Report

Model comparison report for AQSR

Report to The Department for Environment, Food and Rural Affairs, Welsh Assembly Government, the Scottish Executive and the Department of the Environment for Northern Ireland

John Stedman
Susannah Grice
David Carruthers
Matthew Williams
Helen ApSimon
Tim Oxley
Sally Cooke

AEAT/ENV/R/2456/Issue 1
January 2007

Title	Model comparison report for AQSR
Customer	The Department for Environment, Food and Rural Affairs, Welsh Assembly Government, the Scottish Executive and the Department of the Environment for Northern Ireland
Customer reference	CPEA 15
Confidentiality, copyright and reproduction	
File reference	W:\dd2003\aqsreview2005reporting\ comparisonreport/Model comparison report for AQSR v7.doc
Reference number	AEAT/ENV/R/2456/Issue 1

Address for Correspondence

netcen
The Gemini Building
Fermi Avenue
Harwell IBC
Didcot
Oxon
OX11 0QR

Telephone 0870 190 6573
Facsimile 1870 190 6318
john.stedman@aeat.co.uk

netcen is an operating division of AEA Technology plc
netcen is certificated to ISO9001 & ISO 14001

	Name	Signature	Date
Author	John Stedman Susannah Grice David Carruthers Matthew Williams Helen ApSimon Tim Oxley Sally Cooke		
Reviewed by			
Approved by			

Executive Summary

Introduction

This report provides a summary of a comparison of the results of three air quality modelling studies carried out to support the 2006 review of the Air Quality Strategy for England, Scotland, Wales and Northern Ireland. The 2006 review was focussed on measures to reduce concentrations of particulate matter and nitrogen dioxide. The air quality modelling results presented in the review were carried out by netcen using national scale GIS-based models (known as the PCM model). Modelling studies were also carried out by CERC using the ADMS-Urban model and Imperial College using the UKIAM model specifically to provide a comparison with the results of the PCM model.

This report provides a summary of the key results from the three modelling studies and some discussion of the main reasons for some of the similarities and differences between the models. There are several distinct areas to consider when comparing the results of the different models:

1. The representation of base year concentrations: this should be reasonable for all the models, within the limitations of spatial scale. The information on the verification of the models by comparison with ambient monitoring data is provided in the individual modelling reports.
2. Trends in predicted concentrations for the baseline from the base year to 2020.
3. Impact of measure Q in 2010 and 2020 in terms of the change in predicted concentrations.
4. The implications of key assumptions in the design and use of each model, including the spatial resolution, PM/NO_X background concentrations, source apportionment, imported contributions and chemical transformations etc.

The source apportionment of base year concentrations and the assumptions on the impact of the changes in emissions represented by the baseline and additional measures to reduce concentrations on the different components are key to understanding the differences between the different models. The changes in population-weighted mean PM concentrations are probably the most important statistics since the impact of changes in long-term PM concentrations dominate the health benefits of the predicted reductions in concentrations.

NO_x and NO_2

The comparison of site-specific predictions of concentrations shows reasonable consistency between the ADMS-Urban and PCM models. There are some differences in detail in both NO_x and NO_2. The latter are likely to be due, in part, to the differences in the way that NO_2 has been predicted from NO_x.

There is reasonable agreement between the predictions of population-weighted mean concentrations and extents of exceedences between the different models. Some of the differences can be explained by the different spatial scales of the models. UKIAM is based on a 5km grid, PCM is based on a 1km grid with an additional single value of the increment for each road segment whilst ADMS-Urban considers sources explicitly, so that ADMS-Urban has concentration gradients along, across and in the neighbourhood of roads. This results in higher predicted population-weighted mean concentrations for ADMS-Urban, particularly for NO_2.

The predicted impact of measures is dependent on the assumptions on the impact of measures on regional background NO_x concentrations. UKIAM indicates a smaller impact because of the way it includes imported contributions from shipping and sources outside the UK.

The source apportionment of NO_x concentrations predicted at monitoring site locations is quite similar for ADMS-Urban and PCM even though different emission inventories and modelling methods have been adopted. This helps to explain the similarity in the model results in terms of trends and the impact of measures. Similarly there is good agreement between the modelled roadside concentrations in London.

The three models use different methods to predict NO_2 from NO_x. The most important difference is that ADMS-Urban predicts hourly concentrations of NO_2 while the other two models only predict annual mean concentrations. The different approaches are, however, found to produce quite similar results with some differences in detail.

PM_{10}

The choice of base year has an important influence on the predicted PM_{10} concentrations. The highest PM_{10} concentrations are typically predicted by the PCM model for which a base year of 2003, a year with unusually high secondary PM concentrations, was used. Overall the agreement between the model results for PM_{10} is reasonably good.

The predicted decline in baseline concentrations to 2020 and the impact of measures is least for UKIAM. This is likely to be due to a different treatment of the changes in regional background concentrations, which is particularly important for PM. The predicted extent of exceedences is very sensitive to small changes in concentrations and thus on the choice of base year and the assumptions for regional background concentrations.

The site-specific source apportionments for PCM and ADMS-Urban are reasonably consistent for the main contributors: the regional background (largest) and road traffic. This is despite the complications of the somewhat different definition of the source categories in PCM and ADMS-Urban.

The detailed source apportionment of regional background PM_{10} concentrations is different for the three models but the overall apportionment into broad categories is reasonably consistent. The contribution from primary PM in London is quite consistent across the models. UKIAM has the lowest contribution from secondary PM and the highest contribution from other sources. The impact of measures on secondary PM is much less for UKIAM than for the other two models due to the different assumptions concerning the source apportionment of secondary PM and the treatment of imported contributions from shipping and from other European countries and beyond. These differences are reflected in the percentage exposure reduction (ER) between 2010 and 2020 predicted by the models. The results for ADMS-Urban and PCM are quite similar and about twice the magnitude of that predicted by UKIAM.

$PM_{2.5}$

The predicted population-weighted mean $PM_{2.5}$ concentrations from the ADMS-Urban and PCM model are quite similar, as are the predicted declines in baseline concentrations to 2020 and the impact of the measures. The regional background is the largest contributor to the predicted concentrations at monitoring sites in London for which the source apportionment is reasonably consistent between the two models.

A comparison of the source apportionment of the regional background concentrations of $PM_{2.5}$ in contrast to the case for PM_{10} shows that ADMS-Urban has a larger contribution from road traffic and PCM has a larger contribution from secondary nitrates. Comparisons of site specific apportionment shows that the ratio of the $PM_{2.5}/PM_{10}$ concentrations from road traffic is greater for ADMS-Urban than PCM.

The modelled ER for London is higher for PCM than for ADMS-Urban for the baseline and for the additional measures. This is because the predicted population-weighted mean concentration in 2010 is higher than for ADMS-Urban but the 2020 values are very similar.

Conclusions

The use of alternative models has allowed the outputs from the PCM model to be compared with those from models that use different processes and input assumptions. Additional modelling work to support the AQS review can now incorporate a number of changes to the PCM models to take account of some of the key results of this study, in order to improve the confidence with which the results can be used within the cost benefit analyses. These changes include:

- Additional modelling for the 2004 base year (to provide estimates for an additional base year with less unusual meteorological conditions)
- A revised source apportionment of regional rural NO_x concentrations to take account of the contributions from shipping and sources in continental Europe
- Incorporation of non-linearity in the impact of changes in precursor emissions on secondary PM
- A more consistent source apportionment of PM_{10} and $PM_{2.5}$ concentrations

Contents

1 Introduction

1.1 BACKGROUND

This report provides a summary of a comparison of the results of three air quality modelling studies carried out to support the 2006 review of the Air Quality Strategy for England, Scotland, Wales and Northern Ireland. A consultation document on options for further improvements in air quality was published in April 2006 (Defra et al 2006a, 2006b). This consultation document includes an assessment of current air quality in the UK, projections of future air quality for current policies (known as baseline projections) and projections for a range of possible additional policy measures. The review was focussed on measures to reduce concentrations of particulate matter and nitrogen dioxide.

1.2 PCM MODEL

The air quality modelling results presented in the review were carried out by netcen using national scale GIS-based models (known as the PCM model). Details of the modelling methods have been published to accompany the review (Stedman et al 2005, Grice et al 2006, Stedman et al 2006a). The PCM model has been used to calculate estimates of NO_x, NO_2, PM_{10} and $PM_{2.5}$ concentrations for background and urban roadside locations across the UK. Concentrations for background locations were calculated on a 1 km x 1 km grid and estimates of roadside concentrations were calculated for a total of 9882 road links, with a single concentration estimate calculated for each road link. Projections were calculated from a base year of 2003 for the baseline and a wide range of possible policy measures and from a base year of 2002 for the baseline and a limited number of measures. The results for the 2003 base year modelling of the baseline and measure Q (early Euro 5, low emission vehicles and measures for small combustion plants) are presented in this comparison report. Emission estimates from the NAEI were used for the PCM modelling.

Additional modelling work has also been carried out to support the AQS review. The use of alternative models allows the outputs from the PCM model to be compared with those from models that use different processes and input assumptions.

1.3 ADMS-URBAN MODEL

The dispersion model ADMS-Urban was used by CERC to provide estimates of the concentrations of NO_x, NO_2, PM_{10} and $PM_{2.5}$ at a high spatial resolution for Greater London. Significant sources, including roads, are treated explicitly and the concentration from these sources calculated hour by hour using the ADMS-Urban dispersion algorithms and chemical routines. Output typically has a resolution of 10m near roads and 100m elsewhere. In contrast to PCM and UKIAM the model includes the impact of street canyons and calculates gradients of concentration with distance from roads. The base year for these calculations was 2001 and results are presented here for the baseline and for measure Q. Full details of the ADMS-Urban modelling carried out to support the review of the AQS are available (Williams et al, 2006). Emission estimates from the LAEI were used for the ADMS-Urban modelling.

1.4 UKIAM MODEL

The UKIAM model (Oxley et al 2003) has been used by Imperial College to provide estimates of the concentrations of NO_x, NO_2 and PM_{10} across the UK at a spatial resolution of 5 km x 5 km with imported contributions calculated using ASAM (see Oxley & ApSimon 2006 for details). The base year for these calculations was 2000 and results are presented here for the baseline and for measure Q. Full details of the UKIAM modelling carried out to support the review of the AQS are available elsewhere (ApSimon et al 2006). Emission estimates from the NAEI were used for the UKIAM modelling.

1.5 THIS REPORT

This report provides a summary of the key results from the three modelling studies and some discussion of the main reasons for some of the similarities and differences between the models. Full details of the models and the assumptions made in the calculations are provided in the individual modelling reports. Further modelling work has been completed by netcen since the publication of the consultation document (Defra et al 2006a, 2006b) to take account of more recently published energy projections, 2004 base year meteorology and model revisions, some of which have been made in the light of the findings of this comparison study. The new PCM model results are discussed in Grice et al (2007a).

There are several distinct areas to consider when comparing the results of the different models:

1. The representation of base year concentrations: this should be reasonable for all the models, within the limitations of spatial scale. The information on the verification of the models by comparison with ambient monitoring data is provided in the individual modelling reports.
2. Trends in predicted concentrations for the baseline from the base year to 2020.
3. Impact of measure Q in 2010 and 2020 in terms of the change in predicted concentrations.
4. The implications of key assumptions in the design and use of each model, including the spatial resolution, PM/NO_X background concentrations, chemical transformations, source apportionment and imported contributions etc.

The source apportionment of base year concentrations and the assumptions on the impact of the changes in emissions represented by the baseline and measure Q on the different components are key to understanding the differences between the different models. The changes in population-weighted mean PM concentrations are probably the most important statistics since the impact of changes in long-term PM concentrations dominate the health benefits of the predicted reductions in concentrations.

The following sections provide a summary of the comparison of modelling results for NO_x and NO_2, PM_{10} and $PM_{2.5}$. A similar set of comparisons have been carried out for each of the pollutants, so each section has roughly the same structure.

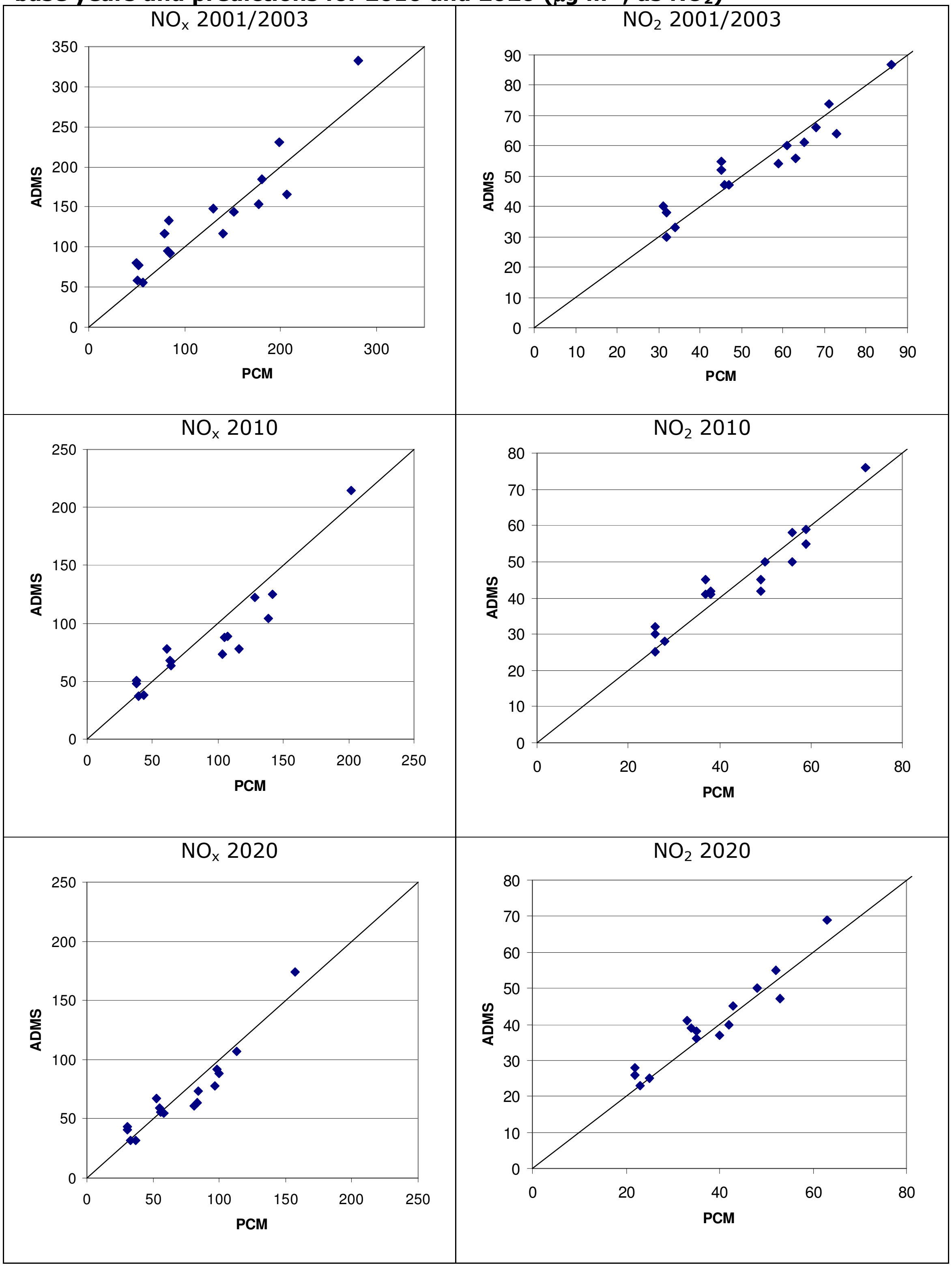
Section 5 provides a summary table of the main differences between the different models and the implications for the use of these models for the development of air quality policy in the UK.

2 NO_x and NO_2

2.1 SITE-SPECIFIC COMPARISON FOR MONITORING SITES IN LONDON

Table 2.1 shows a comparison of the model results for monitoring sites in London for the PCM and ADMS-Urban models. These data are further illustrated in Figure 2.1 which shows scatter plots of annual mean NO_x and NO_2 concentrations for the base years and predictions for 2010 and 2020. Overall the two models are reasonably consistent however there are some differences in detail. At roadside PCM predicts higher NO_x than ADMS-Urban for 2010 and 2020 and similar values for the base case despite the fact the PCM base case, being for 2003, has lower emissions than the ADMS-Urban base case (2001). Background NO_x values are similar for 2010 and 2020 whilst ADMS-Urban is higher for 2001 than PCM for 2003 as expected. NO_2 values are similar both at roadside and background which shows that at roadside the ADMS-Urban chemical scheme generates somewhat more NO_2 for a given concentration of NO_x since the ADMS-Urban NO_x is lower. Note that at background the reduction in NO_2 from base case to 2020 is small relative to the decrease in NO_x for both models and especially for reductions of NO_x from high levels (e.g. ADMS-Urban for 2001 to 2010). Further analysis of the results of the methods used to predict NO_2 from NO_x is provided in section 2.6.

Figure 2.1: Scatter plots of annual mean NO_x and NO_2 concentrations for the base years and predictions for 2010 and 2020 ($\mu g\ m^{-3}$, as NO_2)



The comparison of baseline predictions for 2010 and 2020 shows that the PCM model predicts somewhat higher NO_x concentrations at the roadside and that the predicted NO_x

concentrations at background locations are similar. This suggests that the predicted decline in NO_x concentration is somewhat greater for ADMS-Urban. The predicted roadside NO_2 concentrations are similar and the predictions for background sites are slightly higher for ADMS-Urban. This suggests that the PCM model predicts similar NO_2 concentrations at somewhat higher roadside NO_x and that the methods used to predict NO_2 from NO_x at background locations provide reasonably consistent results in 2010 and 2020. Further analysis of the results of the methods used to predict NO_2 from NO_x are provided in section 2.6.

Table 2.1 Comparison between annual mean concentrations predicted by the PCM and ADMS-Urban models (μg m^{-3}, as NO_2).

a) NO_x

	Current		2010		2020	
	ADMS-Urban	PCM	ADMS-Urban	PCM	ADMS-Urban	PCM
Base Year	2001	2003	2001	2003	2001	2003
London Marylebone Road	333	281	215	202	174	157
Tower Hamlets Roadside	144	151	89	107	73	84
London Cromwell Road 2	230	199	125	142	107	113
Camden Kerbside	165	207	104	139	88	100
Haringey Roadside	116	140	73	103	61	81
Hounslow Roadside	113		68		55	
London A3 Roadside	153	177	78	116	64	83
Southwark Roadside	184	181	122	128	92	98
London Bromley	114	126	73	89	61	67
London Bloomsbury	148	130	88	105	78	97
London Southwark	117	79	78	61	67	53
West London	95	82	68	63	59	55
London N. Kensington	92	85	63	64	56	56
London Wandsworth	123		75		62	
London Hackney	104		65		55	
London Brent	55	57	38	43	32	37
London Teddington	58	51	37	39	32	33
London Hillingdon	133	83	67	64	55	58
London Sutton	64		45		38	
London Bexley	80	50	51	38	43	31
London Eltham	77	52	48	38	41	31
Roadside common average	**180**	**183**	**110**	**128**	**90**	**98**
Background common average	**95**	**74**	**60**	**57**	**51**	**50**

b) NO_2

	Current		2010		2020	
	ADMS-Urban	PCM	ADMS-Urban	PCM	ADMS-Urban	PCM
Base Year	2001	2003	2001	2003	2001	2003
London Marylebone Road	87	86	76	72	69	63
Tower Hamlets Roadside	60	61	50	50	45	43
London Cromwell Road 2	74	71	59	59	55	52
Camden Kerbside	64	73	55	59	50	48
Haringey Roadside	54	59	45	49	40	42
Hounslow Roadside	49		40		35	
London A3 Roadside	56	63	42	49	37	40
Southwark Roadside	66	68	58	56	50	48
London Bromley	49	52	41	42	37	35
London Bloomsbury	61	65	50	56	47	53
London Southwark	52	45	45	37	41	33
West London	47	46	42	38	39	34
London N. Kensington	47	47	41	38	38	35
London Wandsworth	54		44		39	
London Hackney	50		41		37	
London Brent	33	34	28	28	25	25
London Teddington	30	32	25	26	23	23
London Hillingdon	55	45	41	37	36	35
London Sutton	33		28		25	
London Bexley	40	31	32	26	28	22
London Eltham	38	32	30	26	26	22
Roadside common average	**64**	**67**	**53**	**55**	**48**	**46**
Background common average	**45**	**42**	**37**	**35**	**34**	**31**

2.2 COMPARISON OF POPULATION-WEIGHTED MEAN CONCENTRATIONS AND EXCEEDENCES

Figure 2.2a shows a comparison of the population-weighted mean annual NO_x and NO_2 concentrations predicted by the PCM, ADMS-Urban and UKIAM models for London (all three models) and for the UK as a whole (PCM and UKIAM). Figure 2.2b shows the percentage of areas, population and road lengths in London that are predicted by the PCM, ADMS-Urban and UKIAM models (road lengths ADMS-Urban and PCM only) to have an annual mean NO_2 exceeding 40µgm^{-3}. Figure 2.2c shows the percentage of areas, population and road lengths in the UK that are predicted by the PCM and UKIAM models (road lengths PCM only) to have an annual mean NO_2 exceeding 40µg m^{-3}. The model results are also listed in Table 2.2.

In comparing the model predictions it is important to recognise that UKIAM is based on a 5km grid, PCM is based on a 1km grid with an additional single value of the increment for each road segment whilst ADMS-Urban considers sources explicitly. Therefore there are concentration gradients along, across and in the neighbourhood of roads for ADMS-Urban. Firstly comparing the population-weighted mean concentrations for the base case, it is seen that ADMS-Urban and UKIAM give similar values for NO_x for London (ADMS-Urban are somewhat larger), PCM gives lower values for the population-weighted mean concentration despite showing quite similar but larger values to ADMS-Urban at monitoring sites. This is likely to be due to PCM predicting only 'background levels' close to roads.

The impact of measure Q in terms of the change in population-weighted mean NO_x concentration is similar for PCM and ADMS-Urban and rather less for UKIAM. For NO_2 ADMS-Urban predicts the highest concentration and PCM the lowest. Again UKIAM shows less decline in the baseline. This is likely to be due to differing assumption on the impact of reduction in UK NO_x emissions on regional background NO_x concentrations, as UKIAM allows for an imported contribution from outside the UK from shipping and other European sources. ADMS-Urban and PCM assumed a 1 to 1 relationship, while UKIAM assumed that only 50% of the regional NO_x in the UK was attributable to UK sources. The impact of the measures for ADMS-Urban is predicted to be less than for PCM, although the predicted impact for NO_x was similar. This is likely to be a result of the different ways of predicting NO_2 from NO_x and the different spatial scales of the models. The comparison of ADMS-Urban and PCM at monitoring sites shows good agreement for NO_2 at both roadside and background sites, thus the difference in the population weighted mean concentration requires some explanation. A significant difference between the two models which is consistent with the difference in the population weighted mean concentrations is that in PCM the background concentration near a road does not take account of the road emissions explicitly instead they only contribute to the background on a larger spatial scale. On the other hand ADMS-Urban takes full account of gradients of concentration neighbouring a road. Thus ADMS-Urban and PCM can show good agreement at roadside and background but give quite different predictions in areas close to roads but not at roadside (neither roadside nor background).

Figure 2.2a: Population-weighted mean annual NO_x and NO_2 concentrations predicted by the PCM, ADMS-Urban and UKIAM models for London (all three models) and for the UK as a whole (PCM and UKIAM)

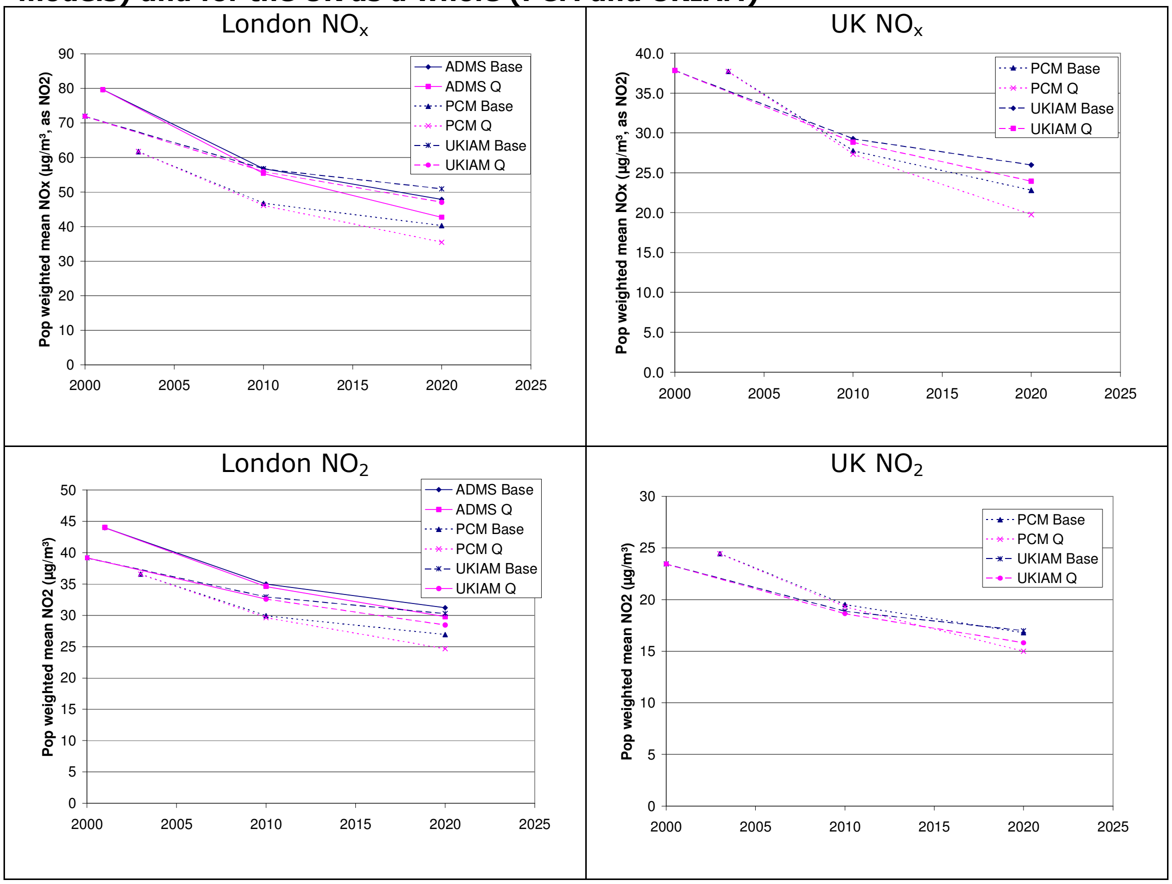
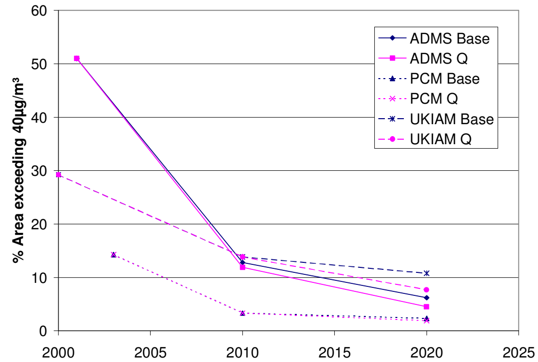
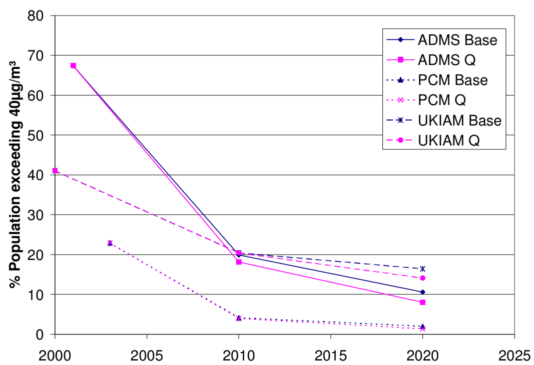


Figure 2.2b: Percentage of areas, population and road lengths in London that are predicted by the PCM, ADMS-Urban and UKIAM models (road length ADMS-Urban and PCM only) to have an annual mean NO_2 exceeding $40\mu gm^{-3}$

London NO_2 area



London NO_2 population



London NO_2 road

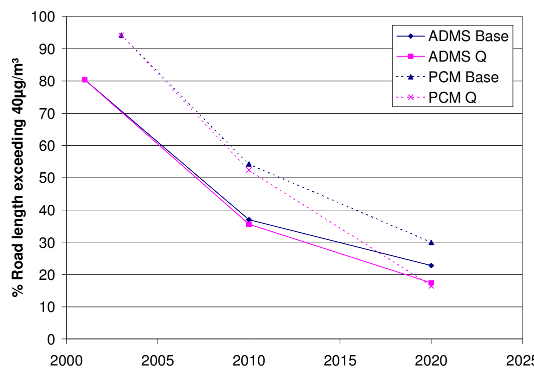
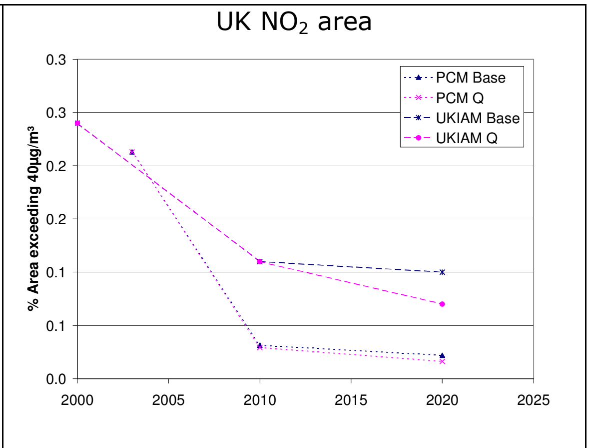
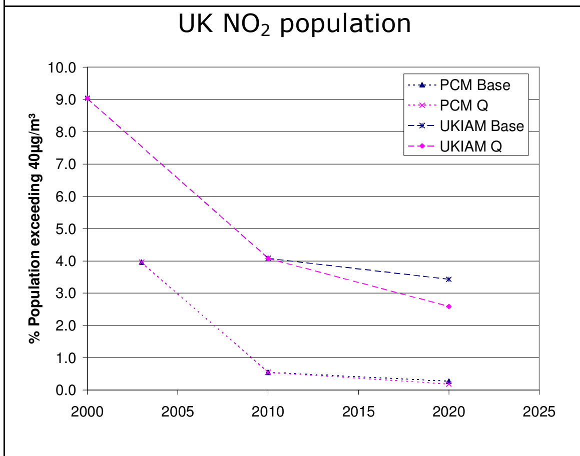
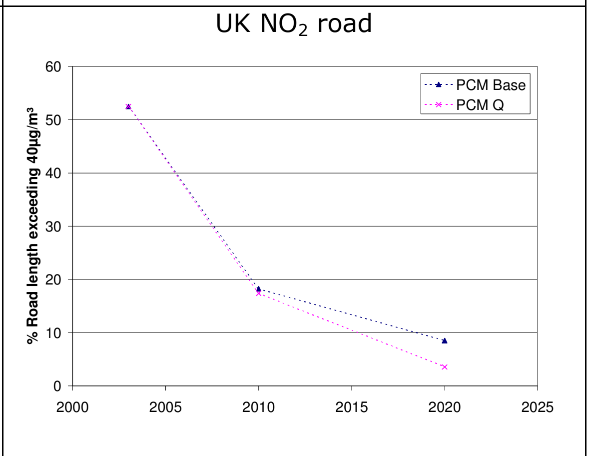


Figure 2.2c: Percentage of areas, population and road lengths in the UK that are predicted by the PCM and UKIAM models (road length PCM only) to have an annual mean NO_2 exceeding $40\mu gm^{-3}$







For the UK, UKIAM predicts a less steep decline in baseline NO_x and NO_2 concentrations than PCM and a rather smaller impact of measure Q on ambient concentrations. These differences are likely to be due to the smaller reduction in background concentrations in UKIAM, and also to some extent to the different spatial scales of the models. Overall the agreement in terms of estimates of absolute concentrations is very good. A comparison of population-weighted mean NO_2 concentrations calculated from the PCM results at spatial scales of 1 km x 1km (as provided by the model) and averaged up to a scale of 5 km x 5 km (the same spatial scale as the results provided by UKIAM) shows that the 5 km x 5 km concentrations were typically lower by about 7% for the UK as a whole and by about 13% for Inner London. This is because concentrations are generally higher in the 1 km x 1km grid squares with the highest populations.

Table 2.2 Comparison of population-weighted mean concentrations ($\mu g\ m^{-3}$, as NO_2) and exceedence statistics

a) NO_x

London	ADMS-Urban Base			ADMS-Urban Q	
	2001	2010	2020	2010	2020
Population weighted mean	79.6	56.7	47.9	55.4	42.7
	PCM Base			PCM Q	
	2003	2010	2020	2010	2020
Population weighted mean	61.7	46.8	40.3	46.1	35.5
	UKIAM Base			UKIAM Q	
	2000	2010	2020	2010	2020
Population weighted mean	71.9	56.7	50.9	55.9	47.0
UK	PCM Base			PCM Q	
	2003	2010	2020	2010	2020
Population weighted mean	37.7	27.7	22.8	27.3	19.8
	UKIAM Base			UKIAM Q	
	2000	2010	2020	2010	2020
Population weighted mean	37.8	29.3	26.0	28.8	23.9

b) NO_2

London	ADMS-Urban Base			ADMS-Urban Q	
	2001	2010	2020	2010	2020
Population weighted mean	44.0	35.0	31.2	34.6	29.8
% Area exceeding 40µg/m³	51.0	12.8	6.2	11.9	4.5
% Population exceeding 40µg/m³	67.4	19.9	10.6	18.1	8.0
% Road length exceeding 40µg/m³	80.4	37.0	22.8	35.6	17.4
	PCM Base			PCM Q	
	2003	2010	2020	2010	2020
Population weighted mean	36.6	29.9	26.9	29.6	24.7
% Area exceeding 40µg/m³	14.3	3.3	2.3	3.3	1.9
% Population exceeding 40µg/m³	22.9	4.1	2.0	3.9	1.3
% Road length exceeding 40µg/m³	94.1	54.3	29.9	52.4	16.4
	UKIAM Base			UKIAM Q	
	2000	2010	2020	2010	2020
Population weighted mean	39.2	32.9	30.3	32.6	28.5
% Area exceeding 40µg/m³	29.2	13.9	10.8	13.9	7.7
% Population exceeding 40µg/m³	41.1	20.4	16.4	20.4	14.1
UK	PCM Base			PCM Q	
	2003	2010	2020	2010	2020
Population weighted mean	24.5	19.5	16.8	19.3	15.0
% Area exceeding 40µg/m³	0.2	0.0	0.0	0.0	0.0
% Population exceeding 40µg/m³	4.0	0.5	0.3	0.5	0.2
% Road length exceeding 40µg/m³	52.5	18.2	8.5	17.4	3.5
	UKIAM Base			UKIAM Q	
	2000	2010	2020	2010	2020
Population weighted mean	23.4	18.9	17.0	18.6	15.8
% Area exceeding 40µg/m³	0.2	0.1	0.1	0.1	0.1
% Population exceeding 40µg/m³	9.0	4.1	3.4	4.1	2.6

ADMS-Urban predicts a larger area and population to be exceeding 40 μg m^{-3} in London than PCM. This is probably due to the higher near road concentrations predicted by ADMS-Urban, which treats such areas explicitly, as apposed to the PCM model, which provides predictions for background and roadside locations only. UKIAM predicts an extent of exceedence intermediate between ADMS-Urban and PCM in the base years and quite similar to ADMS-Urban in 2010 and 2020. The decline in the area and population exceeding is less for UKIAM, presumably due to the more gentle decline in regional background concentrations due to imported contributions assumed in this model. PCM predicts more roadside exceedences than ADMS-Urban and also predicts a larger reduction in exceedences for measure Q. Overall, however, the predicted extents of roadside exceedence and the trends to 2020 are very similar. Both UKIAM and PCM predict only very small areas and population to be exceeding 40 μg m^{-3} at background locations in 2010 and 2020.

2.3 IMPACT OF MEASURES ON POPULATION-WEIGHTED MEAN CONCENTRATIONS

Table 2.3 lists the impact of measure Q on the predicted population-weighted mean concentrations in 2010 and 2020, as discussed above.

Table 2.3 the impact of measure Q on population-weighted mean concentrations (μg m^{-3}, as NO_2)

a) NO_x

	2010	2020
London ADMS-Urban	-1.30	-5.20
London PCM	-0.63	-4.80
London UKIAM	-0.77	-3.86
UK PCM	-0.40	-3.05
UK UKIAM	-0.43	-2.03

b) NO_2

	2010	2020
London ADMS-Urban	-0.40	-1.40
London PCM	-0.29	-2.26
London UKIAM	-0.34	-1.83
UK PCM	-0.21	-1.80
UK UKIAM	-0.24	-1.18

2.4 SITE-SPECIFIC SOURCE APPORTIONMENT OF NO_X CONCENTRATIONS IN LONDON

Table 2.4 shows a comparison of the source apportionment of annual mean NO_x concentrations in the base year and in 2010 and 2020 for the baseline predictions from ADMS-Urban and PCM for selected monitoring sites in London. There are a number of differences in the detailed source apportionment and from site to site due to the different inventories used (LAEI and NAEI), base years and modelling methods. A direct comparison is also not possible due to the different ways the models work, such as the splits into major and minor roads for ADMS-Urban and roadside increment and other roads for PCM. Overall, however, the source apportionment results are quite similar and this explains why the model results for NO_x in terms of trends and the impact of measures are broadly similar. Averaged over the sites considered the total contribution from roads declines from 59% in the base year to 48% in 2020 for ADMS-Urban and from 61% to 44% for PCM. The contribution from the regional background remains at 12% for ADMS-Urban and declines from 10% to 9% for PCM. The contribution from all other sources increases from 29% to 40% for ADMS-Urban and from 29% to 47% for PCM.

Table 2.4. Comparison of site-specific source apportionment of annual mean NO_x concentrations ($\mu g\ m^{-3}$, as NO_2)

a) ADMS-Urban

2001	Total	Major Roads	Minor Roads	Industrial	Other - gridded	Background
London Marylebone Road	333.0	280.1	4.8	2.8	27.2	18.0
London Bloomsbury	148.0	52.7	5.7	3.5	68.1	18.0
Camden Kerbside	165.0	105.6	4.9	2.0	34.5	18.0
London N. Kensington	92.0	36.2	4.4	2.0	31.4	18.0
2010						
London Marylebone Road	215.2	173.3	2.7	3.5	23.4	12.3
London Bloomsbury	88.3	27.9	3.1	4.3	40.8	12.3
Camden Kerbside	104.2	58.8	2.7	2.6	27.9	12.3
London N. Kensington	63.0	19.0	2.4	2.7	26.5	12.3
2020						
London Marylebone Road	174.2	135.9	2.0	3.5	23.3	9.6
London Bloomsbury	77.8	20.9	2.3	4.3	40.8	9.6
Camden Kerbside	87.9	45.8	2.0	2.6	27.9	9.6
London N. Kensington	55.7	14.2	1.8	2.7	27.4	9.6

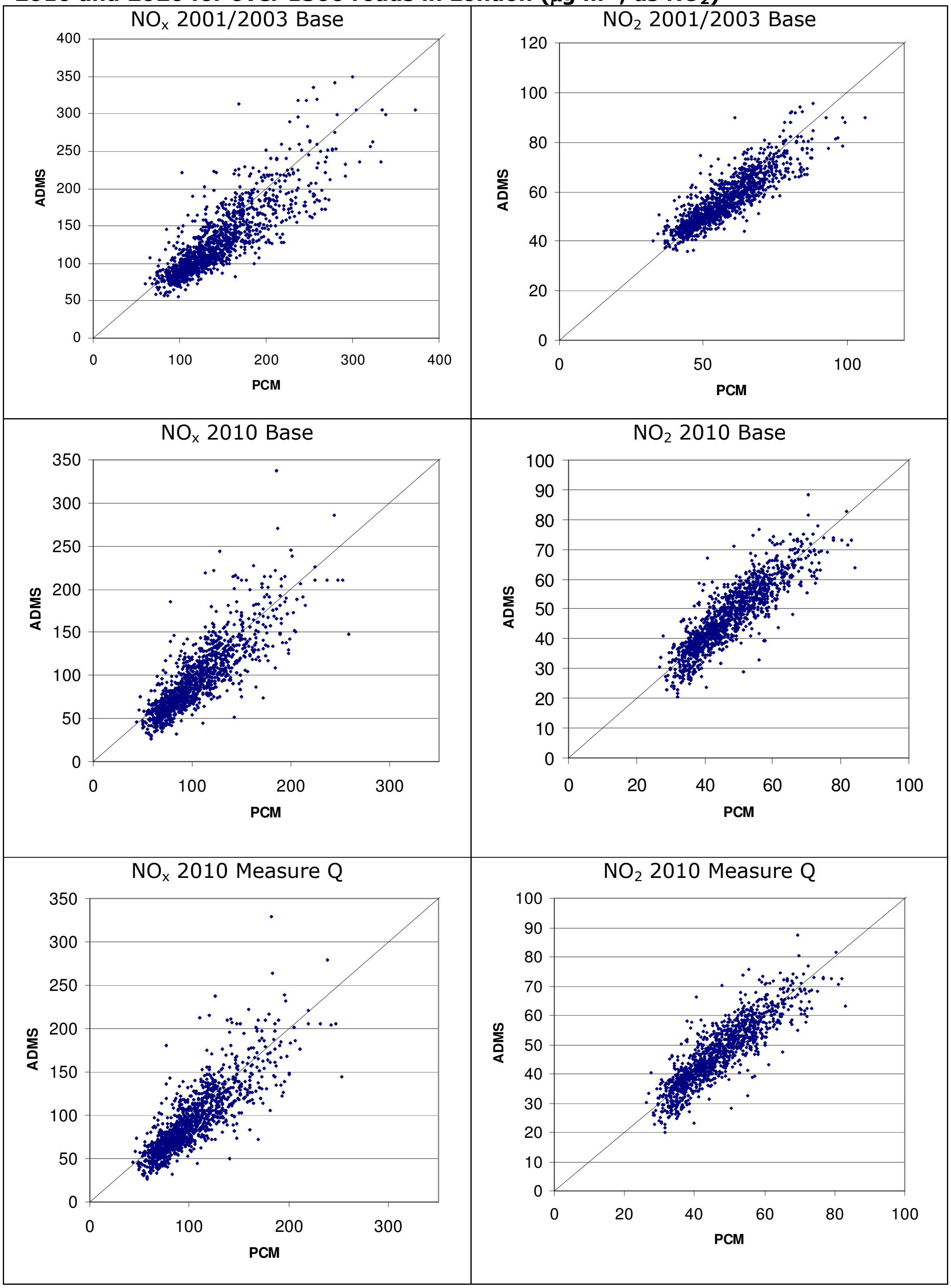
b) PCM

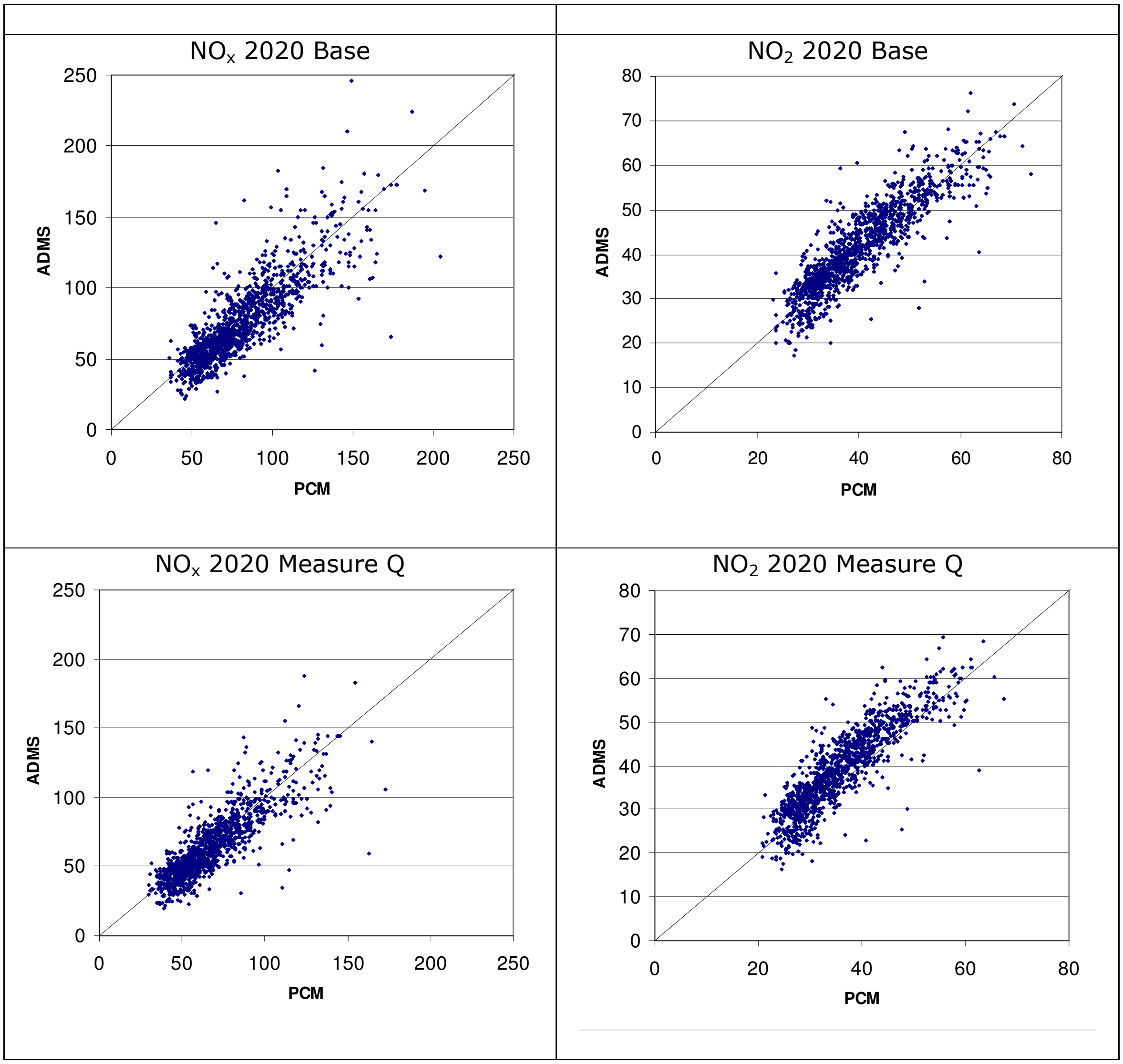
2003	Total	Roadside increment	Other roads	Industrial	Other	Rural
London Marylebone Road	280.5	163.5	47.5	15.8	39.7	14.0
London Bloomsbury	129.7	0.0	52.8	17.4	45.6	14.0
Camden Kerbside	206.8	134.2	32.1	6.0	20.5	14.0
London N. Kensington	84.5	0.0	40.0	7.2	23.2	14.1
2010						
London Marylebone Road	202.1	107.8	30.4	15.4	38.0	10.5
London Bloomsbury	104.9	0.0	33.8	16.9	43.8	10.5
Camden Kerbside	139.3	83.9	19.8	5.8	19.2	10.5
London N. Kensington	64.4	0.0	24.9	7.0	21.7	10.6
2020						
London Marylebone Road	157.3	71.0	20.7	16.9	40.4	8.3
London Bloomsbury	96.6	0.0	23.0	18.6	47.0	8.3
Camden Kerbside	99.5	50.7	13.6	6.3	20.6	8.3
London N. Kensington	56.4	0.0	17.0	7.7	23.4	8.4

2.5 COMPARISON OF MODELLED ROADSIDE ANNUAL MEAN NO_X AND NO_2 CONCENTRATIONS

Figure 2.5 shows comparisons of modelled roadside annual mean NO_x and NO_2 concentrations from the ADMS-Urban and PCM models for the base years and for 2010 and 2020 for over 1300 roads in London. Overall the agreement between the models is good. For NO_x the PCM model predicts somewhat higher concentrations at lower concentrations in the base year and in 2020. For NO_2 the PCM predictions are slightly higher at higher concentrations in the base year and the predictions for Q in 2020 are somewhat higher for ADMS-Urban. The results are very similar when averaged over all the roads compared. The mean roadside NO_2 concentration predicted by ADMS-Urban for the baseline declines from 56 $\mu g\ m^{-3}$ in the base year to 42 $\mu g\ m^{-3}$ in 2020 (to 39 $\mu g\ m^{-3}$ for measure Q in 2020) and the mean roadside concentration predicted by PCM declines from 57 $\mu g\ m^{-3}$ to 40 $\mu g\ m^{-3}$ (to 36 $\mu g\ m^{-3}$ for measure Q in 2020).

Figure 2.5: Comparisons of modelled roadside annual mean NO_x and NO_2 concentrations from the ADMS-Urban and PCM models for the base years and for 2010 and 2020 for over 1300 roads in London ($\mu g\ m^{-3}$, as NO_2)

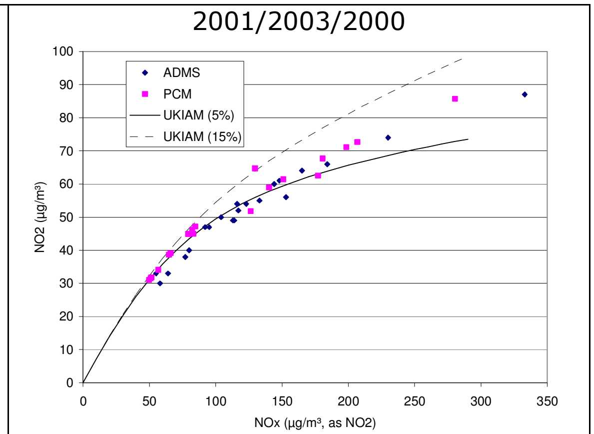


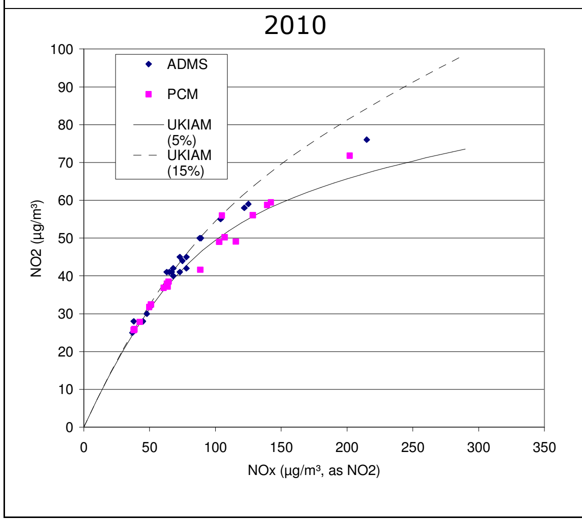


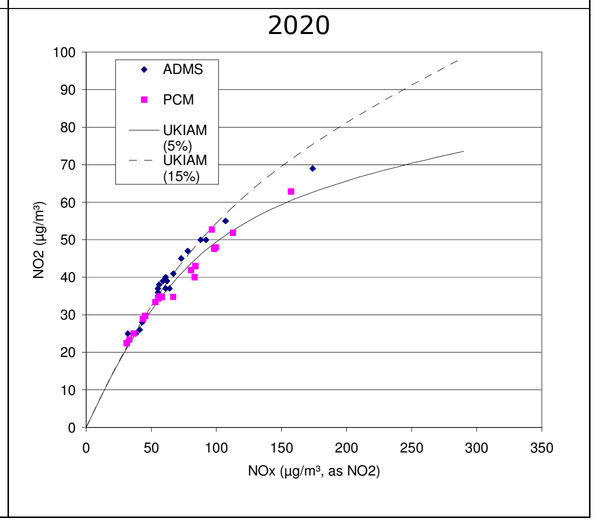
2.6 RELATIONSHIP BETWEEN NO_X AND NO_2 CONCENTRATIONS

Figure 2.6 shows a comparison of the predicted annual mean NO_x and NO_2 concentrations predicted by the ADMS-Urban and PCM models for monitoring sites in London. Both models predict NO_2 concentrations from modelled NO_x concentrations but using different methods. Hourly values of NO_2 are predicted from hourly NO_x using a chemical scheme in ADMS-Urban, while the PCM model predicts annual mean NO_2 from annual mean NO_x using an oxidant partitioning model. UKIAM uses a slightly different approach that agrees well with that of Jenkin et al (AQEG 2004) at background sites, and incorporates allowance for the fraction of NO_x emissions as primary NO_2 (Carslaw 2005, AQEG 2006). The approach used within UKIAM is also illustrated in this figure, which includes curves showing background NO_2 concentrations for 5% and 15% primary NO_2 emissions fractions (5% was used for the results presented in this report but also see appendix A for a discussion of the results for 15%).

Figure 2.6: Predicted annual mean NO_x and NO_2 concentrations







As discussed in section 2.1, the results of the ADMS-Urban and PCM models are broadly very similar with some differences in the detailed modelling results. The PCM model predicts higher NO_2 concentrations at similar NO_x concentrations at background locations in the base year and ADMS-Urban predicts higher NO_2 at similar NO_x concentrations at roadside locations in 2020.

2.7 SOURCE APPORTIONMENT OF REGIONAL BACKGROUND NO_X CONCENTRATIONS

The source apportionment of regional background NO_x concentrations in the UKIAM model is different from that assumed in the PCM and ADMS-Urban models. This is one of the reasons why UKIAM generally shows less of a decline in baseline concentrations and a smaller impact of the measures on ambient concentrations. Both the PCM and ADMS-Urban models assume that base year regional background NO_x concentrations are directly proportional to UK total NO_x emissions and thus a decline in emissions will lead to a proportional decline in concentrations. The UKIAM results presented here are based on the assumption that only 50% of base year regional background NO_x concentrations in the UK are due to UK emissions, the remainder (due to a combination of increasing shipping emissions and decreasing emissions in other countries) being assumed to remain roughly constant. Thus reductions in UK emissions lead to a smaller reduction in ambient concentrations than in the other models. The impact of a range of different assumptions concerning the impact of emission changes on regional background concentrations have been assessed by ApSimon et al (2006) and a summary is presented in Appendix A.

It is probably unrealistic to assume that 100% of base year regional background NO_x concentrations are due to UK sources or to assume that a large percentage are unchanged in all scenarios. A UKIAM derived source apportionment of regional background NO_x concentrations into contributions from UK, other European and shipping emissions has therefore been incorporated into the PCM modelling from a base year of 2004 also carried out to support the AQSR (Stedman et al 2006b).

2.8 CONCLUDING REMARKS

The comparison of site-specific predictions of concentrations shows reasonable consistency between the ADMS-Urban and PCM models. There are some differences in detail in both NO_x and NO_2. The latter are likely to be due, in part, to the differences in the way that NO_2 has been predicted from NO_x.

There is reasonable agreement between the predictions of population-weighted mean concentrations and extents of exceedences between the different models. Some of the differences can be explained by the different spatial scales of the models. UKIAM is based on a 5km grid, PCM is based on a 1km grid with an additional single value of the increment for each road segment whilst ADMS-Urban considers sources explicitly, so that ADMS-Urban has concentration gradients along, across and in the neighbourhood of roads. This results in higher predicted population-weighted mean concentrations for ADMS-Urban, particularly for NO_2.

The predicted impact of measures is dependent on the assumptions on the impact of measures on regional background NO_x concentrations. UKIAM indicates a smaller impact because of the way it includes imported contributions from shipping and sources outside the UK.

The source apportionment of NO_x concentrations predicted at monitoring site locations is quite similar for ADMS-Urban and PCM even though different emission inventories and modelling methods have been adopted. This helps to explain the similarity in the model results in terms of trends and the impact of measures. Similarly there is good agreement between the modelled roadside concentrations in London.

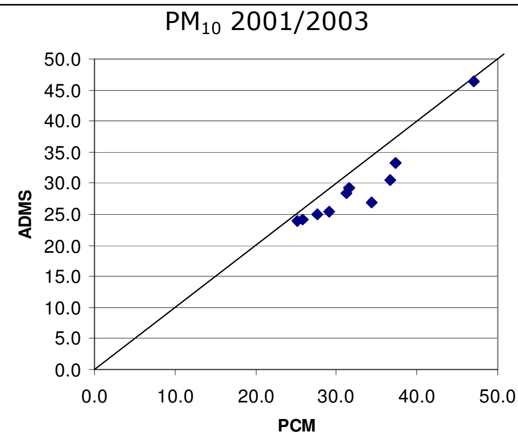
The three models use different methods to predict NO_2 from NO_x. The most important difference is that ADMS-Urban predicts hourly concentrations of NO_2 while the other two models only predict annual mean concentrations. The different approaches are, however, found to produce quite similar results with some differences in detail.

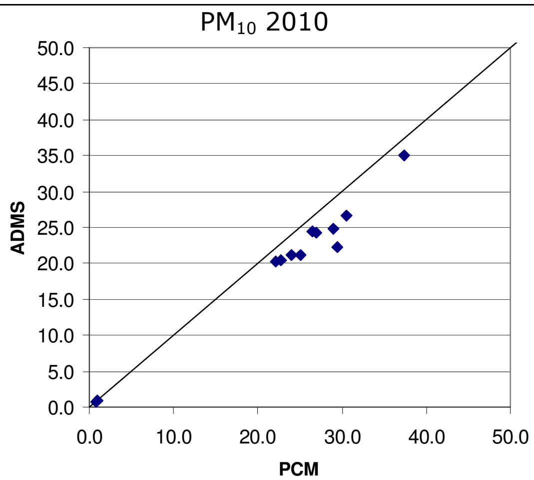
3 PM_{10}

3.1 SITE-SPECIFIC COMPARISON FOR MONITORING SITES IN LONDON

Table 3.1 shows a comparison of the model results for monitoring sites in London for the PCM and ADMS-Urban models. These data are further illustrated in Figure 3.1 which shows scatter plots of annual mean PM_{10} concentrations for the base years and predictions for 2010 and 2020. The most important reason for the difference between the results for the two different models is the base years used. There were a number of periods of elevated secondary PM during 2003 and this is reflected in the higher PCM base year and projected concentrations. Apart from this systematic difference the agreement between the two modelling methods is reasonably good in terms of the ranking of the sites and the trend to 2020.

Figure 3.1: Scatter plots of annual mean PM_{10} concentrations for the base years and predictions for 2010 and 2020 ($\mu g\ m^{-3}$, gravimetric)





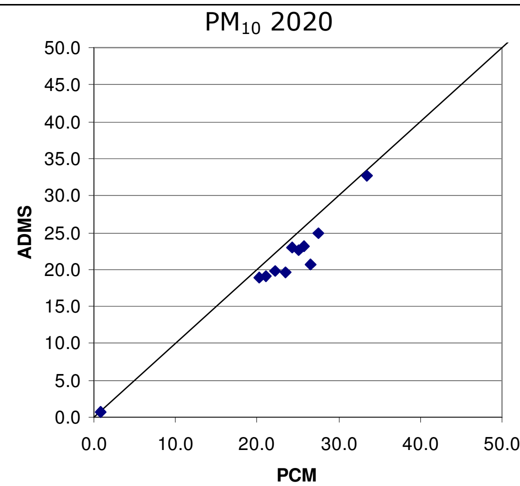


Table 3.1 Comparison between annual mean PM_{10} concentrations predicted by the PCM and ADMS-Urban models ($\mu g\ m^{-3}$, gravimetric).

	Current		2010		2020	
	ADMS-Urban	PCM	ADMS-Urban	PCM	ADMS-Urban	PCM
Base Year	2001	2003	2001	2003	2001	2003
London Marylebone Road	46.5	47.1	35.1	37.4	32.7	33.4
Camden Kerbside	30.4	36.6	24.8	29.0	23.2	25.8
Haringey Roadside	29.3	31.6	24.5	26.5	22.9	24.2
London A3 Roadside	27.0	34.3	22.2	29.5	20.7	26.6
London Bloomsbury	28.5	31.3	24.2	26.9	22.7	25.0
London N. Kensington	25.7	28.5	21.8	24.8	20.4	22.9
London Bexley	24.2	25.8	20.5	22.8	19.0	21.1
London Eltham	24.0	25.2	20.3	22.1	18.9	20.3
London Brent	22.7	25.6	19.3	22.5	17.9	20.7
London Hillingdon	25.5	29.1	21.2	25.0	19.6	23.5
Roadside average	**33.3**	**37.4**	**26.7**	**30.6**	**24.9**	**27.5**
Background average	**25.1**	**27.6**	**21.2**	**24.0**	**19.8**	**22.3**

3.2 COMPARISON OF POPULATION-WEIGHTED MEAN CONCENTRATIONS AND EXCEEDENCES

Figure 3.2a shows a comparison of the population-weighted annual mean PM_{10} concentrations predicted by the PCM, ADMS-Urban and UKIAM models for London (all three models) and for the UK as a whole (PCM and UKIAM). Figure 3.2b shows the percentage of areas, population and road lengths in London that are predicted by the PCM, ADMS-Urban and UKIAM models (road lengths ADMS-Urban and PCM only) to have exceedences of $20\mu gm^{-3}$ annual mean PM_{10}. Figure 3.2c shows the percentage of areas, population and road lengths in the UK that are predicted by the PCM and UKIAM models (road lengths PCM only) to have exceedences of $20\mu gm^{-3}$ annual mean PM_{10}. The model results in terms of population-weighted mean concentrations and exceedences are also listed in Table 3.2.

PCM predicts the highest concentrations in London and UKIAM the lowest and UKIAM shows the least decline in baseline concentrations to 2020. The impact of measure Q in terms of the change in population-weighted mean concentration is greatest for PCM and rather less for UKIAM. For the UK, UKIAM predicts a less steep decline in baseline concentrations than PCM and a smaller impact of measure Q on ambient concentrations. These differences are likely to be due mainly to the treatment of changes in regional background concentrations, where again UKIAM treats imported contributions differently and a smaller decline is assumed. Overall the agreement in terms of estimates of absolute concentrations is reasonably good. A comparison of population-weighted mean PM_{10} concentrations calculated from the PCM results at spatial scales of 1 km x 1km (as provided by the model) and averaged up to a scale of 5 km x 5 km (the same spatial scale as the results provided by UKIAM) shows that the 5 km x 5 km concentrations were typically lower by about 5% for the UK as a whole and by about 3% for Inner London. Thus the spatial scale has less of an impact on the results than for NO_2 because the regional background component is more dominant for PM_{10}.

Figure 3.2a: Population-weighted annual mean PM_{10} concentrations predicted by the PCM, ADMS-Urban and UKIAM models for London (all three models) and for the UK as a whole (PCM and UKIAM)

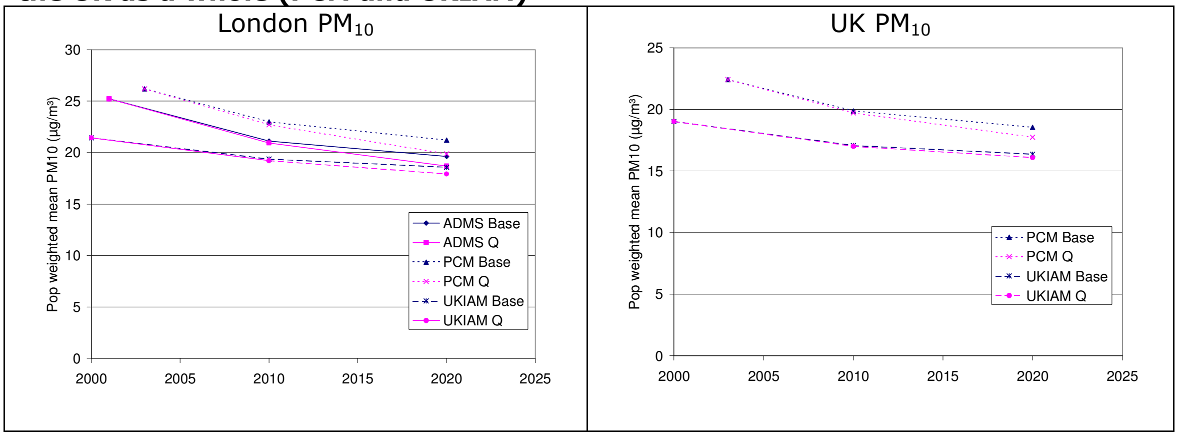
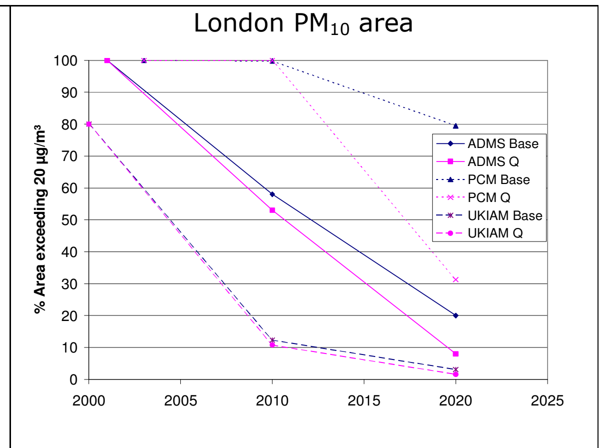


Figure 3.2b: Percentage of areas, population and road lengths in London that are predicted by the PCM, ADMS-Urban and UKIAM models (road length ADMS-Urban and PCM only) to have exceedences



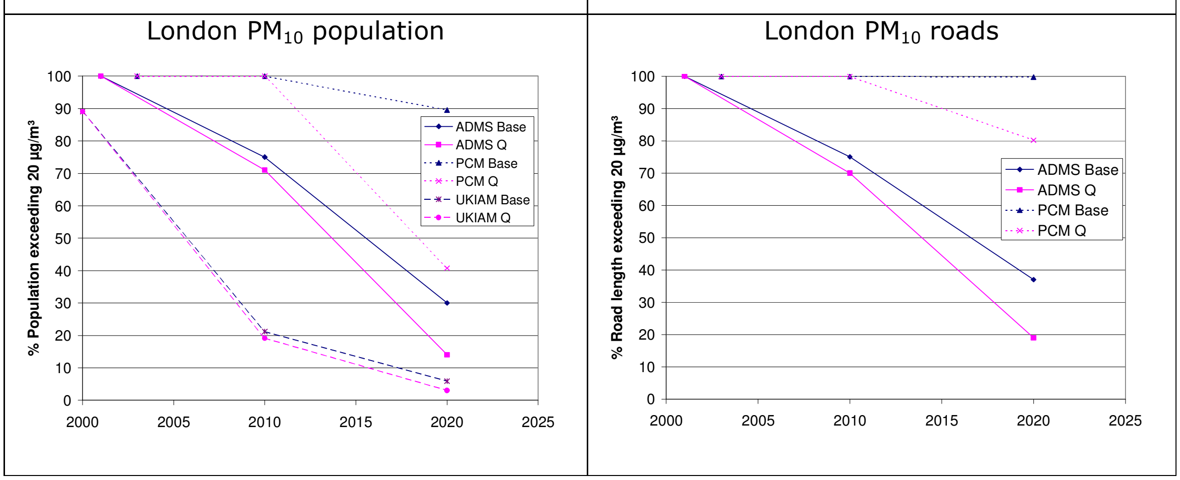


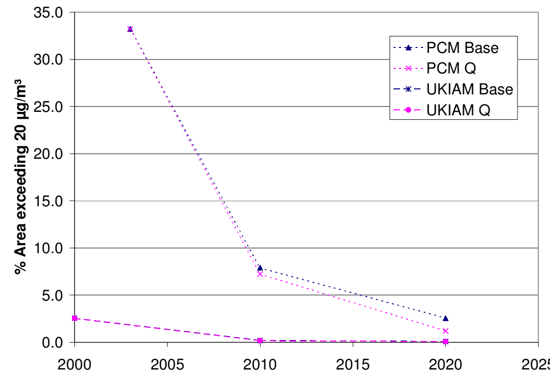
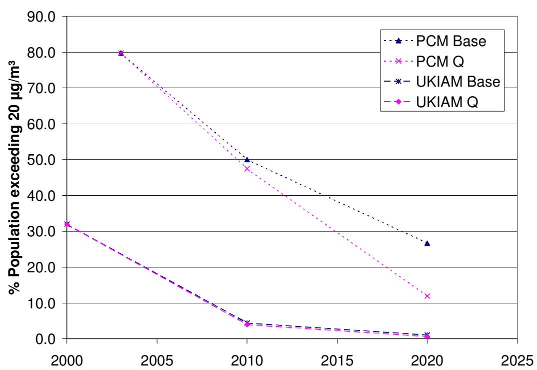
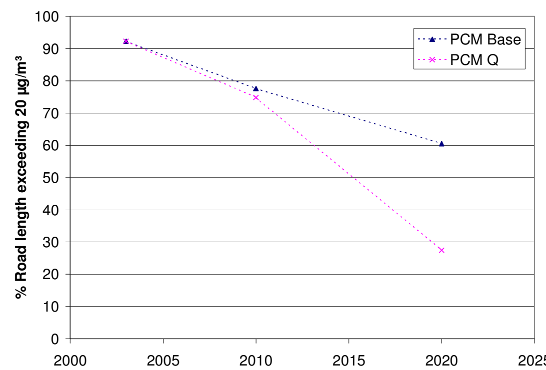
Figure 3.2c: Percentage of areas, population and road lengths in the UK that are predicted by the PCM and UKIAM models (road length PCM only) to have exceedences	UK PM_{10} area 
UK PM_{10} population 	UK PM_{10} roads 

Table 3.2 Comparison of population-weighted mean concentrations (μg m^{-3}, gravimetric) and exceedence statistics

London	ADMS-Urban Base			ADMS-Urban Q	
	2001	2010	2020	2010	2020
Population weighted mean	25.2	21.1	19.6	20.9	18.7
% Area exceeding 20µg/m³	100	58	20	53	8
% Population exceeding 20µg/m³	100	75	30	71	14
% Road length exceeding 20µg/m³	100	75	37	70	19
	PCM Base			PCM Q	
	2003	2010	2020	2010	2020
Population weighted mean	26.2	23.0	21.2	22.7	19.9
% Area exceeding 20µg/m³	100.0	99.8	79.5	99.8	31.3
% Population exceeding 20µg/m³	100.0	100.0	89.5	100.0	40.8
% Road length exceeding 20µg/m³	99.9	99.9	99.7	99.9	80.2
	UKIAM Base			UKIAM Q	
	2000	2010	2020	2010	2020
Population weighted mean	21.4	19.4	18.6	19.2	17.9
% Area exceeding 20µg/m³	80.0	12.3	3.1	10.8	1.5
% Population exceeding 20µg/m³	89.0	21.2	5.9	19.2	3.0
UK	PCM Base			PCM Q	
	2003	2010	2020	2010	2020
Population weighted mean	22.4	19.9	18.5	19.7	17.7
% Area exceeding 20µg/m³	33.2	7.9	2.6	7.2	1.2
% Population exceeding 20µg/m³	79.7	50.0	26.7	47.5	11.9
% Road length exceeding 20µg/m³	92.3	77.6	60.5	74.9	27.5
	UKIAM Base			UKIAM Q	
	2000	2010	2020	2010	2020
Population weighted mean	19.0	17.1	16.4	17.0	16.1
% Area exceeding 20µg/m³	2.6	0.2	0.1	0.2	0.1
% Population exceeding 20µg/m³	32.0	4.4	1.1	4.0	0.7

PCM predicts a larger area, population and length of major road to be exceeding 20 μg m^{-3} in London than ADMS-Urban. The extent of exceedence predicted by UKIAM is smaller still. This is probably largely due to the different base years used. Given the different modelling methods and base years used and that the extent of exceedence can be very sensitive to small changes in concentrations the agreement between ADMS-Urban and PCM is reasonably good. For the UK, PCM predicts a much larger extent of area and population exceeding in the base year than UKIAM, this is likely to be largely due to the different base years and spatial scales of the assessments. Much smaller areas and populations are predicted to be exceeding 20 μg m^{-3} at background locations in 2020.

3.3 IMPACT OF MEASURES ON POPULATION-WEIGHTED MEAN CONCENTRATIONS

Table 3.3 lists the impact of measure Q on the predicted population-weighted mean concentrations in 2010 and 2020, as discussed above.

Table 3.3 the impact of measure Q on population-weighted mean concentrations (μg m^{-3}, gravimetric)

	2010	2020
London ADMS-Urban	-0.17	-0.96
London PCM	-0.29	-1.34
London UKIAM	-0.15	-0.66
UK PCM	-0.17	-0.80
UK UKIAM	-0.07	-0.28

3.4 SITE-SPECIFIC SOURCE APPORTIONMENT OF PM_{10} CONCENTRATIONS IN LONDON

Table 3.4 shows a comparison of the source apportionment of annual mean PM_{10} concentrations in the base year and in 2010 and 2020 for the baseline predictions from ADMS-Urban and PCM for selected monitoring sites in London. There are a number of differences in the detailed source apportionment and from site to site due to the differences in the inventories used (LAEI and NAEI), base years and modelling methods. A direct comparison is also not possible due to the different ways the models work, such as the splits into major and minor roads in ADMS-Urban for road traffic exhaust emissions and the 'additional' concentration for sources not included in the LAEI (which mostly represents non-exhaust traffic emissions), and the roadside increment and other roads for PCM. Overall, however, the source apportionment results are reasonably similar. Averaged over the sites considered the total contribution from roads declines from 27% in the base year to 22% in 2020 for ADMS-Urban (including the additional source contribution) and from 30% to 26% for PCM. The contribution from the regional background increases from 61% to 63% for ADMS-Urban and from 62% to 64% for PCM. The contribution from all other sources increases from 12% to 16% for ADMS-Urban and from 8% to 9% for PCM.

Table 3.4. Comparison of site-specific source apportionment of annual mean PM_{10} concentrations (µg m^{-3}, gravimetric)

a) ADMS-Urban

2001	Total	Major Roads	Minor Roads	Industrial	Other Area	Additional	Background
London Marylebone Road	46.5	17.1	0.6	1.1	1.0	7.6	19.2
London Bloomsbury	28.5	2.7	0.7	2.2	1.0	2.7	19.2
London N. Kensington	25.7	1.6	0.5	0.7	1.9	1.8	19.2
2010							
London Marylebone Road	35.1	8.4	0.3	1.1	1.1	7.6	16.5
London Bloomsbury	24.2	1.2	0.3	2.4	1.2	2.7	16.5
London N. Kensington	21.8	0.8	0.3	0.8	1.7	1.8	16.5
2020							
London Marylebone Road	32.7	7.4	0.2	1.1	1.1	7.6	15.2
London Bloomsbury	22.7	1.0	0.2	2.4	1.2	2.7	15.2
London N. Kensington	20.4	0.6	0.2	0.8	1.7	1.8	15.2

b) PCM

2003	Total	Roadside increment	Other roads	Industrial	Other Area	Background
London Marylebone Road	47.1	17.1	6.3	0.7	2.0	21.0
London Bloomsbury	31.3	0.0	7.3	0.8	2.2	21.0
London N. Kensington	28.5	0.0	5.2	0.6	1.7	21.0
2010						
London Marylebone Road	37.4	11.7	4.9	0.7	1.5	18.7
London Bloomsbury	26.9	0.0	5.7	0.8	1.7	18.7
London N. Kensington	24.8	0.0	4.2	0.7	1.3	18.7
2020						
London Marylebone Road	33.4	9.6	4.4	0.8	1.7	16.9
London Bloomsbury	25.0	0.0	5.2	0.9	1.9	16.9
London N. Kensington	23.0	0.0	3.8	0.7	1.5	16.9

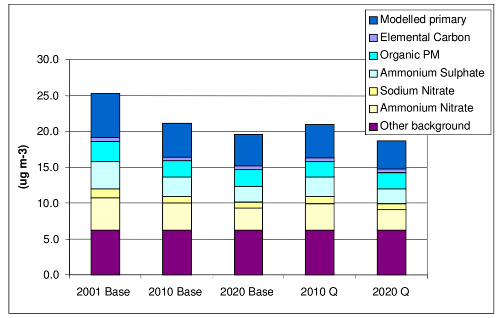
3.5 SOURCE APPORTIONMENT OF REGIONAL BACKGROUND PM_{10} CONCENTRATIONS

Figure 3.5 shows a comparison of the source apportionment of regional background concentrations for the different models in the base year and for baseline and measure Q projections in 2010 and 2020. ADMS-Urban, PCM and UKIAM results are shown for

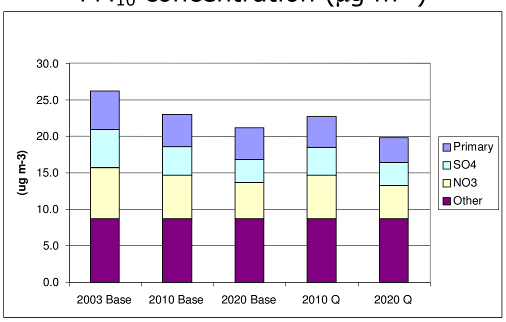
London and PCM and UKIAM results are shown for the UK. Population-weighted mean total concentrations are shown.

Figure 3.5: Source apportionment of regional background concentrations for the different models in the base year and for baseline and measure Q projections in 2010 and 2020. ADMS-Urban, PCM and UKIAM results are shown for London and PCM and UKIAM results are shown for the UK

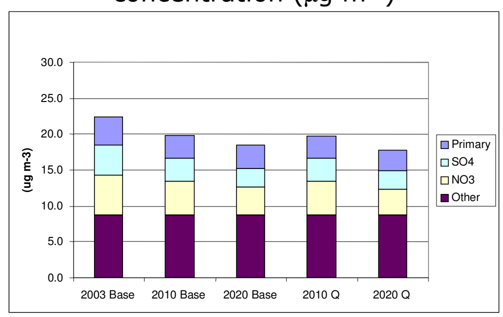
ADMS-Urban London PM_{10} ($\mu g\ m^{-3}$)



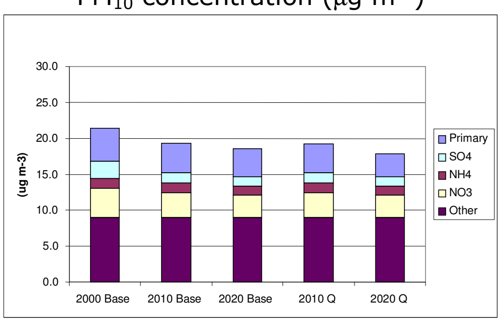
PCM London population-weighted mean PM_{10} concentration ($\mu g\ m^{-3}$)



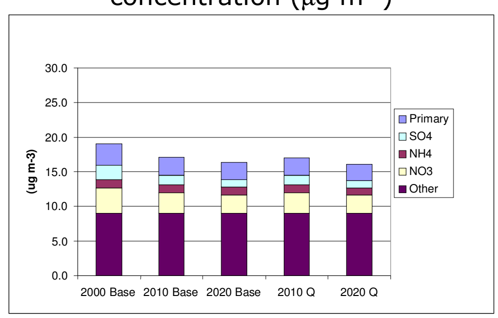
PCM UK population-weighted mean PM_{10} concentration ($\mu g\ m^{-3}$)



UKIAM London population-weighted mean PM_{10} concentration ($\mu g\ m^{-3}$)



UKIAM UK population-weighted mean PM_{10} concentration ($\mu g\ m^{-3}$)



The categories are different for each model, as is the relative source apportionment. The sulphate and nitrate masses in the PCM model include the counter ions, for example. Overall, however, the source apportionment of regional background is reasonably consistent between the different models. Table 3.5 shows the percentage contributions to the concentrations from the broad categories of primary, secondary and other sources of PM for London in 2010. The results for ADMS-Urban and PCM are quite similar, UKIAM has a smaller percentage contribution from secondary and a larger percentage contribution from other PM.

Table 3.5 Source apportionment of background PM_{10} concentrations for London (percent)

a) Percentage of total baseline concentrations in 2010

	ADMS-Urban	PCM	UKIAM
Primary	25	19	21
Secondary	46	43	32
Other	30	38	46

b) Concentration for measure Q as a percentage of the baseline in 2020

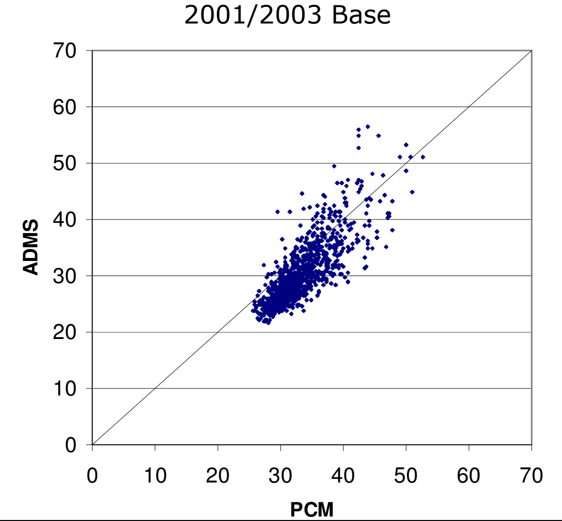
	ADMS-Urban	PCM	UKIAM
Primary	89	78	84
Secondary	95	95	99
Total	95	94	96

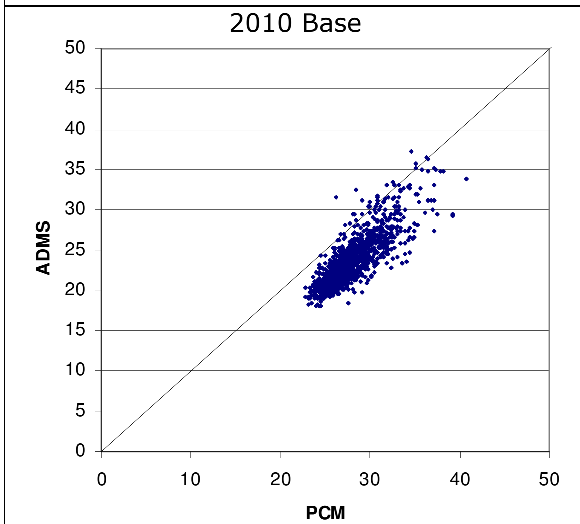
Table 3.5 also shows the regional background concentration for measure Q in 2020 as a percentage of the baseline concentration in the same year. The changes in primary contributions for measure Q are quite similar for PCM and UKIAM, the impact of Q on primary is rather smaller for ADMS-Urban. The percentage changes in secondary PM are similar for ADMS-Urban and PCM but smaller for UKIAM. This is partly because of different assumptions concerning the source apportionment of secondary PM between sources that are influenced by measure Q and those which are not, such as shipping, and assumptions concerning the linearity of the response of concentrations to changes in emissions. This is discussed in more detail in (ApSimon et al 2006, UKIAM report, Stedman et al 2006b). The UKIAM model for example has a 22% response of UK nitrate concentrations to changes in UK emissions of NO_x. This is derived from EMEP source receptor data, which suggests that in 2010 the contributions to changes in nitrate concentrations would be as follows: 22% UK sources, 29% other EU countries, 18% shipping and 31% other sources (outside the EMEP European map area) and non-linearity. The 2003 PCM modelling made the following assumptions: 49% UK, 28% other EU countries, 23% from shipping and no contribution from other sources or non-linearity. Thus the response to changes in NO_x UK and EU emissions was assumed to be greater in the PCM modelling. For the additional PCM modelling presented in Grice et al (2007) a component of non-linearity of response was assumed leading to an effective 25% response of UK nitrate concentrations to changes in UK NO_x emissions, which is more consistent with the UKIAM model.

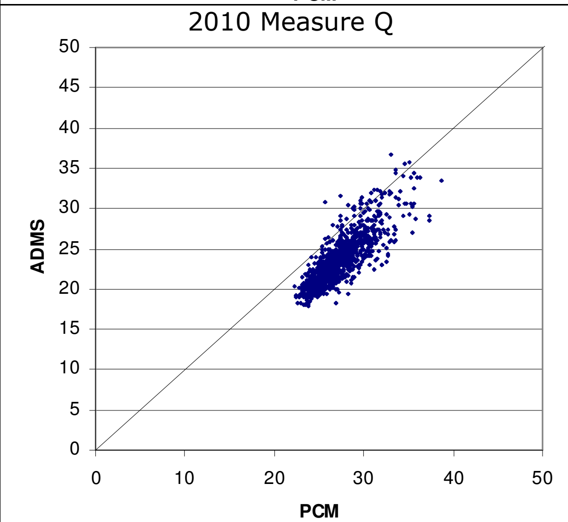
3.6 COMPARISON OF MODELLED ROADSIDE ANNUAL MEAN PM_{10} CONCENTRATIONS

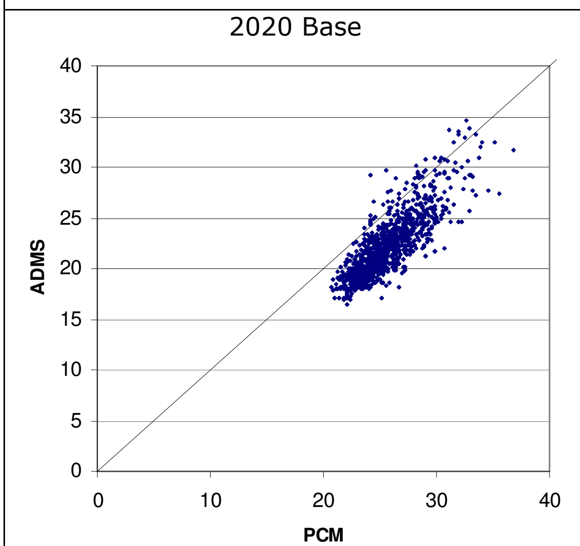
Figure 3.6 shows comparisons of modelled roadside annual mean PM_{10} concentrations from the ADMS-Urban and PCM models for the base years and for 2010 and 2020 for over 1300 roads in London. Overall the comparison is consistent with the site-specific modelling results presented above. The PCM results are generally higher as a result of the higher 2003 base year concentrations. The reduction in concentrations between the base year and 2020 is very similar for the two models. The mean roadside PM_{10} concentration predicted by ADMS-Urban for the baseline declines from 30 $\mu g\ m^{-3}$ to 22 $\mu g\ m^{-3}$ between the base year and 2020 and the mean roadside concentration predicted by PCM declines from 33 $\mu g\ m^{-3}$ to 25 $\mu g\ m^{-3}$.

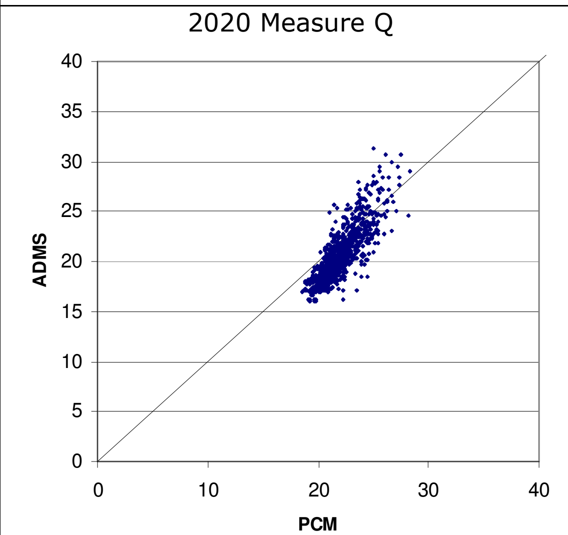
Figure 3.6: Comparisons of modelled roadside annual mean PM_{10} concentrations from the ADMS-Urban and PCM models for the base years and for 2010 and 2020 for over 1300 roads in London ($\mu g\ m^{-3}$, gravimetric)











3.7 EXPOSURE REDUCTION

Table 3.7 shows a comparison of the modelled exposure reduction (ER) in London and in the UK between 2010 and 2020 for the baseline and measure Q calculated from the population-weighted mean concentrations for the population of London and the UK. Note that this is slightly different from the exposure metric proposed in the AQS review which would apply to large urban areas only. The analysis presented in the AQS consultation document (Defra et al 2006a) based on the PCM modelling results for the 2003 base year suggests that the ER for measure Q would be slightly higher when considering the population in large urban areas only.

Table 3.7 Comparison of exposure reduction estimates between 2010 and 2020 (percent)

	Baseline	Measure Q
London		
ADMS-Urban	-7.0%	-10.8%
PCM	-7.8%	-12.5%
UKIAM	-4.1%	-6.7%
UK		
PCM	-6.7%	-10.0%
UKIAM	-4.1%	-5.4%

The modelled ER for London is similar for ADMS-Urban and PCM for the baseline and the value for UKIAM is about half. The increase in ER for measure Q is somewhat greater for the PCM modelling, the impact of the measures on ER is a bit less for UKIAM. The lower ER values for UKIAM probably reflect the differing assumptions concerning the source apportionment of regional background concentrations, non-linearity and the larger spatial resolution of the model. The modelled ER for the UK predicted by UKIAM is also roughly half of that predicted by PCM.

3.8 CONCLUDING REMARKS

The choice of base year has an important influence on the predicted PM_{10} concentrations. The highest PM_{10} concentrations are typically predicted by the PCM model for which a base year of 2003, a year with unusually high secondary PM concentrations, was used. Overall the agreement between the model results for PM_{10} is reasonably good.

The predicted decline in baseline concentrations to 2020 and the impact of measures is least for UKIAM. This is likely to be due to a different treatment of the changes in regional background concentrations, which is particularly important for PM. The predicted extent of exceedences is very sensitive to small changes in concentrations and thus on the choice of base year and the assumptions for regional background concentrations.

The site-specific source apportionments for PCM and ADMS-Urban are reasonably consistent for the main contributors: the regional background (largest) and road traffic. This is despite the complications of the somewhat different definition of the source categories in PCM and ADMS-Urban.

The detailed source apportionment of regional background PM_{10} concentrations is different for the three models but the overall apportionment into broad categories is reasonably consistent. The contribution from primary PM in London is quite consistent across the models. UKIAM has the lowest contribution from secondary PM and the highest contribution from other sources. The impact of measures on secondary PM is much less for UKIAM than for the other two models due to the different assumptions concerning the source apportionment of secondary PM and the treatment of imported contributions from shipping and from other European countries and beyond. These differences are reflected in the percentage exposure reduction (ER) between 2010 and 2020 predicted by the models. The results for ADMS-Urban and PCM are quite similar and about twice the magnitude of that predicted by UKIAM.

4 $PM_{2.5}$

4.1 COMPARISON OF POPULATION-WEIGHTED MEAN CONCENTRATIONS

Figure 4.1 shows a comparison of the population-weighted annual mean $PM_{2.5}$ concentrations predicted by the PCM and ADMS-Urban models for London and for the UK as a whole for the PCM model. The population-weighted mean concentrations are also listed in Table 4.1. The ADMS-Urban and PCM predictions are very similar for $PM_{2.5}$ in contrast to the case for PM_{10} where the higher values for PCM were attributed to the weather in 2003. The explanation for this mainly lies in the road traffic contribution for which the ratio ($PM_{2.5}$/ PM_{10}) of concentrations is greater for ADMS-Urban than for PCM. Whereas this ratio is the same as the ratio of emissions for ADMS-Urban this is not the case for PCM where a different set of regression coefficients are derived for PM_{10} and $PM_{2.5}$. This results in this case in the ratio of concentrations being different (smaller) from the ratio of emissions.

The decline in baseline concentrations and impact of measure Q on population weighted mean concentration is similar for the two models. The decline and impact of the measures were also similar for PM_{10}, for which the absolute concentrations were more different.

Figure 4.1: Population-weighted annual mean $PM_{2.5}$ concentrations predicted by the PCM and ADMS-Urban for London and for the UK as a whole for the PCM model

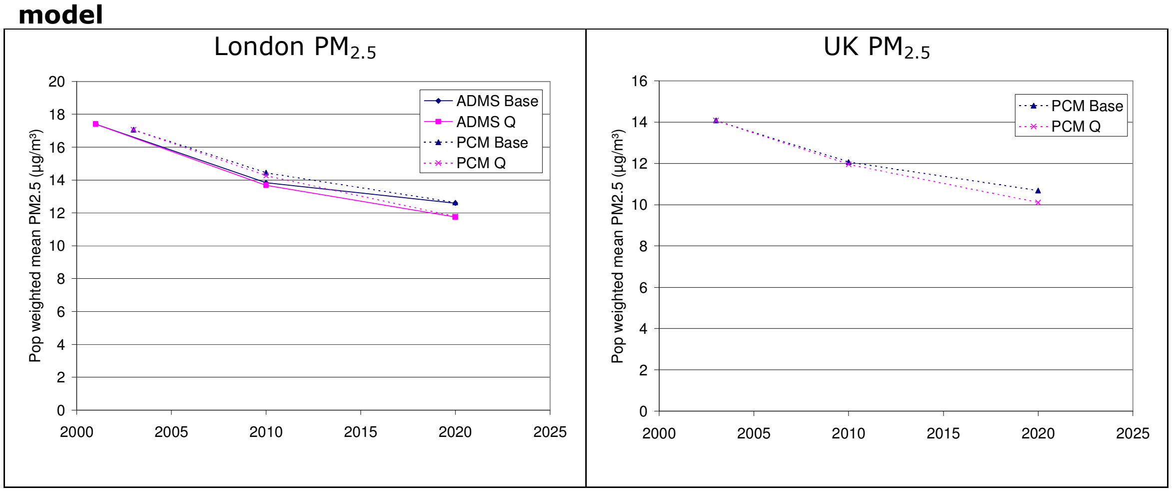


Table 4.1 Comparison of population-weighted mean concentrations ($\mu g\ m^{-3}$, gravimetric)

London	ADMS-Urban Base			ADMS-Urban Q	
	2001	2010	2020	2010	2020
Population weighted mean	17.4	13.8	12.6	13.7	11.8
	PCM Base			PCM Q	
	2003	2010	2020	2010	2020
Population weighted mean	17.1	14.4	12.6	14.3	11.8
UK	PCM Base			PCM Q	
	2003	2010	2020	2010	2020
Population weighted mean	14.1	12.1	10.7	12.0	10.1

4.2 IMPACT OF MEASURES ON POPULATION-WEIGHTED MEAN CONCENTRATIONS

Table 4.2 lists the impact of measure Q on the predicted population-weighted mean concentrations in 2010 and 2020, as discussed above.

Table 4.2 The impact of measure Q on population-weighted mean concentrations ($\mu g\ m^{-3}$, gravimetric)

	2010	2020
London ADMS-Urban	-0.15	-0.84
London PCM	-0.17	-0.84
UK PCM	-0.11	-0.57

4.3 SITE-SPECIFIC SOURCE APPORTIONMENT OF $PM_{2.5}$ CONCENTRATIONS IN LONDON

Table 4.4 shows a comparison of the source apportionment of annual mean $PM_{2.5}$ concentrations in the base year and in 2010 and 2020 for the baseline predictions from ADMS-Urban and PCM for selected monitoring sites in London. There are a number of differences in the detailed source apportionment and from site to site due to the different inventories used (LAEI and NAEI), base years and modelling methods. A direct comparison is also not possible due to the different ways the models work, such as the splits into major and minor roads for ADMS-Urban and roadside increment and other roads for PCM. Overall, however, the source apportionment results are reasonably similar. Averaged over the sites considered the total contribution from roads declines from 35% in the base year to 25% in 2020 for ADMS-Urban and from 29% to 23% for PCM. The contribution from the regional background increases from 58% to 63% for ADMS-Urban and from 67% to 70% for PCM. The contribution from all other sources (including 'additional') increases from 7% to 12% for ADMS-Urban and from 4% to 6% for PCM. The largest differences in the source apportionment are the sizes of the contribution from road and other sources. As for PM_{10} the contribution from regional background is high at about 60 - 70%.

Table 4.3. Comparison of site-specific source apportionment of annual mean $PM_{2.5}$ concentrations (μg m^{-3}, gravimetric)

a) ADMS-Urban

2001	Total	Major Roads	Minor Roads	Industrial	Other Area	Additional	Background
London Marylebone Road	32.5	15.4	0.3	0.6	0.5	1.7	13.9
London Bloomsbury	19.2	2.4	0.4	1.2	0.6	0.6	13.9
2010							
London Marylebone Road	22.2	7.6	0.1	0.6	0.6	1.7	11.5
London Bloomsbury	15.4	1.0	0.2	1.4	0.7	0.6	11.5
2020							
London Marylebone Road	20.1	6.6	0.1	0.6	0.6	1.7	10.4
London Bloomsbury	14.0	0.9	0.1	1.4	0.7	0.6	10.4

b) PCM

2003	Total	Roadside increment	Other roads	Industrial	Other Area	Background
London Marylebone Road	27.4	8.6	2.8	0.2	0.7	15.1
London Bloomsbury	19.3	0.0	3.2	0.3	0.7	15.1
2010						
London Marylebone Road	21.1	5.5	2.0	0.2	0.5	12.9
London Bloomsbury	16.0	0.0	2.3	0.3	0.5	12.9
2020						
London Marylebone Road	18.2	4.3	1.6	0.3	0.7	11.2
London Bloomsbury	14.3	0.0	1.9	0.3	0.8	11.2

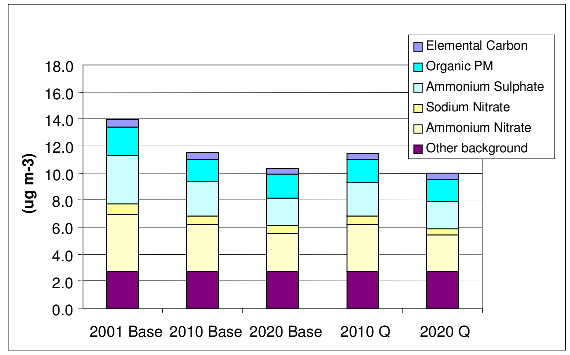
4.4 SOURCE APPORTIONMENT OF REGIONAL BACKGROUND $PM_{2.5}$ CONCENTRATIONS

Figure 4.4 shows a comparison of the source apportionment of regional background concentrations for the different models in the base year and for baseline and measure Q projections in 2010 and 2020. ADMS-Urban and PCM results are shown for London and PCM results are shown for the UK. Population-weighted mean total concentrations are shown.

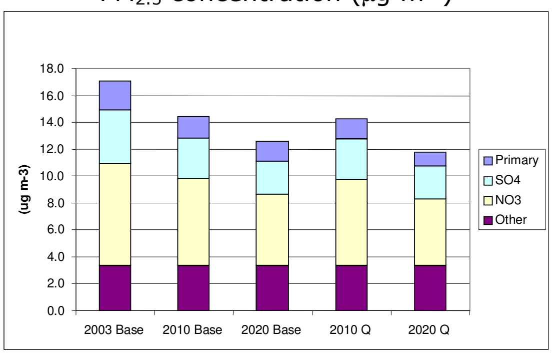
The categories are different for each model, as is the relative source apportionment. The sulphate and nitrate masses in the PCM model include the counter ions, for example. Overall, however, the source apportionment of regional background is reasonably consistent between the two models. Table 4.4 shows the percentage contributions to the concentrations from the broad categories of primary, secondary and other sources of PM for London in 2010. The results for ADMS-Urban and PCM are quite similar but ADMS-Urban has a larger primary component. The PCM nitrate contribution is larger than for ADMS-Urban and the PCM modelling may therefore overstate the relative contribution from nitrate to the total concentration. The source apportionment of regional background secondary PM within the PCM model has been completely revised for the 2004 base year modelling (Stedman et al 2006b) and the nitrate component for $PM_{2.5}$ is now more in line with other assessments.

Figure 4.4: Source apportionment of regional background concentrations for the different models in the base year and for baseline and measure Q projections in 2010 and 2020. ADMS-Urban and PCM results are shown for London and PCM results are shown for the UK

ADMS-Urban London $PM_{2.5}$ ($\mu g\ m^{-3}$)



PCM London population-weighted mean $PM_{2.5}$ concentration ($\mu g\ m^{-3}$)



PCM UK population-weighted mean $PM_{2.5}$ concentration ($\mu g\ m^{-3}$)

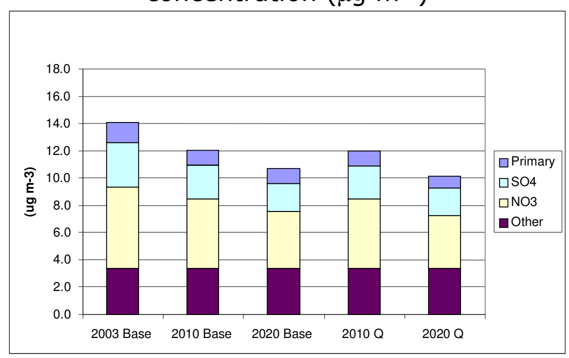


Table 4.4 Source apportionment of background $PM_{2.5}$ concentrations for London (percent)

a) Percentage of total baseline concentrations in 2010

	ADMS-Urban	PCM
Primary	20	11
Secondary	60	66
Other	19	23

b) Concentration for measure Q as a percentage of the baseline in 2020

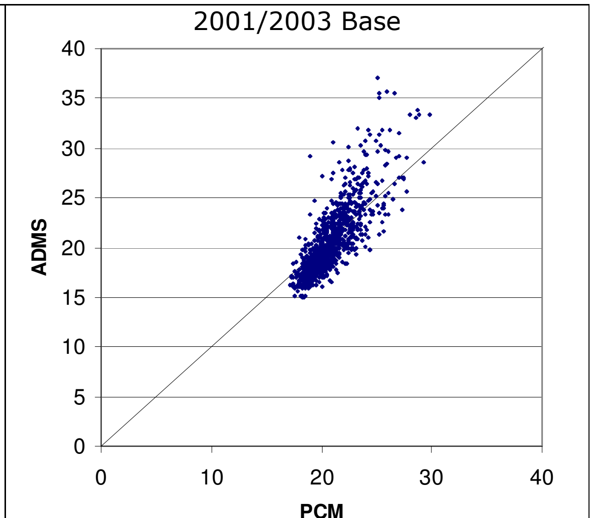
	ADMS-Urban	PCM
Primary	82	71
Secondary	95	95
Total	93	93

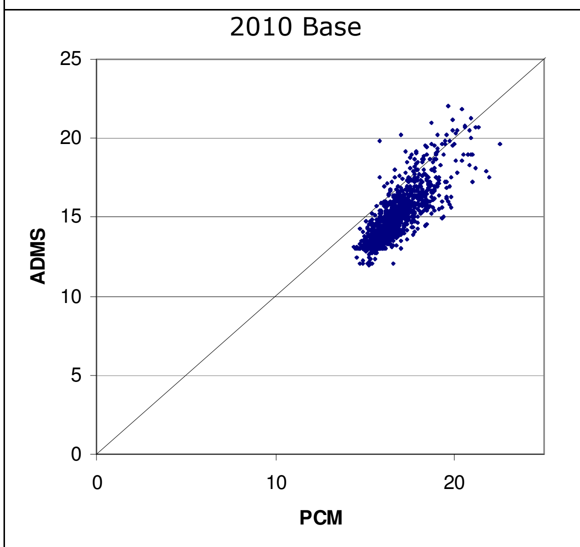
Table 4.4 also shows the regional background concentration for measure Q in 2020 as a percentage of the baseline concentration in the same year. The changes are very similar for the two models.

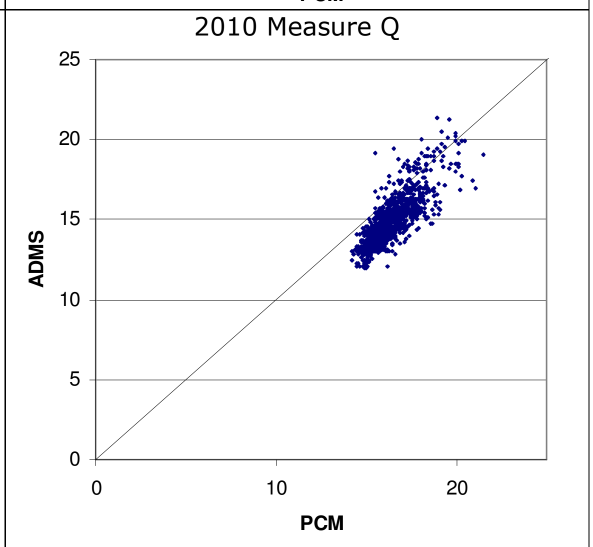
4.5 COMPARISON OF MODELLED ROADSIDE ANNUAL MEAN $PM_{2.5}$ CONCENTRATIONS

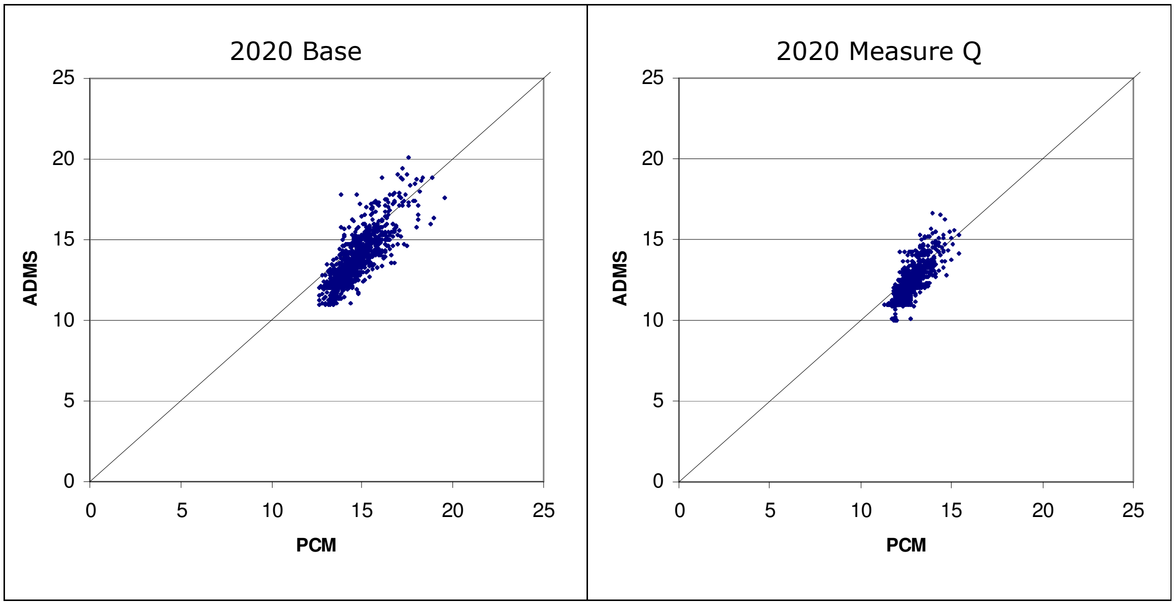
Figure 4.5 shows comparisons of modelled roadside annual mean $PM_{2.5}$ concentrations from the ADMS-Urban and PCM models for the base years and for 2010 and 2020 for over 1300 roads in London. The PCM results are generally higher as a result of the higher 2003 base year concentrations, particularly at lower concentrations in the base year but across the full range of concentrations for the projections. The reduction in concentrations between the base year and 2020 is very similar for the two models. The mean roadside $PM_{2.5}$ concentration predicted by ADMS-Urban for the baseline declines from 20 µg m^{-3} to 13 µg m^{-3} between the base year and 2020 and the mean roadside concentration predicted by PCM declines from 21 µg m^{-3} to 14 µg m^{-3}.

Figure 4.5: Comparisons of modelled roadside annual mean $PM_{2.5}$ concentrations from the ADMS-Urban and PCM models for the base years and for 2010 and 2020 for over 1300 roads in London (µg m^{-3}, gravimetric)









4.6 EXPOSURE REDUCTION

Table 4.6 shows a comparison of the modelled exposure reduction (ER) in London and in the UK between 2010 and 2020 for the baseline and measure Q calculated from the population-weighted mean concentrations for the population of London and the UK. Note that this is slightly different from the exposure metric proposed in the AQS review which would apply to large urban areas only. The analysis presented in the AQS consultation document (Defra et al 2006b) based on the PCM modelling results for the 2003 base year suggests that the ER for measure Q would be slightly higher when considering the population in large urban areas only.

Table 4.6 Comparison of exposure reduction estimates between 2010 and 2020 (percent)

	Baseline	Measure Q
London		
ADMS-Urban	-9.0%	-14.1%
PCM	-12.6%	-17.4%
UK		
PCM	-11.5%	-15.5%

The modelled ER for London is higher for PCM than for ADMS-Urban for the baseline and for measure Q. This is because the predicted population-weighted mean concentration in 2010 is higher than for ADMS-Urban but the 2020 values are very similar.

4.7 CONCLUDING REMARKS

The predicted population-weighted mean $PM_{2.5}$ concentrations from the ADMS-Urban and PCM model are quite similar, as are the predicted declines in baseline concentrations to 2020 and the impact of the measures. The regional background is the largest contributor to the predicted concentrations at monitoring sites in London for which the source apportionment is reasonably consistent between the two models.

A comparison of the source apportionment of the regional background concentrations of $PM_{2.5}$ in contrast to the case for PM_{10} shows that ADMS-Urban has a larger contribution from road traffic and PCM has a larger contribution from secondary nitrates. Comparisons of site specific apportionment shows that the ratio of the $PM_{2.5}/PM_{10}$ concentrations from road traffic is greater for ADMS-Urban than PCM.

The modelled ER for London is higher for PCM than for ADMS-Urban for the baseline and for the additional measures. This is because the predicted population-weighted mean concentration in 2010 is higher than for ADMS-Urban but the 2020 values are very similar.

5 Conclusions

5.1 INTRODUCTION

The use of alternative models allows the outputs from the PCM model to be compared with those from models that use different processes and input assumptions. The implications of the findings of this inter-comparison study for the development of UK air quality policy are discussed in this section.

Some of the main differences between the different models considered in the report are listed in Table 5.1. The impact of measure Q on predicted population-weighted mean concentrations in 2020 for each of the models is summarised in Table 5.2.

In this section the key parts of this model intercomparison exercise are synthesised. We discuss in turn differences and similarities in the formulation of the three models, comparisons of modelled concentrations and derived quantities such as population weighted mean concentrations and finally the policy implications of the study comparisons.

Table 5.1 summarises model input and model methodology and gives comments on the impacts of the differences as appropriate. The different approaches arise partly from the different purposes for which the models were designed. Of definite significance for the model comparisons are the base year utilised, the modelling methodology and spatial resolution of the model, the method of calculating NO_2 from NO_x and the specification of background concentrations and their future projections. It is not clear from this study whether the different emission inventories utilised have any significant impact on the comparisons.

Table 5.1 Summary of features and differences of approach

Feature	PCM	ADMS-Urban	UKIAM	Comments/Impacts of differences
Area covered in study	UK	London	UK	
Emission inventory	NAEI	LAEI	NAEI	The effect of the inventory is unclear from this study since in PCM concentrations calculated from emissions are adjusted empirically, whilst ADMS-Urban and UKIAM are difficult to compare because of the large difference in spatial resolution.
Base year	2003	2001	2000	Background PM concentrations are higher for 2003 meteorology due to higher secondary PM production and enhanced photochemical activity.
Model methodology	Based on dispersion modelling with empirical adjustment plus simple valued roadside increment for each road segment. Regional background from annual measurements	Dispersion modelling for each hour; sources treated explicitly. Regional background from rural measurements for each hour.	Source receptor model on 5km×5km grid.	These differences are reflected in the modelled concentrations and output for each model.
Spatial resolution of output	1km × 1km grid plus roadside increments	10m – 100m includes concentration gradients near roads	5km × 5km grid	A coarser spatial resolution generally leads to lower estimates of population-weighted mean concentrations and reduced sensitivity to local emission reduction measures.
Temporal resolution	Annual	Hourly	Annual	Uncertain and difficult to test. Difference may be greater in 'atypical' years.

Method used to predict NO_2 from NO_x	Empirically based partitioning model for annual averages	Explicit NO_x, O_3 chemistry; simplified chemistry for VOCs. Hourly.	Annual empirical relationship for annual averages.	There are differences in the response of NO_2 to changes in NO_x at the roadside and in background locations. The ratio of NO_2:NO_x increases more in future years for ADMS-Urban when NO_x concentrations are lower than either PCM or UKIAM.
Source apportionment of regional NOx (percentage from UK sources)	100%	100%	50%	Assuming 100% of regional NO_x is due to UK sources may overestimate the impact of UK measures on concentrations. Actual source apportionment may be somewhere between 100 and 50%
Response of UK secondary PM concentrations to changes in precursor emissions	Linear	Linear	Based on the EMEP model	The observed response is non-linear so a non-linear response may be an improvement depending on its formulation.

Table 5.2 brings together key results from the intercomparison and includes the following: for each of NO_x, NO_2, PM_{10} and $PM_{2.5}$ results are shown for 2010 base case, 2020 base case, 2020 measure Q and the change from 2020 base case to 2020 measure Q. For each of the pollutants the population-weighted mean concentrations (PWM) are given, whilst for NO_2 and PM_{10} the percentage of the population exceeding annual mean thresholds are presented – the annual mean of 40μgm^{-3} for NO_2 (PE40) and 20μgm^{-3} for PM_{10} (PE20). The results are given for London (ADMS-Urban, PCM, UKIAM) and the UK (PCM, UKIAM). The base case results for the base meteorological year have not been included here as they can add to the difficulty in interpretation between the different models because the emissions are significantly different between the years.

Table 5.2 (a) NO_x Population weighted mean concentrations

	2010 Base	2020 Base	2020 Measure Q		
				Reduction from 2020 base	
	μgm^{-3}	μgm^{-3}	μgm^{-3}	μgm^{-3}	%
London					
ADMS-Urban	56.7	47.9	42.7	5.2	10.9
PCM	46.8	40.3	35.5	4.8	11.9
UKIAM	56.7	50.9	47.0	3.9	7.7
UK					
PCM	27.7	22.8	19.8	3.0	13.2
UKIAM	29.3	26.0	23.9	2.1	8.1

(b) NO_2 Population weighted mean concentrations (PWM) and percentage of population exceeding limit value of 40μgm^{-3} (PE40)

	2010 Base		2020 Base		2020 Measure Q				
					Magnitude		Reduction from 2020 base		
	PWM μgm^{-3}	PE40 %	PWM μgm^{-3}	PE40 %	PWM μgm^{-3}	PE40 %	PWM μgm^{-3}	PWM %	PE40 %
London									
ADMS-Urban	35.0	19.9	31.2	10.6	27.8	8.0	3.4	12.2	2.6
PCM	29.9	4.1	26.9	2.0	24.7	1.3	2.2	8.9	0.7
UKIAM	32.9	20.4	30.3	16.4	28.5	7.7	1.8	6.3	8.7
UK									
PCM	19.5	0.5	16.8	0.3	15.0	0.2	1.8	12.0	0.1
UKIAM	18.9	4.1	17.0	3.4	15.8	2.6	1.2	7.6	0.8

(c) PM_{10} Population weighted mean concentrations (PWM) and percentage of pollution exceeding annual mean of 20μgm^{-3} (PE20)

	2010 Base		2020 Base		2020 Measure Q				
					Magnitude		Reduction from 2010 base		
	PWM μgm^{-3}	PE20 %	PWM μgm^{-3}	PE20 %	PWM μgm^{-3}	PE20 %	PWM μgm^{-3}	PWM %	PE20 %
London									
ADMS-Urban	21.1	75.0	19.6	30.0	18.7	14.9	0.9	4.8	15.1
PCM	23.0	100.0	21.2	89.5	19.9	40.8	1.3	6.5	48.7
UKIAM	19.4	21.2	18.6	5.9	17.9	3.0	0.7	3.9	2.9
UK									
PCM	19.9	50.0	18.5	26.7	17.7	11.9	0.8	4.5	14.8
UKIAM	17.1	4.4	16.4	1.1	16.1	0.7	0.3	1.9	0.4

(d) $PM_{2.5}$ Population weighted mean concentrations

	2010 Base	2020 Base	2020 Measure Q		
	μgm^{-3}	μgm^{-3}	μgm^{-3}	Reduction from 2010 base μgm^{-3}	Reduction from 2010 base %
London					
ADMS-Urban	13.8	12.6	11.8	0.8	6.3
PCM	14.4	12.6	11.8	0.8	6.3

(e) The impact of measure Q on population-weighted mean concentrations (μg m^{-3}, gravimetric)

	PCM	ADMS-Urban	UKIAM
NO_2 London	-2.26	-1.40	-1.83
NO_2 UK	-1.80	-	-1.18
PM_{10} London	-1.34	-0.96	-0.66
PM_{10} UK	-0.80	-	-0.28
$PM_{2.5}$ London	-0.84	-0.84	-
$PM_{2.5}$ UK	-0.57	-	-

The source apportionment of base year concentrations and the assumptions on the impact of the changes in emissions represented by the baseline and additional measures to reduce concentrations on the different components are key to understanding the differences between the different models. The changes in population-weighted mean PM concentrations between the baseline and measure Q are probably the most important statistics since the impact of changes in long-term PM concentrations dominate the health benefits of the predicted reductions in concentrations. The extent of exceedences predicted by the models are also of interest in terms of the development of air quality policy, although the formal cost benefit analyses are dominated by the changes in population-weighted mean concentrations.

In addition to differences in data on emissions the models also make different assumptions about the contributions imported into the areas modelled, including the contribution from outside the UK. These include contributions to NO_x emissions from shipping, which are steadily increasing over time, as well as from other European countries; and also contributions to NO_3 and SO_4 from North America and outside Europe. Uncertainties arise as to how these contributions will change over time, and the models make different assumptions- UKIAM being more pessimistic than PCM and ADMS.

5.2 NO_2

The predicted impacts of measure Q in 2020 in terms of the population-weighted mean NO_2 concentrations are listed in Table 5.2. The largest changes are predicted by the PCM model. A smaller impact is predicted by the ADMS-Urban model and this is likely to be as a result of the finer spatial scale and chemical scheme adopted, which takes explicit account of concentrations in the vicinity, but not adjacent to, the roadside. Smaller changes are also predicted by the UKIAM model and this is likely to be due to a combination of UKIAM making more pessimistic assumptions about the imported components and the larger spatial resolution of the model. The health impacts of NO_2 do not make a large contribution to the quantified health impacts in the cost benefit analysis.

The predicted extents of exceedence of 40 µg m^{-3} at background and roadside locations predicted for 2010 and 2020 by the different models are reasonably consistent.

For the cases of NO_x and NO_2 it is noted that for both pollutants PCM exhibits a general tendency for the lowest population-weighted mean concentrations, the smallest areas of exceedence (PE40s) and the largest reductions between base case 2010 and 2020 measure Q for the population-weighted mean concentrations, but the smallest reduction in areas of exceedence (PE40) because in the case of PCM these are small by 2010. The lower values as compared to ADMS-Urban (in London) may be partly explained by lower spatial resolution (for NO_x and NO_2) and smaller increase in rates of conversion of NO_x to NO_2 as NO_x reduces resulting in greater sensitivity to NO_x reduction (for NO_2). The lower values as compared to UKIAM are partly explained by the lower projected decreases in background NO_x in UKIAM, however we would expect this effect to be offset by the lower spatial resolution of UKIAM which is not apparent.

5.3 PM_{10}

The PCM model predicts the larger impact of measure Q on population-weighted mean PM_{10} concentration in 2020 than the UKIAM model (Table 5.2). This is likely to be due to a combination of different assumptions about the response of secondary PM to changes in precursor emissions, the source apportionment of regional background concentrations (UKIAM has rather less secondary PM overall), the base year and the spatial scale of the models. The impact predicted by ADMS-Urban is also somewhat lower and this is likely to have been due to differing source apportionment of the local contribution to ambient PM_{10} with the PCM model having a somewhat larger contribution from road traffic sources. These differences also have implications for the predicted percentage of exposure reduction between 2010 and 2020 for which the PCM model predicts the largest reductions.

The comparison of the model assumptions and results for PM_{10} suggests that it is more likely that the PCM modelling (which informed the AQS review consultation, Defra et al 2006a, 2006b) would have over-predicted the impact of measure Q on ambient PM concentrations, and thus the benefits of these reductions, rather than underestimated.

The predicted extent of exceedences for PM_{10} has also informed the review of the AQS and the results of this inter-comparison clearly show that the predicted extent of exceedences is highly variable between the different models. This confirms the results of the sensitivity analyses presented by Stedman et al (2006a) and Defra (2006b) that showed that the predictions of annual mean PM_{10} concentrations are subject to considerable uncertainty. The accuracy of predictions of exceedences of threshold concentrations are likely to be highly dependent on the weather in any future year, uncertainties in the response of PM concentrations to changes in emissions of precursor gases and uncertainties about the source apportionment of PM. The predicted extent of exceedence is known to be particularly uncertain (AQEG, 2005). The analysis presented here confirms that the predicted extent of exceedences is subject to more uncertainty than predictions of the marginal changes in PM concentrations likely to result from current or possible future policy measures. This is a useful insight since it is the marginal changes in concentrations that dominate the cost-benefit analyses, rather than the predicted extent of exceedences.

For the case of PM_{10} the PCM population-weighted mean concentrations are larger than those for ADMS-Urban and UKIAM which can be attributed entirely to the difference in the secondary component (without this PCM concentrations are somewhat lower). As with NO_x and NO_2 PCM shows the largest changes in population-weighted mean concentrations between 2010 and 2020 with measure Q. In this case it also shows the largest changes in PE20; these changes in PE20 vary significantly between the models despite the modest reductions in population-weighted mean concentrations confirming that areas of exceedence can be very sensitive to small changes in concentrations. UKIAM shows smaller differences between 2010 and 2020 measure Q than either ADMS-Urban or PCM on population-weighted mean concentrations (absolute and percentages) because of smaller future reductions in background.

5.4 $PM_{2.5}$

The modelling of $PM_{2.5}$ concentrations is subject to greater uncertainty than the modelling of PM_{10} due to the much smaller amount of monitoring data available for model verification and development. The population-weighted mean concentrations predicted by the PCM and ADMS-Urban are in very good agreement for $PM_{2.5}$, as are the predicted changes in concentration for measure Q. The differences in the source apportionment suggest that this very good agreement is partly fortuitous and the uncertainties associated with the modelling of ambient $PM_{2.5}$ remain high. Remember, also, that both the PCM and ADMS-Urban models assumed a linear response of secondary PM to changes in precursor emissions. The predicted exposure reduction between 2010 and 2020 is somewhat greater for the PCM modelling. This is likely to be due to the differing source apportionment between the two models, the PCM model has a larger contribution from nitrate and a smaller contribution from primary PM. The ADMS-Urban modelling is more consistent between PM_{10} and $PM_{2.5}$ than the PCM modelling for which the source apportionment of PM_{10} and $PM_{2.5}$ is less consistent.

The relatively close agreement between PCM and ADMS-Urban for $PM_{2.5}$ is not consistent with the differences in PM_{10} due to the different base years utilised and may be due to the fact that the relationship between primary emissions and concentrations is not fully consistent for PM_{10} and $PM_{2.5}$ within the 2003 base year PCM modelling.

5.5 POLICY IMPLICATIONS

Each of the models compared in the report have associated with them uncertainties arising from their various different features and modelling methodologies (for example see Table 5.1 and also Stedman et al (2006a) and DEFRA (2006b) which in this case for PCM show the considerable uncertainty in annual mean concentrations of PM_{10}. However the comparison exercise has revealed some consistency and therefore robustness in the differences in the models which do have clear policy implications. PCM generally gives a more optimistic picture then either ADMS-Urban or UKIAM. It predicts the largest reductions in both absolute and percentage terms in both PM_{10} and $PM_{2.5}$ for both UK and London even though in these cases it predicts higher concentrations because of the base year considered. In the case of NO_2 it is more 'optimistic' then either ADMS-Urban or UKIAM in London and predicts a greater impact of measure Q on the population-weighted mean concentrations than UKIAM across the UK. These differences may partly be explained by differences in the forward projection of background concentrations (which in future studies could be harmonised between the models), however the other differences arising mainly from differences in model resolution (spatial and temporal), the differences in the chemical conversion schemes for NO_x to NO_2 and the extent to which monitoring data are used directly in the models are not easily addressed because of inherent differences in the model methodologies.

5.6 ADDITIONAL MODELLING WORK

Additional PCM modelling work has been carried out to support the AQS review since the publication of the consultation documents (Defra et al, 2006a, 2006b). This additional modelling work includes the following:

- Revised energy projections UEP21 (the previous modelling used UEP12)
- Revised energy projections UEP26
- Revised packages of additional measures (individual and combined measures)

This additional modelling (Grice et al, 2007) has incorporated a number of changes to the PCM models to take account of some of the key results of this model comparison, in order to improve the confidence with which the results can be used within the cost benefit analyses. These changes include:

- Additional modelling for the 2004 base year (to provide estimates for an additional base year with less unusual meteorological conditions)
- A revised source apportionment of regional rural NO_x concentrations to take account of the contributions from shipping and sources in continental Europe
- Incorporation of non-linearity in the impact of changes in precursor emissions on secondary PM
- A more consistent source apportionment of PM_{10} and $PM_{2.5}$ concentrations (Stedman et al 2007b)

6 Acknowledgements

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

7 References

ApSimon, H., Oxley, T. & Valiantis, M., 2006, Application of the UKIAM to scenarios relating to the DEFRA Air Quality Strategy (AQS), Final report to DEFRA, Contract CPEA4, Imperial College.

AQEG (2004). Nitrogen Dioxide in the United Kingdom. Defra, London. http://www.defra.gov.uk/environment/airquality/aqeg/nitrogen-dioxide/index.htm

AQEG (2006). Air Quality Expert Group. Trends in Primary Nitrogen Dioxide in the UK. Draft report. http://www.defra.gov.uk/corporate/consult/aqeg-nitrogendioxide/index.htm

Carslaw D C (2005). Evidence of an Increasing NO_2/NO_X Emissions Ratio from Road Traffic Emissions. *Atmospheric Environment*, **39** 4793-4802.

DEFRA et al (2006a). Department for Environment, Food and Rural Affairs, The Scottish Executive, Welsh Assembly Government and The Department of the Environment for Northern Ireland. The Air Quality Strategy for England, Scotland, Wales and Northern Ireland. Volume 1: A Consultation Document on Options for Further Improvements in Air Quality.

DEFRA et al (2006b). Department for Environment, Food and Rural Affairs, The Scottish Executive, Welsh Assembly Government and The Department of the Environment for Northern Ireland. The Air Quality Strategy for England, Scotland, Wales and Northern Ireland. Volume 2: Technical Annex and Regulatory Impact Assessment.

Grice, S E, Bush, T J, Stedman, J R, Vincent, K J, Kent, A J, Targa, J, Hobson, M. (2006). Baseline Projections of Air Quality in the UK for the 2006 Review of the Air Quality Strategy. AEA Technology, National Environmental Technology Centre. Report AEAT/ENV/R/1936.

Grice, S, Stedman, J R, Murrells, T and Hobson, M. (2007). Report on Additional Projections of Air Quality in the UK for Additional Measures Scenarios for the 2007 Review of the Air Quality Strategy. Report to be prepared.

Oxley, T., ApSimon, H., Dore, A., Sutton, M., Hall, J., Heywood, E., Gonzales del Campo T., & Warren, R., 2003, The UK Integrated Assessment Model, UKIAM: A National Scale Approach to the Analysis of Strategies for Abatement of Atmospheric Pollutants under the Convention on Long-Range Transboundary Air Pollution, Integrated Assessment, 4(4), pp 236-249.

Oxley, T. & ApSimon, H., 2006, Space, Time and nesting Integrated Assessment Models, J. Environmental Modelling & Software (in press)

Stedman, J R, Bush, T J, Vincent, K J, Kent, A J, Grice, S, Abbott, J (2005a) UK Air Quality Modelling for Annual Reporting 2003 on Ambient Air Quality Assessment under Council Directives 96/62/EC, 1999/30/EC and 2000/69/EC. National Atmospheric Emissions Inventory, AEA Technology, National Environmental Technology Centre. Report AEAT/ENV/R/1790.

Stedman, J R, Grice, S, Bush, T J, Murrells, T P and Hobson, M (2006a) Projections of Air Quality in the UK for Additional Measures Scenarios for the 2006 Review of the Air Quality Strategy. National Atmospheric Emissions Inventory, AEA Technology, National Environmental Technology Centre. Report AEAT/ENV/R/1986.

Stedman, J. R., Kent, A. J., Grice, S., Bush, T. J. and Derwent, R. G. (2007b). A Consistent Method for Modelling PM_{10} and $PM_{2.5}$ Concentrations across the United Kingdom in 2004 for Air Quality Assessment. *Atmospheric Environment,* **41**, 161-172.

Williams, M, Carruthers, D, Johnson, K (2006). Modelling of Current and Future Concentrations of PM, NO_x and O_3 in London Using ADMS-Urban. CERC Report to Defra PM642/TR04/R1/06.

Appendix A: Uncertainties & Assumptions

H.M. ApSimon & T. Oxley
Imperial College London

The modelling results produced by the UKIAM (and summarised in the main text of this report) should be interpreted in the context of a number of assumptions and uncertainties in the representation of NO_2 and PM_{10}. These primarily include:

- The representation of primary NO_2;
- Scaling of background NO_X concentrations; and
- NO_3 source-apportionment.

The key results from the UKIAM and the effects of the assumptions made are summarised in Table A1 (below), providing both a source-apportionment of PM concentrations and a comparison between different assumptions regarding NO_2. Further information is provided in the complete description of AQS simulations carried out with the UKIAM[i].

In respect of primary NO_2 we ran simulations based upon the assumption of an NO_2:NO_X ratio of 5% (10% was assumed by ADMS-Urban and the PCM modelling was based on an analysis of monitoring data, also equating to about 10%). However, recent findings suggest that in urban areas this relationship may increase to 15% or more (see, for example, Carslaw 2005). The AQS scenarios were thus also simulated based upon the assumption of a 15% relationship in urban areas. Table A1 highlights the relative effect of these assumptions with PWM concentrations increasing by 3-4% (whole UK) and 6-8% (London only) when higher primary NO_2 is assumed.

TABLE A1: Results from UK Integrated Assessment Model (July 2006)
DEFRA Air Quality Scenario Q (UEP21 Emissions projections)
Population Weighted Mean (PWM) Concentration (µg/m3)

UK	PPM	NH_4	NO_3	SO_4	PM_{10}(59)	*PM_{10}(9)*	NO_2	NO_2a	NO_2i	NO_2i+
B2010	2.629	1.135	2.986	1.314	15.639	*17.064*	19.809	17.907	18.867	19.652
Q2010	2.573	1.135	2.974	1.314	15.571	*16.996*	19.619	17.618	18.628	19.390
B2020	2.559	1.119	2.629	1.059	14.941	*16.366*	18.461	15.484	16.990	17.616
Q2020	2.334	1.119	2.575	1.055	14.658	*16.083*	17.520	14.058	15.811	16.345
Greater London										
B2010	4.077	1.325	3.473	1.493	19.259	*19.369*	33.772	32.075	32.933	35.557
Q2010	3.936	1.325	3.466	1.493	19.110	*19.220*	33.478	31.687	32.593	35.149
B2020	3.940	1.304	3.121	1.219	18.473	*18.584*	31.630	28.891	30.282	32.421
Q2020	3.317	1.304	3.088	1.215	17.813	*17.923*	30.049	26.797	28.451	30.287
Notes			SIA results are calculated by ASAM using EMEP4 2010/2020 projections & dispersion with the UK emissions scaled to scenario		Background PM: Rural 5µg/m^3, Urban 9µg/m^3	*Background PM: 9µg/m^3*	Un-scaled Background NO_X	All background NO_X scaled to scenario emissions	Only 50% background NO_X scaled to scenario	50% background NO_X scaled, plus increased NO_2:NO_X

Simulations were also repeated with differing assumptions regarding background NO_X concentrations. As stated by Stedman and others in the main report, PCM and ADMS-Urban have assumed a 1:1 relationship between background NO_X and UK emissions. However, the UKIAM assumes a 50% relationship and these are the results which have been compared with PCM and ADMS-Urban. Preliminary investigations using PPM (Europe) suggested that a 50% scaling in relation to UK emissions is a reasonable interim assumption; details are provided by ApSimon et al (2006). In Tables A1 & A2 we present four alternative sets of results for NO_2 based upon the following assumptions:

- NO_2 - Scenario with un-scaled background NO_X provided by Netcen
- NO_2i - Scenario with 50% of background NO_X scaled to UK NO_X emissions
- NO_2i+ - Scenario NO_2i with increased NO_2:NOx ratio (20%)
- NO_2a - Scenario with 100% of background NO_X scaled to UK NO_X emissions

Taking scenario NO_2i as the base case representing UKIAM assumptions, we can observe a 5% (approx.) reduction in PWM concentrations when all the background is scaled (assumed by PCM and ADMS-Urban), whereas a 5% increase is observed if background NO_X remains unchanged. These findings highlight the need to investigate further these assumptions since the effects of the scaled background may be compensated by increased primary NO_2, thus potentially distorting model calibrations.

Further assumptions were also made which affect the results for PM_{10}. Firstly the source-apportionment of secondary aerosols, and secondly the treatment of coarse background PM. In the latter case the UKIAM assumes background PM = 5µg/m^3 and 9µg/m^3 for rural and urban areas, respectively (labelled *PM_{10}(59)* in Table 1), but for comparison with PCM simulations were also carried out assuming background PM = 9µg/m^3 for all areas. These assumptions have minimal effect in London (mainly urban) but do suggest an 8% reduction in PWM for the UK as a whole. The results presented in Table A2 are based upon the assumption of 9µg/m^3 for all areas.

Table A2: Tabulated Results of Exceedence of 40µg/m^3 (NO_2) and 20µg/m^3 (tPM_{10})

			UKIAM Results				Netcen Results (5km)			
Pollutant	**Scenario**	**µg/m^3**	**Pop (M)**	**%**	**Area (Mha)**	**%**	**Pop (M)**	**%**	**Area (Mha)**	**%**
NO_2	**B2010**	40	2.694	4.93	0.1	0.13				
	B2010a	40	2.041	3.74	0.085	0.11	0.423	0.77	0.007	0.01
	B2010i	40	2.229	4.08	0.087	0.11				
	B2010i+	40	3.231	5.91	0.135	0.17				
	Q2010	40	2.427	4.44	0.095	0.12				
	Q2010a	40	2.041	3.74	0.085	0.11	0.423	0.77	0.007	0.01
	Q2010i	40	2.229	4.08	0.087	0.11				
	Q2010i+	40	3.138	5.74	0.13	0.16				
	B2020	40	2.027	3.71	0.085	0.11				
	B2020a	40	1.415	2.59	0.058	0.07	0.235	0.43	0.005	0.01
	B2020i	40	1.874	3.43	0.075	0.1				
	B2020i+	40	2.257	4.13	0.1	0.13				
	Q2020	40	1.639	3	0.07	0.09				
	Q2020a	40	1.395	2.55	0.055	0.07	0.035	0.06	0.003	0
	Q2020i	40	1.415	2.59	0.058	0.07				
	Q2020i+	40	2.054	3.76	0.092	0.12				
tPM_{10}	**B2010**	20	2.406	4.4	0.153	0.19	0.352	0.64	0.015	0.02
	Q2010	20	2.168	3.97	0.135	0.17	0.18	0.33	0.01	0.01
	B2020	20	0.59	1.08	0.06	0.08	0.174	0.32	0.007	0.01
	Q2020	20	0.36	0.66	0.055	0.07	0.082	0.15	0.003	0

Contributions to NO_3 concentrations from UK, European and other sources have been estimated by running emissions scenarios using ASAM[1], omitting different sources in turn. Since there are non-linearities involved in NO_3 concentrations, the estimates of relative contributions presented in Table A3 will hold for small emissions reductions (in the region of 15%). However these relative contributions may become distorted for larger reductions in NO_X emissions.

Table A3 – Source apportionment of NO_3 concentrations based upon EMEP data

NO_X Source	*NO_3 Exposure (UK)*			*NO_3 Exposure (London)*		
	Exposure (pers.g/m^3)	PWM (µg/m^3)	% Contrib.	Exposure (pers.g/m^3)	PWM (µg/m^3)	% Contrib.
EMEP 2010 Baseline	161	2.95		23	0.42	
UK Contribution	36	0.65	22%	3	0.05	12%
EU25 (excl.UK Contrib.)	47	0.85	29%	7	0.12	30%
Shipping Contribution	29	0.52	18%	4	0.07	17%
All other sources	50	0.92	31%	10	0.18	42%
			100%			100%

These findings suggest that in relation to both NO_2 and PM_{10} concentrations there are significant uncertainties in the modelling assumptions of the UKIAM and PCM. In relation to both increased urban primary NO_2 and background NO_X from non-UK sources the potential effect on the PWM results is between 5% and 8% for the UK as a whole. In relation to PM_{10} further investigation is needed to quantify the imported contributions of secondary aerosols and the coarse background PM in urban and rural areas.

Finally, as noted in the main text, comparisons between models which are implemented at different spatial resolutions should be interpreted with care since up to a 5% variation in PWM concentrations can result from aggregation from 1km to 5km resolution alone.

[1] ASAM is a European scale integrated assessment tool that includes atmospheric modelling based on the EMEP model, and is used to assess the imported contributions to secondary PM over the UK.

Appendix 2
Title

CONTENTS

Appendix 3
Title

CONTENTS