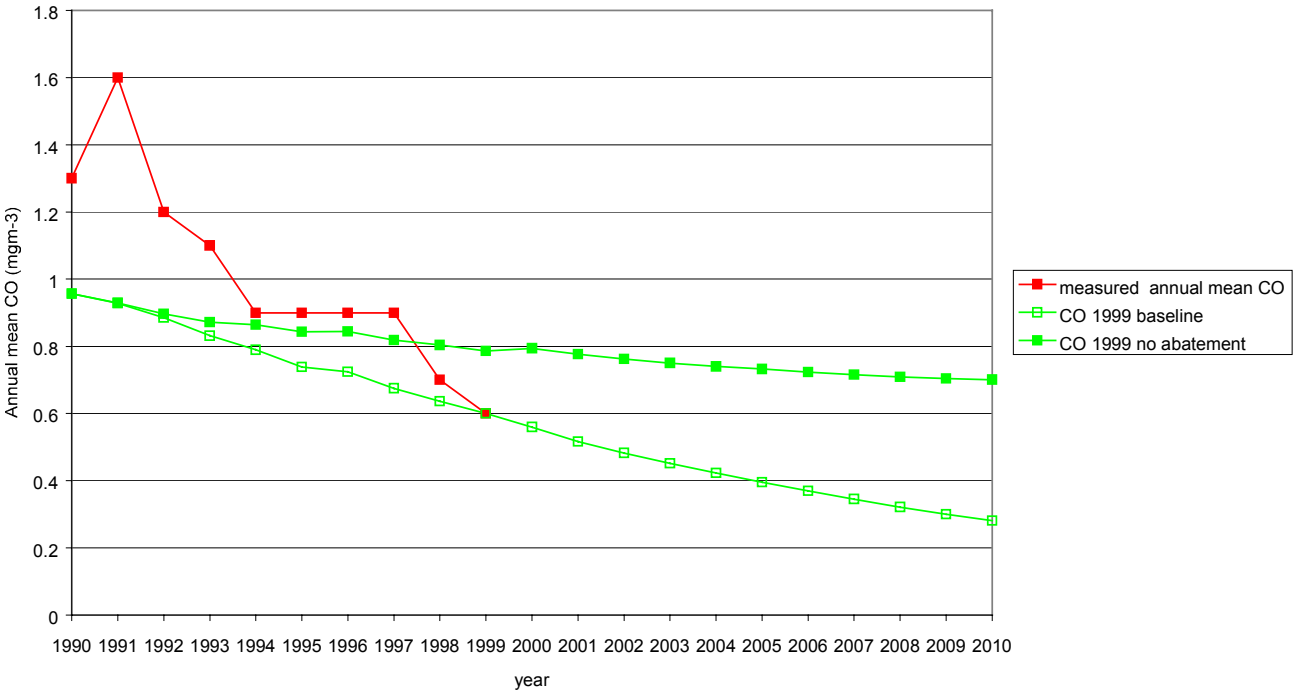


Figure 19 Projected maximum 8-hour mean CO concentrations at Bridge Place based on 1999 monitoring data plus baseline and no technology abatement emissions scenarios

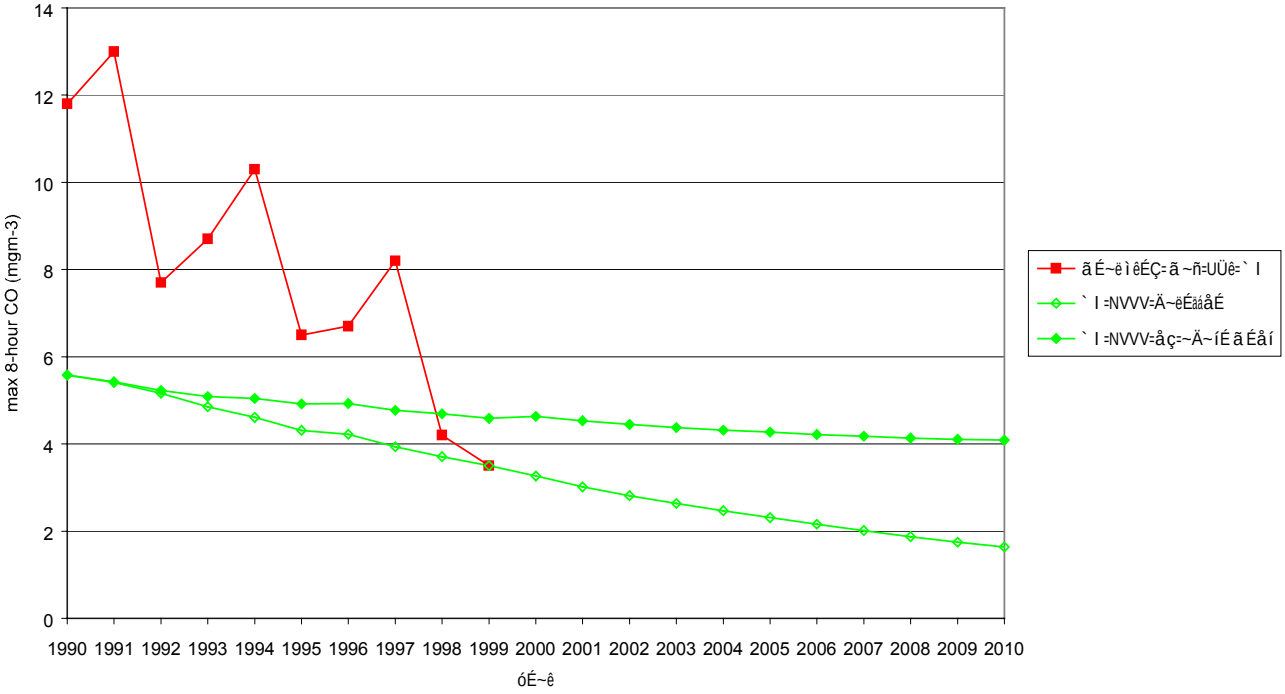


Figure 20 Projected maximum annual mean CO concentrations at Marylebone Road based on 1999 monitoring data plus baseline and no technology abatement emissions scenarios

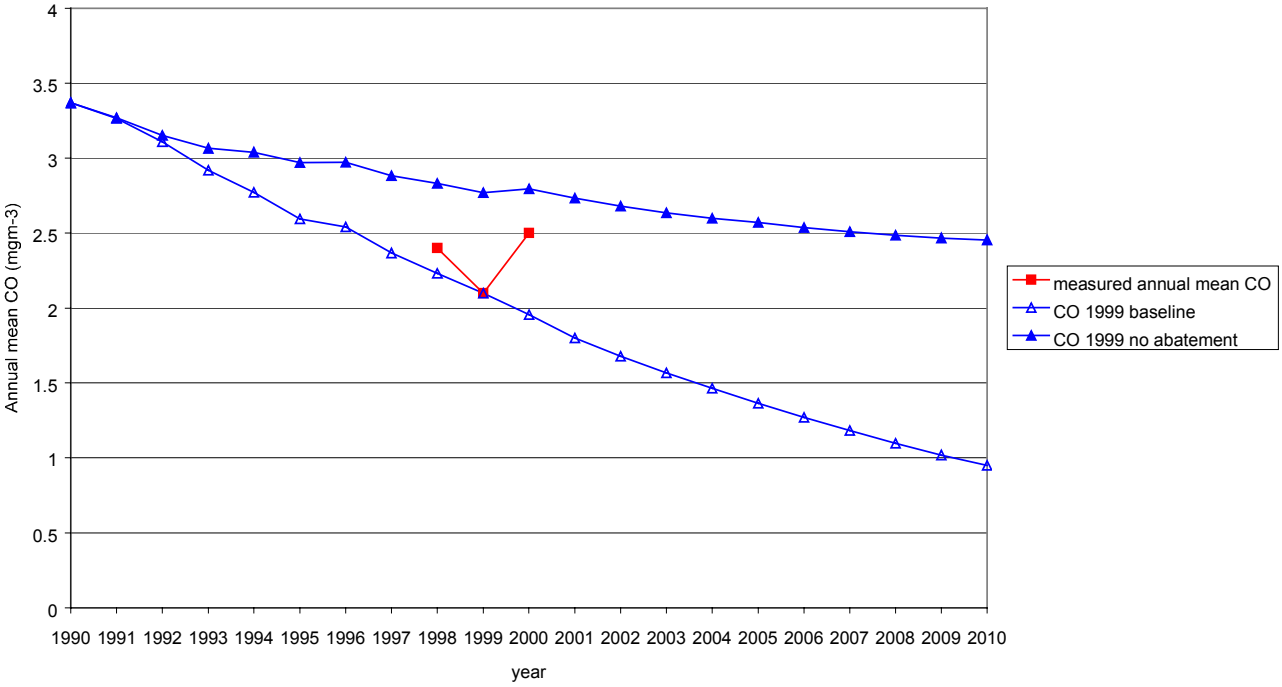
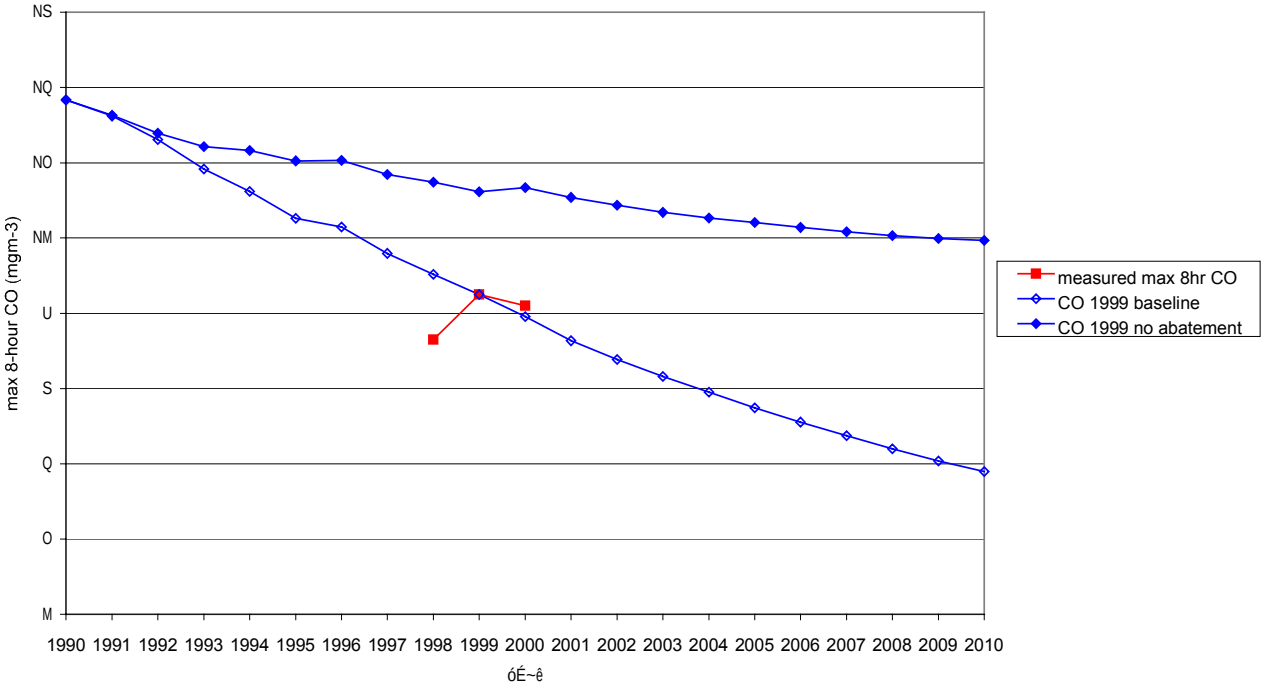


Figure 21 Projected maximum 8-hour mean CO concentrations at Marylebone Road based on 1999 monitoring data plus baseline and no technology abatement emissions scenarios



6.2 MEASURED CONCENTRATIONS 1999

Measured annual mean and 8-hour mean CO concentrations for the 1999 base year are listed in Table 13 for the sites for which site-specific projections have been calculated. Estimated CO concentrations for the no abatement scenario are also listed.

Table 13 Measured annual mean and 8-hour mean concentrations 1999 (mgm^{-3})

	Measured annual mean CO	Projected annual mean CO (no abatement scenario)
Bridge Place	0.6	0.8
Cardiff Centre	0.5	0.7
Edinburgh Centre	0.5	0.7
Glasgow City Chambers	0.7	1.0
West London	0.4	0.5
Cromwell Road	1.5	2.1
Exeter Roadside	1.2	1.6
Glasgow Roadside	0.8	1.1
Marylebone Road	2.1	2.8
Sutton Roadside	0.9	1.2
Tower Hamlets Roadside	1.2	1.6
	Measured maximum 8-hour mean CO	Projected maximum 8-hour mean CO (no abatement)
Bridge Place	3.5	4.6
Cardiff Centre	2.7	3.5
Edinburgh Centre	1.7	2.2
Glasgow City Chambers	4.2	5.5
West London	4.3	5.6
Cromwell Road	5.1	7.2
Exeter Roadside	6.0	8.4
Glasgow Roadside	4.4	6.2
Marylebone Road	8.5	11.2
Sutton Roadside	4.3	5.7
Tower Hamlets Roadside	6.5	8.6

6.2.1 Comparison of measured data with baseline and no-abatement scenario projections

Baseline emissions scenario projections

- Measured maximum 8-hour mean CO concentrations at all background monitoring sites were below the AQS maximum 8-hour mean objective for 2003 (11.6 mgm^{-3}).
- No exceedences of the AQS maximum 8-hour mean objective for 2003 were measured in 1999.
- The proposed AQDD2 sets a provisional maximum 8-hour mean objective of 10 mgm^{-3} to be achieved by 2005.Table 12 shows that no measured exceedences are identified for 1999.

No abatement emissions scenario projections

- For 1999 we have estimated that maximum 8-hour mean CO concentrations would have been on average 1.0mgm^{-3} higher at urban background sites and 2.1 mgm^{-3} higher at roadside site had vehicle abatement technologies not been introduced.
- No exceedences of the AQS objective are predicted.
- Exceedences of the proposed AQDD2 objective for 2005 are estimated at Marylebone Road

6.3 BASELINE AND NO ABATEMENT PROJECTIONS FOR 2010

Projected CO concentrations for 2010 (1999 base year) are listed in Table 14 for the baseline and no abatement technology scenarios.

Table 14 Projected maximum 8-hour mean CO concentrations 2010 from the 1999 base year for the baseline and no abatement technology scenarios (mgm^{-3})

	Projected max 8-hour mean CO 2010 (baseline scenario)	Projected max 8-hour mean CO 2010 (no abatement scenario)
Bridge Place	1.6	4.1
Cardiff Centre	1.3	3.1
Edinburgh Centre	0.8	2.0
Glasgow City Chambers	2.0	4.9
West London	2.0	5.0
Cromwell Road	2.3	6.3
Exeter Roadside	2.7	7.4
Glasgow Roadside	2.0	5.5
Marylebone Road	3.8	9.9
Sutton Roadside	1.9	5.0
Tower Hamlets Roadside	2.9	7.6

6.3.1 Comparison of baseline and no-abatement scenario projections for 2010

Baseline emissions scenario projections

- Maximum 8-hour mean CO concentrations are well below the AQS objective (for 2003) and the proposed AQDD2 Limit Value (for 2005) by 2010.

No abatement emissions scenario projections

- Had vehicle abatement technologies not been introduced however, concentrations by 2010 are predicted to have been on average 2.3 mgm^{-3} higher at urban background locations and 4.6 mgm^{-3} at roadside sites.
- No exceedences of the AQS objective (for 2003) and the proposed AQDD2 Limit Value (for 2005) are predicted using the 1999 base year.

7 Maps of NO_x and NO_2 concentrations

7.1 METHOD FOR MAPS OF BACKGROUND CONCENTRATIONS

The methods used to calculate maps of background NO_2 concentrations have been developed over a number of years and are described in detail in a number of reports and papers including Stedman et al (1997), Stedman (1998), Stedman et al (2001a) and Stedman and Bush (2000). These methods have been continually revised and updated to incorporate more up-to-date monitoring data and emission inventory and projection information.

This section briefly summarises the methods used.

Measured annual mean background NO_x concentrations have been assumed to consist of two parts:

- A contribution from relatively distant major point and area sources such as power stations or large conurbations. Measurements from monitoring sites well away from local sources, for example from rural sites within the UK Acid Deposition Secondary Network, provide good indications of the spatial variation of concentrations due to distant sources.
- A contribution from more local emissions.

The difference, *diff*, between measured ambient NO_x and the underlying rural concentration field is calculated at automatic monitoring site locations (not roadside, industrial sites or urban or suburban sites that are significantly influenced by emissions from a nearby road).

$$diff = \text{measured annual mean urban } NO_x \text{ concentration - mapped rural } NO_x \text{ concentration}$$

A regression analysis is then performed to find the coefficient, k_b, for the relationship between *diff* and estimated NO_x emissions in the vicinity of the monitoring sites taken from the NAEI (Goodwin et al 2000):

$$diff = k_b.emissions$$

This coefficient, which is the equivalent of an empirical box model coefficient, can then be used to derive a map of annual mean concentrations from a combination of rural mapped concentrations and emissions inventory estimates. Thus, automatic monitoring data are used to calibrate the relationship between ambient air quality and emissions inventories.

In earlier work on the estimation of air pollutant concentrations from emission related parameters (Stedman et al, 1997) we have studied the spatial scale at which local emissions seem to influence ambient air quality. We found that estimates of emissions in an area of 25 km^2 centred on a background monitoring site provide the most robust relationships. In subsequent work incorporating improved spatially resolved emission inventories and more extensive monitoring data it became clear that contributions from outside the 25 km^2 area should be included. This is particularly important for large urban areas such as London, where an

empirically derived 'out of square' contribution was added for inner London (Stedman et al, 2001a, Stedman and Bush 2000).

This has been addressed in the current work by including contributions to ambient concentrations from emissions in an area of 1225 km^2, with the contribution weighted by distance and direction from the central receptor. We have adapted an ADMS based approach described by Abbott and Vincent (1999) and others. The ADMS dispersion model was used to calculate the contribution to concentrations at a receptor point from a 35 x 35 km hypothetical grid of 1 x 1 km cells of unit emissions, grouped into blocks of 5 x 5 km. This level of spatial resolution was chosen to retain consistency with earlier work and avoid discontinuities in predicted concentrations at the borders of 1 x 1 km cells. Long period average meteorological data from Heathrow was used. The weighted sum of emissions around each monitoring site location was calculated and compared with *diff* to derived the empirical dispersion coefficient k_b.

estimated background NO_x concentration (μgm^{-3} as NO_2) = rural NO_x map (μgm^{-3} as NO_2) + k_b. emissions (Tonnes NO_x as NO_2 per year, weighted by distance and direction)

This revised method therefore, implicitly includes a contribution from 'out of square' emissions but the calibration of dispersion coefficients by automatic monitoring data is retained.

Area emissions maps were calculated for 1999 as described in section 2. Empirical dispersion coefficients were calculated by comparing emissions with automatic monitoring results. The meteorological conditions of the base year are, therefore, included in the dispersion coefficients and this should be the only difference between the coefficients for different years because the year to year changes in emissions have been accounted for.

Coefficients are listed in Table 15 for the relationship between the weighted sum of emissions and the local source contribution to ambient annual mean NO_x concentration. Monitoring sites were found to fall into two groups: those in the large urban centres of Greater London, the West Midlands and Greater Manchester and those in the rest of the UK. The empirical dispersion coefficients were found to be lower in the large urban areas, presumably due to a combination of urban influences on local meteorology. This observation has been confirmed by dispersion modelling studies in London recently carried out by Abbott and Vincent (2001).

Table 15 Coefficient used to calculate background annual mean NO_x maps (sm^{-1})

Base year	1999
Large urban areas	3.89
Elsewhere in the UK	7.18

Maps of estimated annual mean background NO_2 concentrations were then calculated from the maps of NO_x using the following non-linear relationships: (which are consistent with those used for the site-specific analysis; 1 ppb NO_2 = 1.91 ugm^{-3} NO_2).

Rural Background NO_2 *(ppb)* $=0.833.\ NO_x$ *(ppb)*
Central London Background NO_2 *(ppb)* $= 1.750.NO_x$ *(ppb)*$^{0.7}$
Elsewhere Background NO_2 *(ppb)* $= 2.375.NO_x$ *(ppb)*$^{0.6}$

7.2 METHOD FOR MAPS OF ROADSIDE CONCENTRATIONS

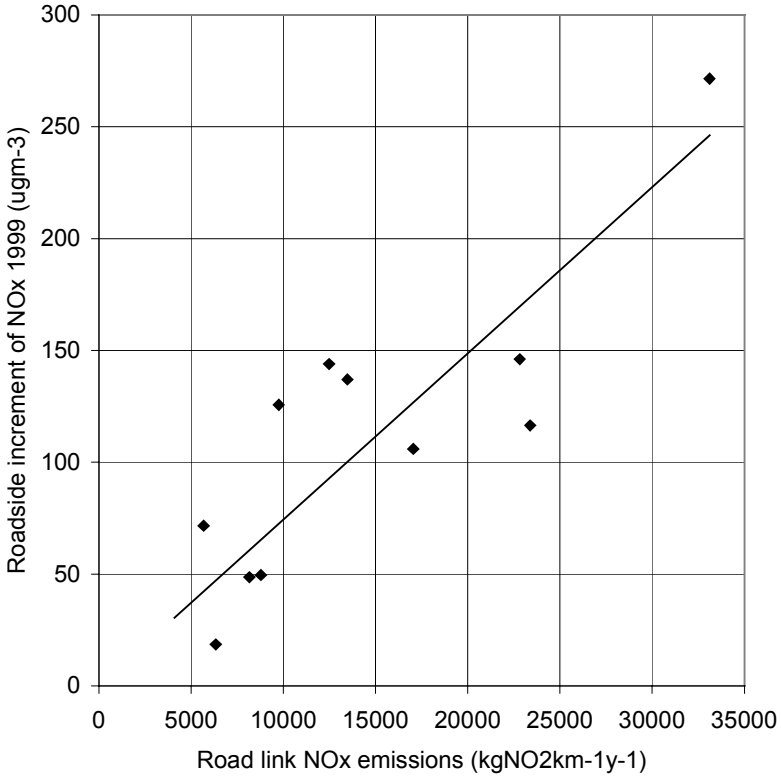
We have considered that the annual mean concentration of NO_x at a roadside location is made up of two parts: the background concentration (as described above) and a roadside increment (Stedman et al 1998a).

roadside concentration = background concentration + roadside increment

The NAEI provides estimates of NO_x emissions for a total of 7,180 built-up major road links in the UK for 1998 (Goodwin et al, 2000). Figure 22 below shows a comparison of the roadside increment of annual mean NO_x concentrations at roadside or kerbside national automatic monitoring sites with NO_x emission estimates for the individual road links alongside which these sites are located. The background NO_x component at these roadside monitoring sites was derived from the map described above. The sites chosen for this analysis are those for which emission estimates are available that are in built-up areas. There is clearly a strong dependence of the roadside increment on NO_x emission at these sites.

roadside increment of annual mean NO_x *(*μgm^{-3} *as* NO_2*)* $= k_r.NO_x$ *emission from road link (kg* NO_2 km^{-1} y^{-1}*)*

Figure 22 Comparison of annual mean NO_x roadside increment and road link NO_x emission (μgm^{-3} as NO_2)



The values of k_r for the 1999 base year listed in Table 16.

Table 16 Coefficient used to calculate the roadside increment of annual mean NO_x concentration (sm^{-2})

Base year	1999
Coefficient	0.233

Roadside NO_x monitoring sites at locations with a more open aspect, such as roads in rural areas, do not conform to this relationship. The NO_x emissions from vehicles travelling on open aspect roads are generally more effectively dispersed than the emissions on built-up urban roads. We have therefore restricted our mapping to built-up major roads where the relationship is reliable (7,180 A-road and motorway road links),. Built-up motorway road links with speed limits of less than 70 mph were treated in the same as other built-up major road links. Built-up motorway road links with speed limits of 70 mph were treated separately and the roadside increment was set to 0.225 of the value for other built-up major road links. This factor is based on the analysis of the limited monitoring data from sites close to motorways with fast moving traffic, which indicates considerably enhanced dispersion in comparison with other roads in the urban environment.

Roadside annual mean NO_2 concentration was calculated from the estimate of the roadside annual mean NO_x concentration using following relationship (Stedman et al 2000b):

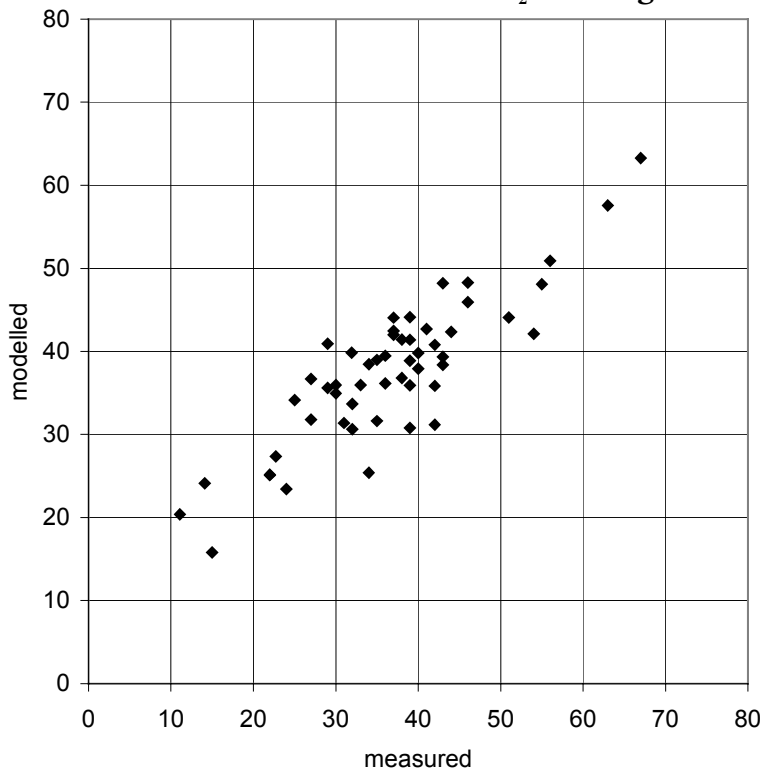
$$\text{Roadside } NO_2 \text{ (ppb)} = 1.8767.NO_x\,(ppb)^{0.6}$$

NO_2 concentrations at roadside monitoring sites are lower than at background locations with the same total NO_x concentration because these sites are very close to sources and NO_2 concentrations are limited by the availability of oxidant.

7.3 MAPS OF CONCENTRATIONS 1999

Maps of annual mean background NO_2 concentrations for 1999 are shown in Figure 23 at the end of this section. The highest estimated background concentrations are in the centres of the large cities. Areas strongly influenced by emissions from busy motorways are also evident. Scatter plots of estimated and measured concentrations are shown in Figure 24. Summary statistics for the comparison between mapped and measured background concentrations of NO_x and NO_2 are listed in Table 17.

Figure 24 Measured and modelled annual mean NO_2 at background sites 1999 (μgm^{-3})



It is possible to obtain a sensible looking estimate of NO_2 from a combination of an inaccurate estimate of NO_x and an inappropriate NO_x to NO_2 conversion. It is therefore prudent to compare modelled and measured NO_x concentrations as well as those of NO_2. There is good agreement between the mapped and measured concentrations of both NO_x and NO_2. The measurement data presented in these comparisons is the same as that used to calibrate the relationships between measurements and emissions. A separate report describing the verification of the mapping results by comparison with an independent set of measurement data has also been published (Stedman and Handley, 2001).

Table 17 Summary statistics for comparison between estimated and measured concentrations of NO_x and NO_2 at background site

	Mean of measurements (μgm^{-3})	Mean of model estimates (μgm^{-3})	r^2	Number of sites
NO_x, 1999[a]	64.6	63.4	0.76	55
NO_2, 1999	34.6	36.5	0.76	55

[a] **(μgm^{-3} as NO_2)**

Maps of annual mean NO_2 concentrations at the roadside of built-up major road links for 1999 are presented in Figure 25 at the end of this section. Scatter plots of estimated and measured concentrations are shown in Figure 26 and the summary statistics for the comparison of mapped and measured background concentrations of NO_x and NO_2 are listed in Table 18. There is generally good agreement between the mapped and measured concentrations of both NO_x and NO_2. The verification of these mapping results by comparison with an independent set of measurement data has also been published (Stedman and Handley, 2001).

Figure 26 Measured and modelled annual mean NO_2 at roadside site 1999 (μgm^{-3})

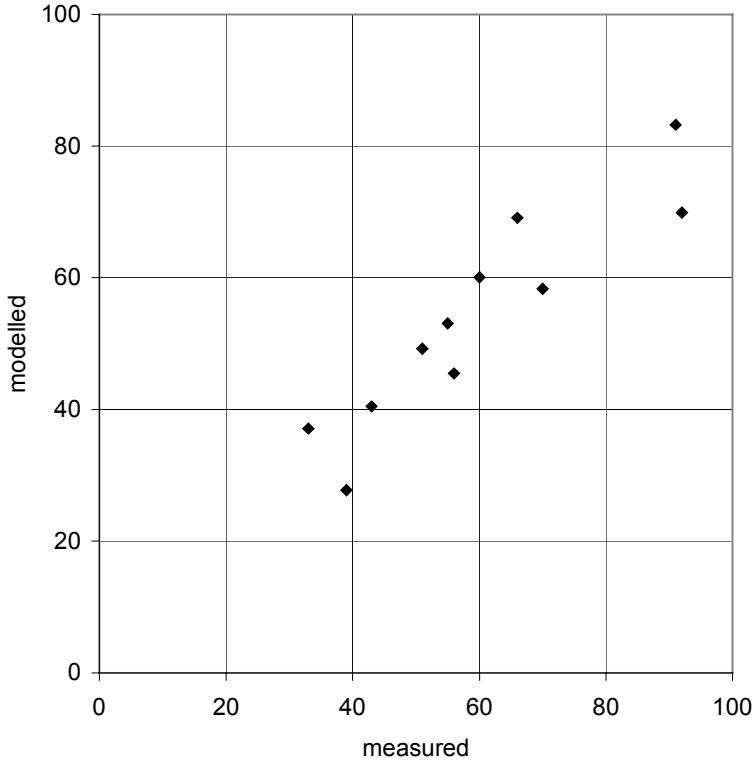


Table 18 Summary statistics for comparison between estimated and measured concentrations of NO_x and NO_2 at roadside sites

	Mean of measurements (μgm^{-3})	Mean of model estimates (μgm^{-3})	r^2	Number of sites
NO_x, 1999[a]	192.2	182.4	0.83	11
NO_2, 1999	59.6	54.0	0.84	11

[a] **(μgm^{-3} as NO_2)**

7.4 BASELINE AND NO ABATEMENT PROJECTIONS

Maps of annual mean background NO_2 concentrations for the 1999, 2005 and 2010 for the baseline and no abatement emissions scenarios and 1999 base year are shown in Figure 23. Comparison of mapped concentrations for the baseline and no abatement emissions scenarios clearly show an increase in NO_2 concentration relative to the baseline under the no abatement scenario. Greatest increases in concentrations are in urban areas.

Maps of roadside NO_2 concentrations for the 1999, 2005 and 2010 for the baseline and no abatement emissions scenarios and 1999 base year are shown in Figure 25. Table 19 lists the number of road links with estimated roadside annual mean concentrations $NO_2 \geq 40$ μgm^{-3}. Values are provided for 1999, 2005 and 2010 for each emissions scenario and for the 1999 base year for six geographical areas of the UK. 40 μgm^{-3} is the annual mean objective for 2005 within the AQS and the annual mean limit values for 2010 within the AQDD1.

Table 19 The number of built-up major road links with estimated NO_2 concentrations greater than or equal to 40 μgm^{-3} for baseline and no abatement emissions scenarios 1999, 2005 and 2010

Geographical area	Scotland	Wales	Northern Ireland	Inner London	Outer London	Rest of England	UK
Number of road links modelled	548	282	101	760	789	4700	7180
1999 Baseline	148	34	11	759	755	2218	3925
1999 No Abatement	282	92	18	760	784	3700	5636
2005 Baseline	22	5	20	702	225	463	1437
2005 No Abatement	302	100	21	760	786	3827	5796
2010 Baseline	7	0	1	421	35	77	541
2010 No Abatement	322	113	24	760	787	3965	5971

Table 19 shows that estimates of the number of road links ≥ 40 μgm^{-3} based on the no abatement scenario are greater than the current baseline emissions scenario for all areas of the UK. Also indicated is that for the UK as a whole, current policy measures expect to deliver an 86% reduction in the number of road links ≥ 40 μgm^{-3} between 1999 and 2010 (reducing the number of road links from 3,925 in 1999 to 541 by 2010). Had such policy measures not been introduced, it is estimated that the number of road links in the UK with annual mean NO_2 concentrations
≥ 40 μgm^{-3} would have increased by 6% over the same period (increasing from 5,636 in 1999 to 5,971 in 2010).

Figure 23 Estimated annual mean background nitrogen dioxide concentration 1999, 2005 and 2010 for baseline and no abatement emission scenarios (μgm^{-3}). Ref NETCEN 15/03/2001

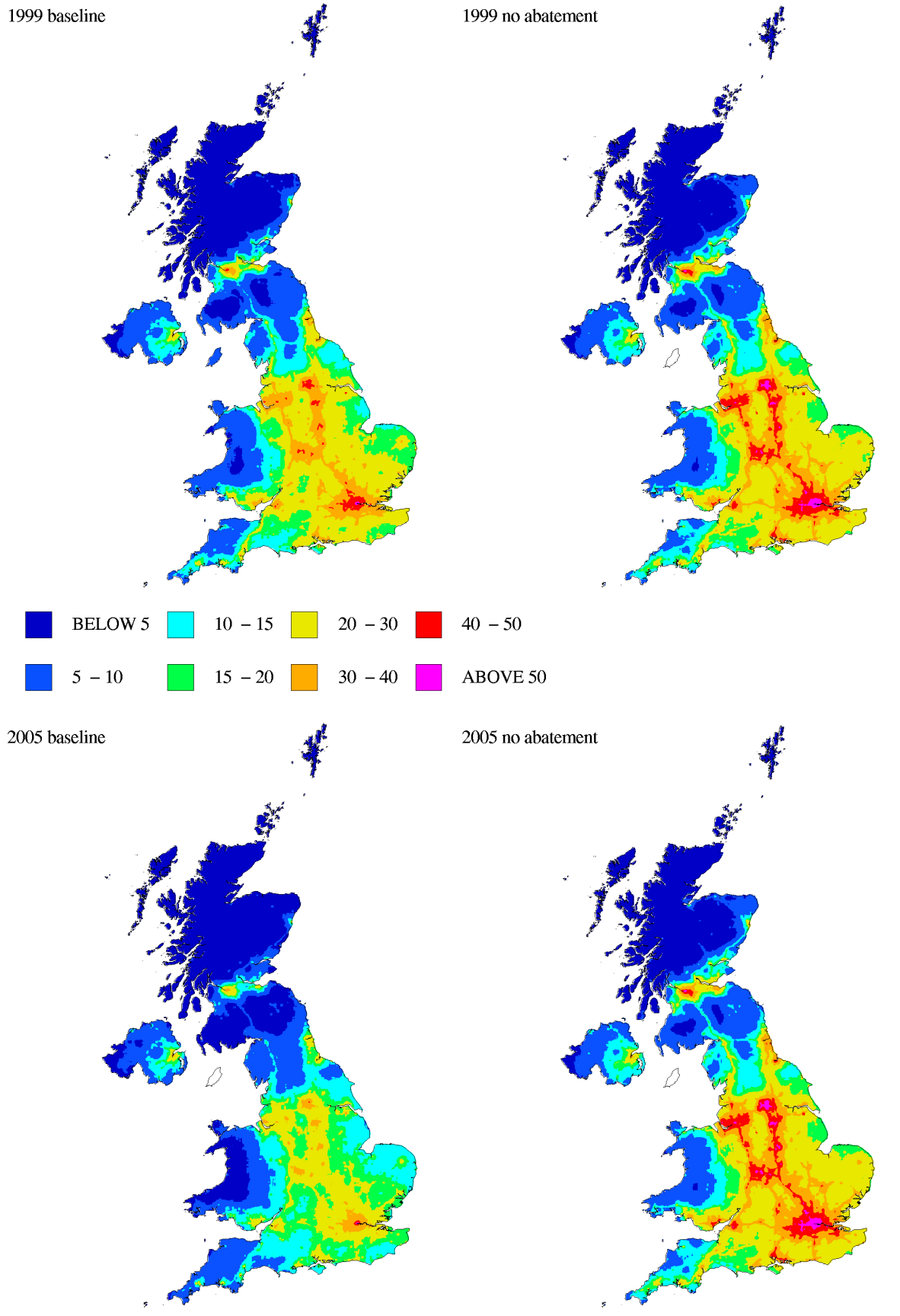


figure 23 continued

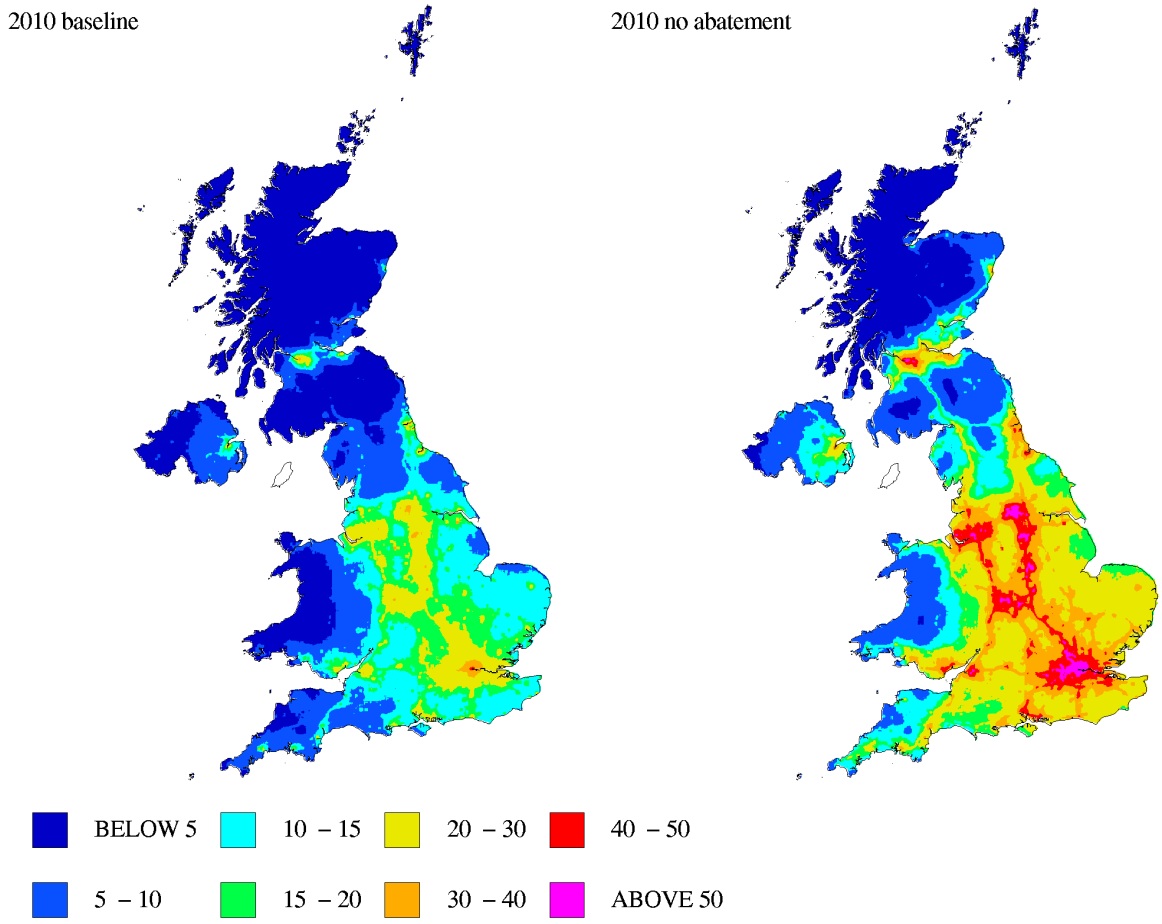


Figure 25 Estimated annual mean NO_2 concentrations on major urban roads 1999, 2005 and 2010 for baseline and no abatement emission scenarios (μgm^{-3}). Ref NETCEN 15/03/2001; census_scen.

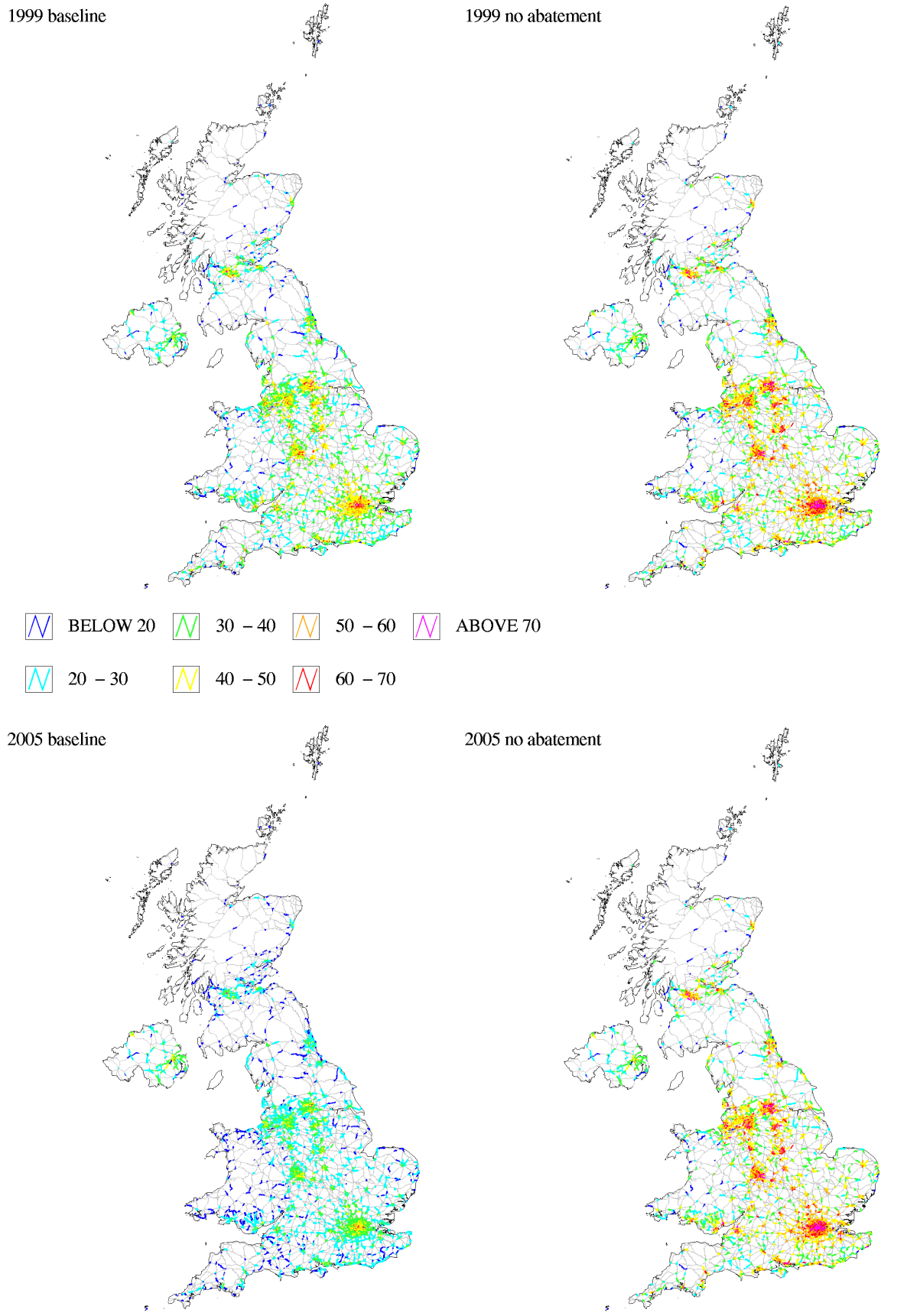
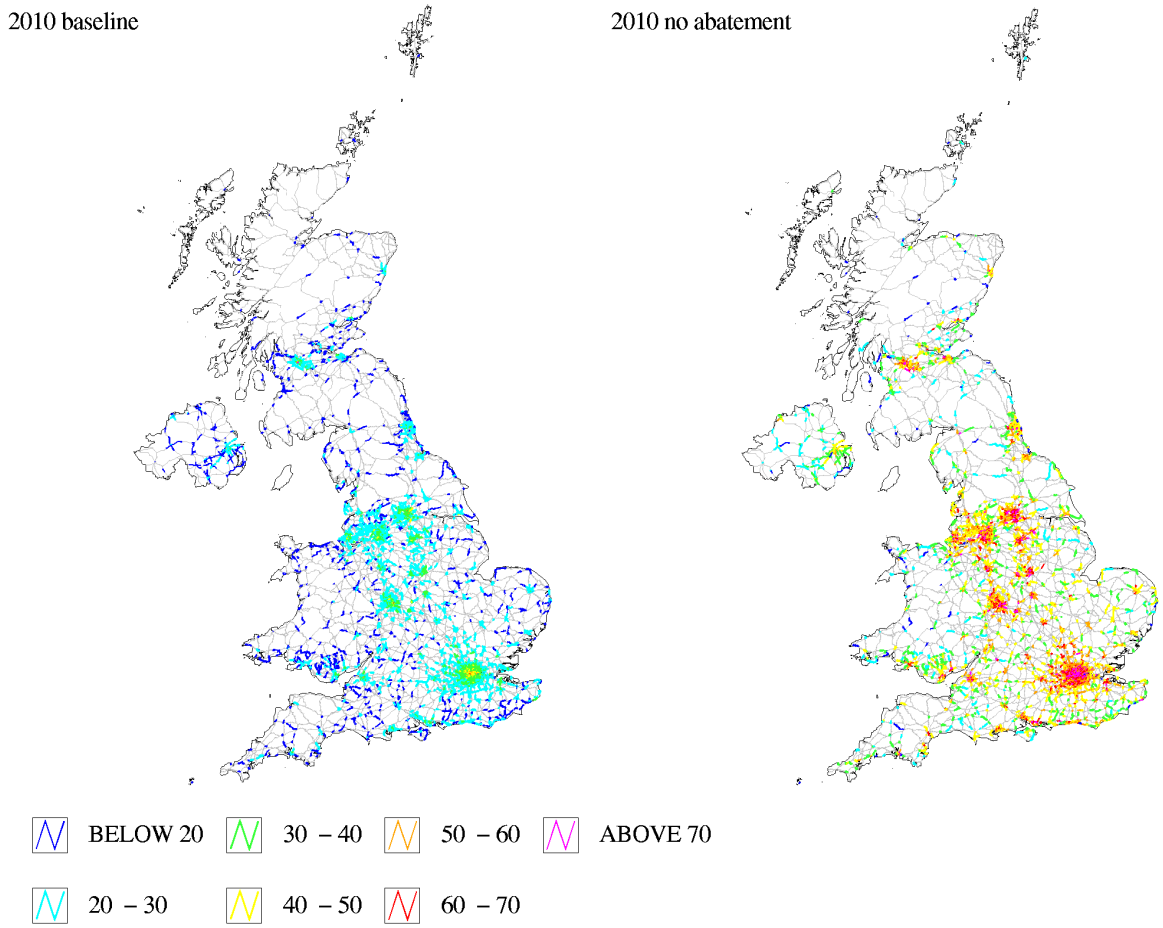


figure 25 continued.



8 Discussion

We have used emissions estimates for both the current baseline and a no technological abatement scenarios, to predict the impact of policy measures introduced in the 1990s, upon concentrations of NO_2, PM10 and CO. Site specific projections have been used to estimate the impact of policy measures at a selection of urban background and roadside monitoring locations relative to the emissions scenario assuming no technological abatement. Projections have also been made to assess impacts in the years 2005 and 2010.

To further illustrate the impact of the vehicle emissions abatement measures introduce in the 1990s, empirical modelling was used to estimate annual mean NO_2 concentration maps for UK background and built-up primary and motorway road links. Concentration maps were calculated for a 1999 base year, 2005 and 2010 using baseline and no abatement emissions scenarios and enabled the number of road links with annual mean concentrations ≥40 μgm^{-3} to be identified.

Table 20 summarises the impact of the policy measures introduced in the 1990s to reduce road traffic emissions, derived from site specific analyses. Figures are provided in terms of μgm^{-3}'s reduction per pollutant and are relative to the estimated no abatement scenario.

Table 20 Average reduction in pollution concentration from site specific analyses arising from the introduction of policy measures, present day and 2010

	Average reduction in pollutant concentration arising from policy measures relative to the no abatement scenario	
	Present Day (1999)	2010
Average NO_2 reduction – Urban background (μgm^{-3})	-9	-22
Range (μgm^{-3})	-15 to +3*	-14 to –31
Average NO_2 reduction – Roadside (μgm^{-3})	-10	-38
Range (μgm^{-3})	-17 to +8*	-25 to –51
Average PM10 reduction – Urban background (μgm^{-3})	-4	-10
Range (μgm^{-3})	-1 to –6	-3 to –14
Average PM10 reduction – Roadside (μgm^{-3})	-12	-25
Range (μgm^{-3})	-6 to –23	-13 to –43
Average CO reduction – Urban background (mgm^{-3})	-1.0	-2.1
Range (mgm^{-3})	-0.5 to –1.3	-1.2 to –3.0
Average CO reduction – Roadside (mgm^{-3})	-2.1	-4.4
Range (mgm^{-3})	-1.4 to –2.7	-3.1 to –6.1

*positive numbers are caused by the comparison of measured NO_2 with NO_2 estimates derived from estimates of NO_x using non-linear relationships

Table 20 shows that policy measures have reduced concentrations of all pollutants and that reductions are evident as early as 1999 at the urban background. On average, in 1999, annual average NO_2 and PM10 were reduced by 9 and 4 μgm^{-3} respectively and 8-hour maximum CO concentrations by 1.0 mgm^{-3} at urban background locations relative to estimates for the no abatement scenario. At roadside locations, reductions are more pronounced as might be

expected from policy measures effecting road traffic emissions; annual average NO_2 and PM10 reduced by 10 μgm^{-3} and 12 μgm^{-3} respectively and 8-hour maximum CO concentrations by 2.1 mgm^{-3}.

By 2010, it is predicted that policy measures will have resulted in further significant reductions in pollutant concentrations. Annual average NO_2 and PM10 are predicted to be 22 and 10 μgm^{-3} lower respectively and 8-hour maximum CO concentrations 23.3 mgm^{-3} lower at urban background locations. At the roadside, reductions relative to the no abatement scenario are estimated at 38 and 25 μgm^{-3} lower for the NO_2 and PM10 annual average respectively and 4.4 mgm^{-3} for the CO maximum 8-hour average.

Table 21 presents a summary of the results derived from the mapping of built-up primary roads and motorways.

Table 21 Reduction in UK road links with annual average NO_2 concentrations ≥40 μgm^{-3} relative to the no abatement scenario arising from policy measures

	UK road links ≥40 μgm^{-3}	Reduction in nos. road links ≥40 μgm^{-3} relative to no abatement scenario	
1999 Baseline	3925	-1711	-30%
1999 No Abatement	5636	-	-
2005 Baseline	1437	-4359	-75%
2005 No Abatement	5796	-	-
2010 Baseline	541	-5430	-91%
2010 No Abatement	5971	-	-

Table 21 indicates that for the annual average NO_2 objective, policy measures have had an important part in reducing the number roads exceeding the AQS objective for 2005. By 2005, abatement measures are predicted to have reduced the number of roads exceeding the AQS objective by 75% relative to the no abatement scenario. Of the roads exceeding the objective by 2005, 65% are located in inner and outer London, and a further 32% in other areas of England. Table 21 also shows that policy measures up to and including Euro IV will not be sufficient to reduce concentrations at all roadsides to below the AQDD1 Limit Value of 40 μgm^{-3} by 2010. Of those roads predicted to exceed the AQS objective in 2010 78% are located in inner London.

As a case study for NO_x and NO_2, the impact of individual policy measures upon NO_x emissions from road transport and NO_2 concentrations at a selection of monitoring locations included in the site specific projections have been assessed. It has been established that, the single largest contributor to reductions in NO_x emission from road transport in 2010 was the introduction of three-way catalysts for petrol vehicles under Euro I. This measure is predicted to account for 46% of the total reduction in NO_x emission, arising from all policy measures, for this year (relative to the no abatement scenario). Cleaner diesel combustion systems introduced under the same Euro standard accounted for a further 18% of the total NO_x reduction in 2010 and all other policies (Euros II to IV plus cleaner fuels) the remaining 36% of NO_x emission reduction.

In terms ambient NO_2 concentrations, the introduction of the 3-way catalyst is likely to accounted for largest proportional reduction in concentrations in areas outside of London (46% of reductions arising from all policies in 2010). In London, however, the largest contributor to reductions at in ambient NO_2 by 2010 is predicted to be the Euro II fuel standard, which is

predicted to account for 39% of the total reduction in ambient NO_2 concentrations arising from all measures by 2010 (14% more than Euro I). The discrepancy in contribution from abatement measures to concentration reductions within London and the rest of the UK is likely to be linked to the effect of cold start emission characteristics of petrol vehicles with catalysts and variations in the diesel/petrol vehicle emission split in these location types.

Clearly from these analyses, its has been demonstrated that the policy measures introducing cleaner vehicle technologies during the 1990s have had and are expected to have significant reductions in concentrations of NO_2, PM10 and CO. However, it is also apparent that, on their own, these policy measures may not deliver the required emissions reductions required to meet Limit Values for these pollutants.

9 Acknowledgement

This work was funded by the UK Department for Environment, Food and Rural Affairs, the National Assembly for Wales, the Scottish Executive and the Department of the Environment in Northern Ireland.

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