Chapter 7

Projected NO_2 concentrations in 2005 and 2010

Key points

- NO_x emissions from road traffic are projected to decrease in the future and the empirical and dispersion model studies indicate that this will lead to a significant reduction in exceedences of 40 µg m^{-3} at the roadside and in background locations, both nationally and in London.
- Projections of annual mean NO_2 concentrations in 2005 and 2010 have been calculated for the 212 monitoring sites for which data are available for 2001. The number of sites with annual mean NO_2 concentration exceeding 40 µg m^{-3} shows little decline between 2001 and 2005 in London but a much greater reduction in the rest of the UK. Concentrations are projected to decline further between 2005 and 2010 with the number of sites with projected concentrations exceeding 40 µg m^{-3} also expect to decline in London by 2010.
- The national modelling projections suggest that in 2005 an annual mean concentration of 40 µg m^{-3} is likely to be exceeded alongside 65% of major roads in London, 18% in the rest of England, 8% in Scotland, 3% in Northern Ireland and 2% in Wales. By 2010 this is expected to reduce to 23% of major roads in London, 5% in the rest of England, 2% in Scotland and zero in Northern Ireland and Wales.
- Additional detailed dispersion modelling studies for London suggest that, despite reductions in projected NO_x emissions between 1999 and 2010, projected exceedences of 40 µg m^{-3} are likely alongside 53-62% of the length of major roads in London in 2005, falling to 26-35% in 2010. Projections of the extent of exceedence in background locations are less consistent between different models, which predict exceedence areas in Greater London of between 5-32% for 2005 and 3-13% for 2010. The predicted areas of exceedences are, however, very sensitive to small changes in modelled concentrations.
- The Local Air Quality Management (LAQM) process has identified the need for approximately one third of the local authorities in Great Britain to declare air quality management areas. The majority of these are for NO_2. While national studies are inevitably focused on London and other conurbations, as well as on the most heavily trafficked roads, the LAQM studies have shown that exceedences can also occur in smaller towns, where narrow streets coincide with congested traffic. An analysis of automatic monitoring data collected as part of the LAQM process suggests that exceedences of 40 µg m^{-3} as an annual mean NO_2 concentrations will be more likely in major conurbations than outside. Outside conurbation, exceedences are more likely alongside single rather than dual carriageway roads. Exceedences will therefore be unlikely more than 9 m from the kerb of single carriageway roads and more than 5 m from the kerb of dual carriageway roads outside conurbations.
- Traffic sources and the total of domestic and commercial emissions are predicted to each contribute roughly one third of the total annual mean NO_x concentration by 2010 in central London. The remaining third includes contributions from regional rural concentrations, industry, other area and point sources.

- Analysis using the current policies NO_x emission projections in the national scale empirical model suggest that reductions in NO_x emissions well beyond those anticipated will be required if a concentration of 40 µg m^{-3} is to be met at all locations by 2005 or 2010. Site-specific modelling for the kerbside location monitoring site at Marylebone Road in London indicate that emission reductions of 90% relative to the 2005 base case traffic emissions or of 65% of the 2005 base case emissions for all sectors would be required to reduce the roadside annual mean NO_2 concentration to 40 µg m^{-3}. Slightly smaller percentage reductions relative to the base case emissions would be required in 2010 due to the expected decline in base case emissions between 2005 and 2010 as a result of current policies.
- Projections of the 99.8 percentile of 1-hour NO_2 concentrations have been calculated for London using a dispersion model. The results suggest that 1-hour exceedences of 200 µg m^{-3} will be less likely in 2005 and 2010 compared with 1999. Peak hourly NO_2 concentrations are, however, highly variable from year to year and dependent on the occurrence of particular summer or winter episode weather conditions.
- The empirical relationships between NO_x and NO_2 developed for the current atmosphere may not hold into the future if baseline O_3 concentrations increase and if the mass fraction of NO_x emitted directly as NO_2 also increases, leading in either case to increased difficulties with achieving an annual mean concentration of 40 µg m^{-3}. Modelling studies suggest that a 12 µg m^{-3} increase in baseline O_3 concentration could lead to an increase in annual mean NO_2 concentration in London of between about 4 and 7 µg m^{-3}. These issues highlight the complexities of predicting future NO_2 concentrations, involving the interactions of influences at global, regional and local scales.

7.1 Introduction

735. Projections of NO_2 concentrations in 2005 and 2010 are key to an assessment of NO_2 concentrations in the UK because the annual and 1-hour AQS objectives have been set for 2005 and subsequent years and the EU LVs apply from 2010 (see Chapter 1). Models are the only means of assessment for future concentrations. This is in contrast to the assessment of current and recent NO_2 concentrations presented in Chapter 6 where a combination of measurements and modelled estimates are available. There are a number of elements of a modelling assessment of future NO_2 concentrations that need to be reasonably well understood before a policy assessment can be made. These include the source apportionment of current concentrations, the expected trends in emissions and the non-linear responses of ambient concentrations to changes in emissions, such as the influences of background concentrations and atmospheric chemistry.

736. Projections of annual mean NO_2 concentrations have been estimated for individual monitoring site locations across the UK using the national empirical model. Projections of both annual mean and hourly NO_2 concentrations (for comparison with the 1-hour objective and LV) have been calculated for sites in London using a more detailed dispersion model. The site-specific projections have the advantage of enabling a direct comparison with current measured concentrations. The national model has also been used to calculate estimates of the emissions reductions that would be needed to reduce concentration to an annual mean concentration of 40 µg m^{-3} at selected monitoring site locations.

737. Mapped projections of annual mean NO_2 concentrations in 2005 and 2010 have been calculated for background and roadside locations across the UK. These results have been compared with the results of more detailed dispersion modelling studies for Greater London in terms of the expected extent of exceedence (areas and lengths of roads) of 40 µg m^{-3}. The frequency distributions of the modelled concentrations have been examined in order to assess the likely impact of small changes in model estimates on the extent of exceedence.

738. The projections presented here have been derived from a combination of base case emission inventory projections and the best estimates of the response of ambient concentrations to changes in emissions. The base case emission projections are based on an analysis of current national and international policies and their likely effect on future NO_x emissions. This chapter concludes with a discussion of some key issues in relation to predicting future NO_2 concentrations. These are the possible impacts of an increase in hemispheric background O_3 concentrations and an increase in the proportion of NO_x emitted as primary NO_2. Neither of these issues are sufficiently well understood at present to be fully incorporated into the base case projections. The sensitivity analyses presented here, however, indicate that these changes have some potential to offset the predicted decreases in NO_x emissions over the next ten years or so, resulting in smaller reductions in ambient NO_2 concentrations than suggested by the base case projections.

7.2 Site-specific projections of NO_2 concentrations in 2005 and 2010

7.2.1 Projections of annual mean concentrations derived from empirical site-specific models

739. Projections of annual mean NO_2 concentrations in 2005 and 2010 have been calculated by netcen from measured concentrations in 2001 using the site-specific projection models described in section 5.2.1.9 and applied in section 6.2.4 to the interpretation of recent trends in concentrations. These analyses and projections are based on the NAEI. Site-specific projections for selected sites are illustrated in Figures 7.1 to 7.4. These projections are listed in Table 7.1 for the sites selected for detailed analysis in Chapter 6. Projections have also been calculated using a simpler 'year factor' approach and the table shows the range of the projections calculated using these two different methods. Generic background and roadside year factors have been used to scale measured concentrations at all sites in this simpler method. This has the advantage of making the calculation much simpler but any spatial variation in emission trends is not accounted for. These 'year factors' have been calculated by averaging the results of site-specific projections at 11 background and 8 roadside national network sites. These year factors have also been published in the LAQM Technical Guidance TG(03) (DEFRA, *et al*, 2003).

Figure 7.1 Site specific projections of NO_x and NO_2 concentrations at West London (µg m^{-3}, as NO_2).

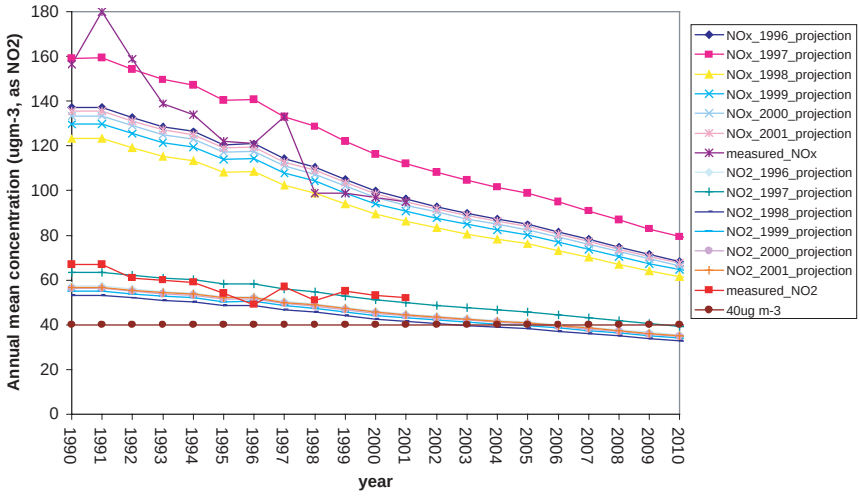


Figure 7.2 Site specific projections of NO_x and NO_2 concentrations at Manchester Town Hall (µg m^{-3}, as NO_2).

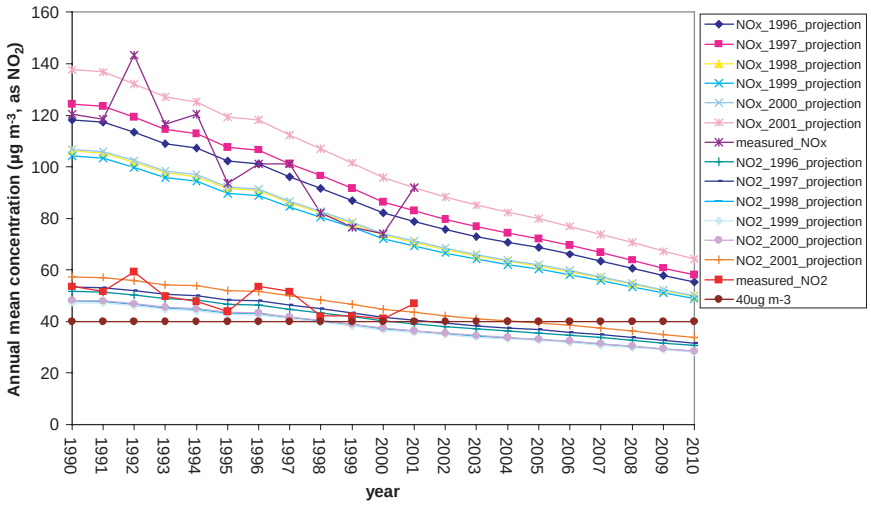


Figure 7.3 Site specific projections of NO_x and NO_2 concentrations at Belfast Centre (µg m^{-3}, as NO_2).

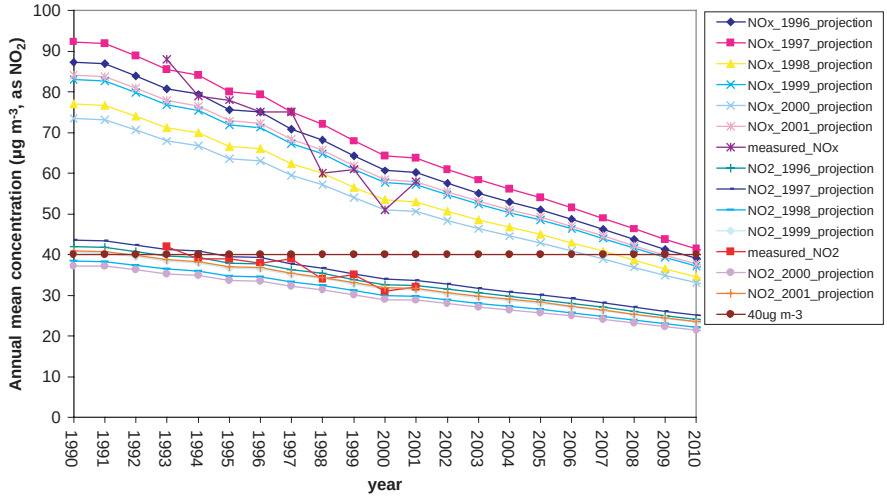


Figure 7.4 Site specific projections of NO_x and NO_2 concentrations at Glasgow Kerbside (µg m^{-3}, as NO_2).

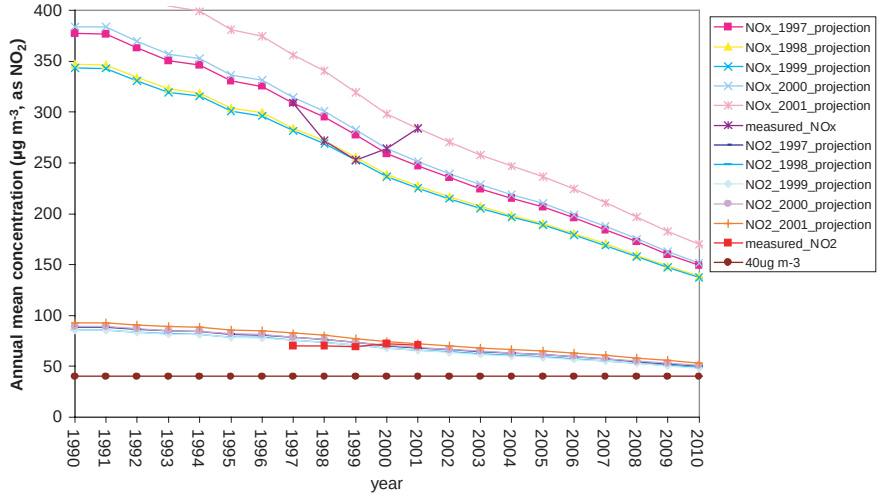


Table 7.1 Site-specific and year factor projections of annual mean NO_x and NO_2 concentrations from 2001 base year (µg m^{-3}, as NO_2). The range of the concentrations predicted by these two methods is listed. Values greater than 40 µg m^{-3} are in bold.

		Measured 2001		Projections 2005		Projections 2010	
Site	Type	NO_x	NO_2	NO_x	NO_2	NO_x	NO_2
Marylebone Road	Kerbside	335	**84**	278 – 282	**75 – 80**	195 – 201	**62 – 66**
Glasgow Kerbside	Kerbside	284	**71**	236 – 237	**63 – 65**	170	**52 – 53**
Haringey Roadside	Roadside	120	**48**	100 – 102	**43**	72 – 80	35 – 36
Redbridge 2	Roadside	355	**120**	288 –294	**66 – 107**	204 – 213	**55 – 88**
M25 Staines	Kerbside	196	**40**	157 –163	36 – **54**	117 – 119	29 – **45**
Bury Roadside	Roadside	270	**69**	219- 224	**61 – 62**	151 – 162	**50 – 51**
Lullington Heath	Rural	15	12.6	13	10 – 11	10 – 11	8 – 10
London Bridge Place (1999)	Urban background	105	**63**	83 – 84	**48 – 54**	67	**41 – 46**
London Bloomsbury	Urban centre	109	**51**	95 – 98	**46 – 54**	76 – 81	40 – **47**
West London	Urban background	95	**52**	83 – 84	**41 – 47**	66 – 67	35 – 40
London Bexley	Urban background	68	36	59	32 – 33	47 – 48	28
Manchester Town Hall	Urban background	92	**47**	80	39 – **43**	64	34 – 37
Glasgow City Chambers	Urban background	107	**46**	93	**42 – 44**	73 – 74	36 - 37
Belfast Centre	Urban centre	58	32	49 – 50	28 – 29	38 – 40	24 – 25
Port Talbot	Urban background	38	22	31 – 33	20 – 21	24 – 26	17
Roadside > 40 µg m^{-3}			**5**		**5 – 6**		**4 – 5**
Background > 40 µg m^{-3}			**5**		**4 – 5**		**1 – 2**
Total > 40 µg m^{-3}			**10**		**10**		**5 – 7**

740. The NO_x projections calculated using the two methods are very similar. The projected NO_2 concentrations are at times quite different because NO_x projections are used to derive projections of NO_2 concentrations using non-linear NO_x/NO_2 relationships within the site-specific model. NO_2 concentrations are projected directly from measured NO_2 concentrations in the year factor approach. The largest difference in predicted NO_2 concentrations are at those sites such as Redbridge 2 and M25 Staines, where the current measured concentrations are not consistent with the empirically derived relationships between NO_x and NO_2 concentrations (see Chapters 5 and 6).

741. Measured annual mean NO_2 concentrations in 2001 were greater than 40 µg m^{-3} at 10 out of 15 of the sites select for detailed analysis. Projected exceedences remained at 10 of the sites in 2005 for both the site-specific and year factor projections. This is reduced to between 5 and 7 sites in 2010 for the two different approaches.

742. The year factor approach has also been applied to calculate projected annual mean NO_2 concentrations in 2005 and 2010 from measured concentrations in 2001 at all of the sites for which data has been collated for this report. The results of this analysis are summarised in Table 7.2. The reduction in the number of sites with concentrations in excess of 40 µg m^{-3} is broadly in line with the mapped results of the national empirical models presented later in this chapter. This is as expected since the two analyses are based on the same emission inventory projections and similar models. The projected concentrations for each site are presented in Appendix 3. The number of sites with annual mean NO_2 concentration exceeding 40 µg m^{-3} shows little decline between 2001 and 2005 in London but a much greater reduction in the rest of the UK. Concentrations are projected to decline further between 2005 and 2010 with the number of sites with projected concentrations exceeding 40 µg m^{-3} also expected to decline in London by 2010.

Table 7.2 Status of NO_2 monitoring sites in 2001 and projections to 2005 and 2010 (R and K = Roadside and Kerbside sites, Other = all other classifications)

		Total number of sites	No. sites annual average > 40 µg m^{-3} measured 2001 (%)	No. sites annual average > 40 µg m^{-3} projected 2005 (%)	No. sites annual average > 40 µg m^{-3} projected 2010 (%)
Scotland	R and K	2	1 (50)	1 (50)	1 (50)
	Other	5	2 (40)	1 (20)	0
Wales	R and K	1	0	0	0
	Other	3	0	0	0
Northern Ireland	R and K	0	0	0	0
	Other	2	0	0	0
London	R and K	41	39 (95)	35 (85)	21 (51)
	Other	36	17 (47)	12 (33)	6 (17)
Rest of England	R and K	33	18 (55)	15 (45)	6 (18)
	Other	89	6 (7)	3 (3)	0
UK	R and K	77	58 (75)	51 (66)	28 (36)
	Other	135	25 (12)	16 (12)	6 (4)

7.2.2 Receptor point projections from dispersion modelling studies

743. Projected NO_x and NO_2 concentrations in 2005 and 2010 have been calculated for monitoring sites in London by CERC using ADMS-Urban from a 1999 base year and are shown in Table 7.3. These analyses and projections are based on the LAEI. The total number of sites with modelled annual mean NO_2 concentrations greater than 40 µg m^{-3} reduces from 21 out of 23 in 1999 (when measured concentrations were above 40 µg m^{-3} at 18 sites) to 17 in 2005 and 15 in 2010. Table 7.4 shows a comparison of predicted NO_x and NO_2 concentrations in 2010 at six sites in London for which predictions are available from both the netcen and CERC models. There is generally good agreement between the model results although there is some tendency for the CERC results to be slightly higher, for example for NO_2 at Haringey Roadside.

Table 7.3 Annual average NO_x and NO_2 concentration predicted by dispersion modelling (µg m^{-3}, as NO_2). Base year is 1999. Values greater than 40 µg m^{-3} are in bold.

	Measured 1999		Modelled 1999		Modelled 2005		Modelled 2010	
	NO_x	NO_2	NO_x	NO_2	NO_x	NO_2	NO_x	NO_2
Roadside monitoring sites								
A3	256	**58**	227	**67**	138	**55**	105	**48**
Camden	210	**66**	204	**71**	143	**61**	117	**55**
Cromwell Road	256	**93**	260	**76**	193	**69**	141	**59**
Haringey	136	**51**	115	**55**	84	**48**	71	**42**
Hounslow	191	**60**	132	**53**	88	**44**	69	**40**
Marylebone Road	390	**91**	386	**88**	290	**78**	220	**71**
Southwark Roadside	227	**75**	183	**67**	132	**59**	107	**52**
Sutton Roadside	117	**44**	76	**42**	57	34	46	29
Tower Hamlets	241	**70**	193	**71**	138	**61**	113	**55**
Background monitoring sites								
Bexley	69	37	78	**40**	61	34	52	31
Bloomsbury	136	**67**	120	**57**	96	**52**	78	**46**
Brent	67	37	76	**44**	57	38	50	32
Bridge Place	105	**63**	111	**53**	90	**48**	71	**42**
Eltham	65	36	86	**44**	67	36	55	32
Hackney	134	**60**	113	**55**	84	**48**	71	**42**
Hillingdon	166	**50**	206	**63**	132	**55**	101	**48**
Lewisham	139	**54**	117	**55**	86	**46**	71	**42**
North Kensington	82	**46**	99	**52**	76	**44**	65	**40**
Southwark Urban Centre	118	**56**	99	**50**	80	**44**	67	38
Sutton Suburban	65	35	67	38	52	32	42	27
Teddington	52	32	59	34	48	29	40	25
Wandsworth	141	**52**	128	**59**	94	**50**	76	**44**
West London	99	**55**	92	**50**	71	**42**	61	38
Roadside sites > 40 µg m^{-3}		9		9		8		8
Background sites > 40 µg m^{-3}		9		12		9		7
Total sites > 40 µg m^{-3}		18		21		17		15

Table 7.4 Comparison of projected annual mean NOx and NO_2 concentrations in 2010 for selected monitoring sites in London (µg m^{-3}, as NO_2).

	netcen		CERC	
	NOx	NO_2	NOx	NO_2
Marylebone Road	195 – 201	62 – 66	220	71
Haringey Roadside	72 – 79	35 – 36	71	42
London Bridge Place	67	41 – 46	71	42
London Bloomsbury	76 – 81	40 – 47	78	46
West London	66 – 67	35 – 40	61	38
London Bexley	47 – 48	28	52	31

744. Mapped projections derived from the ERG modelling are presented later in this chapter. Site-specific projections have also been made by ERG at fewer sites than listed in Table 7.3 and only for 1999 and 2005. Further details relating to these predictions can be found in Carruthers *et al* (2002). Predictions have been made London-wide for 1999, 2005 and 2010 and these are considered later in this chapter.

745. Overall the modelled base case predictions of annual mean NO_2 suggest that concentrations below 40 µg m^{-3} will not be achieved across the whole of the UK by 2010. Outside London the exceedences are likely to be confined to the roadsides of busy roads while many roadside locations and some background locations are expected to exceed in London.

7.2.3 Source apportionment of concentrations in 2005 and 2010

746. The netcen site-specific model works by projecting the contributions to annual mean NO_x from different source sectors into the future and then adding the contributions together to get the total annual mean NO_x concentration. The source apportionment of the measured annual mean NO_x concentrations at selected monitoring sites in 2001 was discussed in section 6.2.4. Figures 7.5 and 7.6 show how the contributions from individual emission sectors are estimated to vary between 1996 and 2020 at London Bloomsbury and Marylebone Road. It is clear that the contributions from the domestic, commercial and regional rural contributions are much more important in 2010, relative to emissions from road traffic sources, than in 2001 as the contributions from traffic sources decline and the contributions from some other sectors show small rises.

Figure 7.5 Source apportionment of annual mean NO_x concentrations at London Bloomsbury (2001 base year).

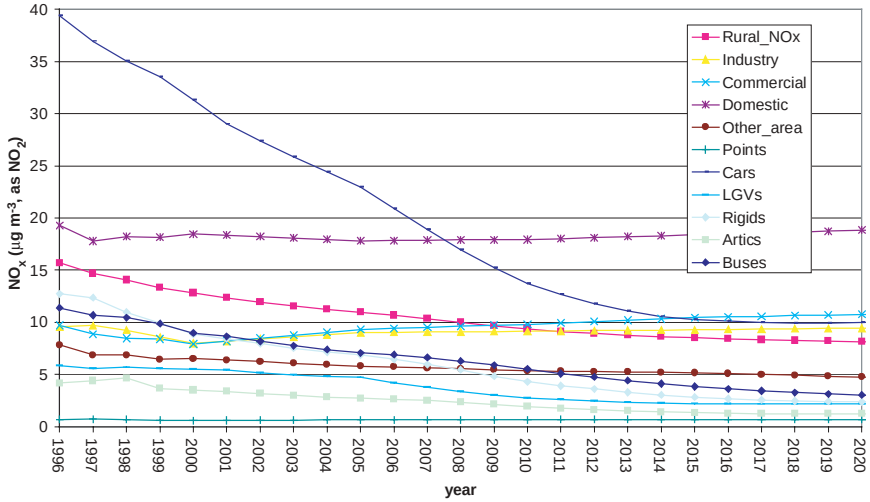
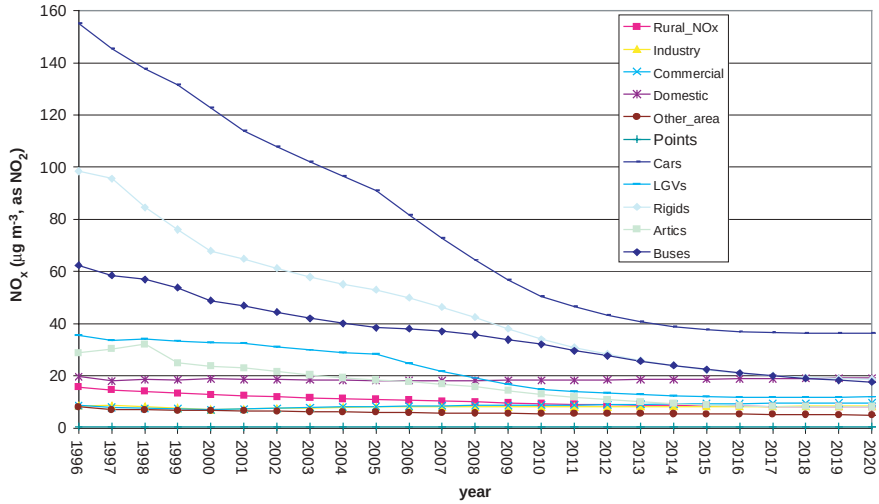


Figure 7.6 Source apportionment of annual mean NO_x concentrations at Marylebone Road (2001 base year).



747. The source apportionment of the projected annual mean NO_x concentrations in 2010 at the sites selected for detailed analysis is listed in Table 7.5 and can be compared with the analysis for 2001 in Table 6.9. Traffic sources are expected to continue to dominate at the roadside sites with contributions ranging from 57% at Haringey Roadside to 86% at Redbridge 2 (down from 70% and 92% in 2001). The percentage contribution from traffic sources is lower at background sites, ranging from 35% at London Bloomsbury to 59% at Belfast Centre (down from 50% and 71% in 2001). The percentage contribution from domestic and commercial emissions increases relative to 2001 to vary from 9% at Port Talbot to 16% at Belfast Centre, 32% at West London and 34% at London Bloomsbury. At London Bloomsbury, traffic sources and the total of domestic and commercial emissions are expected to each contribute roughly one third of the total annual mean NO_x in 2010. The final third of the total annual mean NO_x concentration includes 12% from regional rural concentrations, 11% from industry, 7% from other area sources and 1% from other point sources. The percentage contributions from domestic and commercial emissions at roadside sites are much lower at between 5% and 20% at the sites studied.

Table 7.5 Source apportionment of annual mean NO_x concentration in 2010 (µg m^{-3}, as NO_2), and percentages in brackets) derived from the netcen site-specific models.

Site	Total 2001	Rural	Industry	Commer-cial	Domestic	Other area	Points	Total traffic	Cars	LGV	HGVr	HGVa	Buses
Marylebone Road	195	9 (5)	8 (4)	9 (5)	18 (9)	6 (3)	1 (0)	145 (74)	50 (26)	15 (8)	34 (17)	13 (7)	32 (16)
Glasgow Kerbside	170	3 (2)	7 (4)	7 (4)	7 (4)	4 (2)	0 (0)	142 (84)					
Haringey Roadside	80	10 (12)	6 (8)	7 (8)	9 (11)	2 (2)	1 (1)	46 (57)	19 (24)	4 (5)	6 (8)	3 (4)	13 (16)
Redbridge 2	204	9 (5)	4 (2)	10 (5)	3 (2)	2 (1)	1 (0)	175 (86)					
M25 Staines	119	9 (8)	0 (0)	2 (2)	4 (3)	19 (16)	0 (0)	85 (71)					
Bury Roadside	151	9 (6)	3 (2)	3 (2)	5 (3)	3 (2)	2 (2)	41 (27)	41 (27)	8 (6)	16 (11)	57 (38)	3 (2)
London Bloomsbury	81	9 (12)	9 (11)	10 (12)	18 (22)	5 (7)	1 (1)	28 (35)	14 (17)	3 (3)	4 (5)	2 (2)	6 (7)
West London	67	9 (14)	5 (7)	5 (8)	16 (24)	4 (6)	1 (1)	27 (40)	14 (20)	3 (4)	4 (6)	2 (3)	5 (7)
London Bexley	48	9 (19)	3 (6)	3 (7)	5 (11)	5 (10)	2 (5)	20 (43)					
Manchester Town Hall	64	10 (15)	6 (9)	6 (9)	5 (8)	6 (9)	2 (3)	30 (47)	13 (20)	3 (4)	4 (6)	8 (12)	3 (5)
Glasgow City Chambers	73	3 (4)	8 (11)	9 (12)	6 (9)	4 (96)	0 (0)	42 (58)					
Belfast Centre	38	5 (12)	1 (3)	1 (3)	5 (13)	4 (10)	0 (0)	22 (59)					
Port Talbot	24	5 (20)	1 (4)	1 (4)	1 (5)	2 (7)	1 (4)	13 (55)					

748. The contributions from each vehicle type at each site can be further sub-divided by 'Euro class' (the new vehicle emission standards to which they belong, see section 2.6.5). The split of emissions between the different Euro classes has been assumed to be the same within each vehicle type across the whole of the UK because the same fleet composition information has been used everywhere. Figures 7.7-7.11 show the source apportionment of projected annual mean NO_x between Euro class for each vehicle type at London Bloomsbury. Curves for other sites would have exactly the same shape and relative contributions from different Euro classes but with a different vertical scale for each vehicle type. The contribution from Pre-Euro vehicles is relatively unimportant for all vehicle types after about 2005 and the contribution from Euro I is similarly very small by about 2010. Bus fleets have the slowest turnover and thus a relatively larger contribution in each year from vehicles meeting the older emissions standards. Figure 7.11 is, however, representative of the UK fleet of buses and it is expected that all London Buses will meet at least Euro II standards by 2005.

Figure 7.7 Source apportionment of annual mean NO_x concentrations at London Bloomsbury: Cars by Euro class (2001 base year, P = Petrol, D = Diesel) (µg m^{-3}, as NO_2).

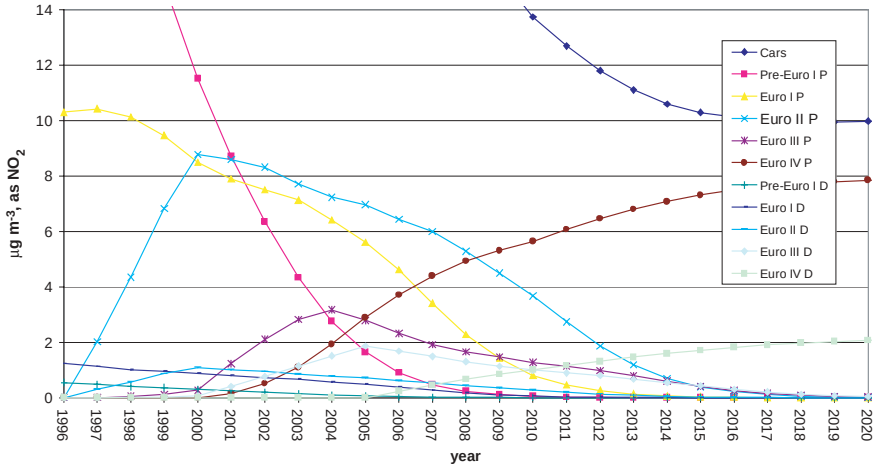


Figure 7.8 Source apportionment of annual mean NO_x concentrations at London Bloomsbury: Light Goods Vehicles by Euro class (2001 base year, P = Petrol, D = Diesel) (µg m^{-3}, as NO_2).

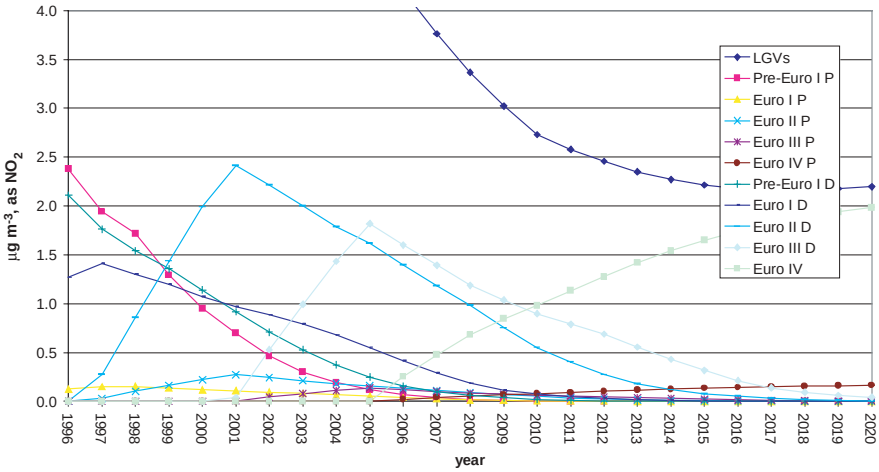


Figure 7.9 Source apportionment of annual mean NO_x concentrations at London Bloomsbury: Rigid Heavy Goods Vehicles by Euro class (2001 base year) (µg m^{-3}, as NO_2).

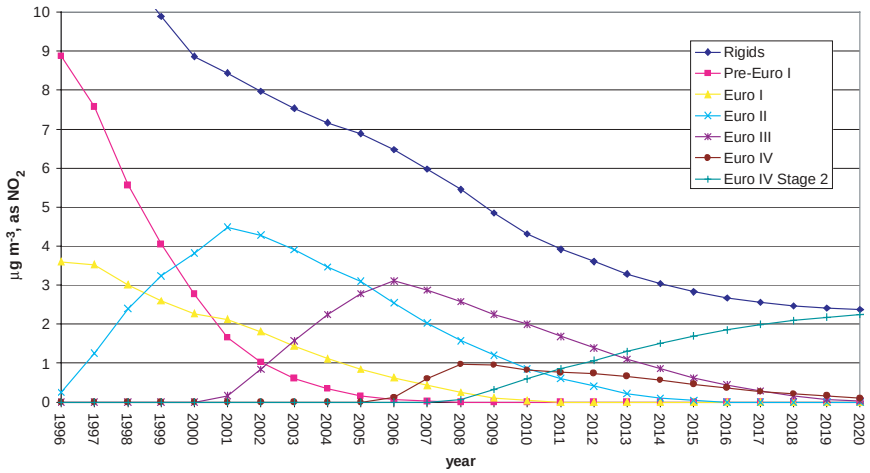


Figure 7.10 Source apportionment of annual mean NO_x concentrations at London Bloomsbury: Articulated Heavy Goods Vehicles by Euro class (2001 base year) (µg m^{-3}, as NO_2).

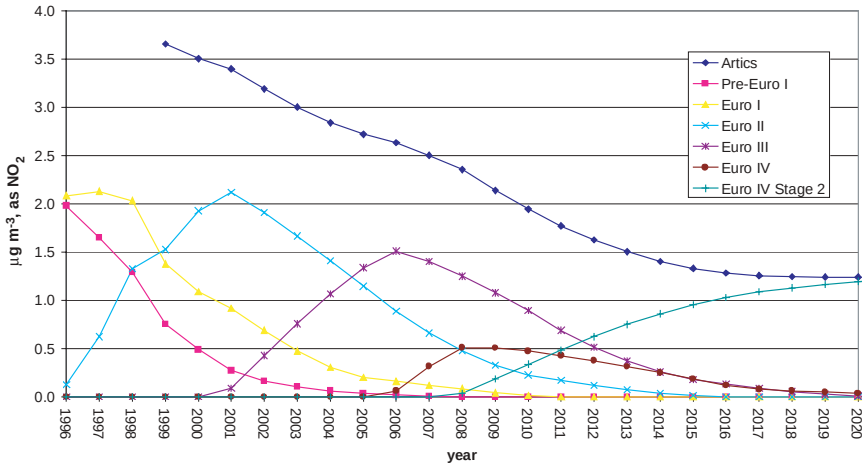
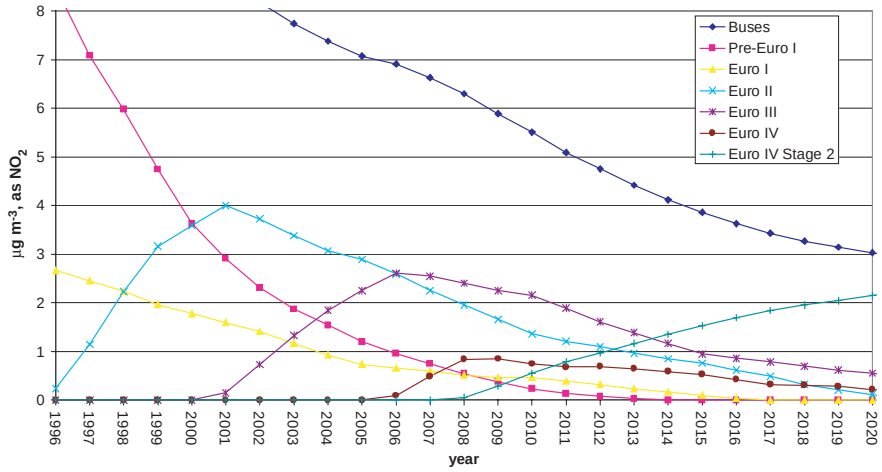


Figure 7.11 Source apportionment of annual mean NO_x concentrations at London Bloomsbury: Buses by Euro class (2001 base year) (µg m^{-3}, as NO_2).



7.2.4 Estimates of emission reductions required to reduce annual mean NO_2 concentrations to 40 µg m^{-3}

749. The netcen site-specific model has also been used to estimate the additional reductions in emissions, beyond those in the base case emission projections, required to reduce annual mean NO_2 concentrations to 40 µg m^{-3}. The results of this analysis are listed in Table 7.6 for both the reductions in traffic emissions required if the emissions from all other sectors remain at base case values and for reductions in emissions from all sectors. The required reductions in 2005 range from a reduction of 90% of base case traffic emissions at Marylebone Road (of 65% of base case emissions from all sectors) to 5% (3% for all sectors) at West London. No reductions beyond those assumed in the base case are required at Manchester Town Hall and Belfast Centre. The reductions relative to the base case are lower in 2010 due to the reduction in base case emissions from 2005. A reduction of 87% of base case traffic emissions (of 53% of all sector emissions) would be required at Marylebone Road to reduce annual mean NO_2 to 40 µg m^{-3}.

Table 7.6 Percentage emission reductions required to reduce annual mean NO_2 concentrations to 40 µg m^{-3} in 2005 and 2010 at selected monitoring sites. Relative to the base case emission projections, calculated using the netcen site-specific model.

	2005		2010	
Reductions applied to	Traffic emissions	All emissions	Traffic emissions	All emissions
Marylebone Road	90	65	83	53
Glasgow Kerbside	63	52	45	35
Haringey Roadside	15	10	0	0
Bury Roadside	57	48	37	29
London Bloomsbury	70	35	53	21
West London	5	3	0	0
Manchester Town Hall	0	0	0	0
Belfast Centre	0	0	0	0

7.2.5 Projections of hourly mean concentrations

750. The CERC dispersion modelling study also provides predictions of hourly mean NO_2 concentration in 2005 and 2010 from a base year of 1999. The 99.8th percentiles of modelled hourly mean concentrations in 2005 and 2010 have been calculated for the 23 national network sites in London listed in Table 7.3. A 99.8th percentile of 200 µg m^{-3} is equivalent to no more than 18 hours with concentrations greater than 200 µg m^{-3} for a full year of data. The model over-predicts 99.8th percentile concentrations in 1999 with 13 sites over 200 µg m^{-3} in comparison with the one measured exceedence of 200 µg m^{-3} (at Marylebone Road). The poor agreement between modelled and measured exceedences is as expected, since it is considerably more difficult to correctly predict concentrations for a single hour than for an annual mean (see Chapter 5). The 99.8th percentile concentrations are predicted to decline by an average of 18% from the 1999 level by 2005 at roadside and 16% at background sites and by 25% and 22% by 2010. Peak hourly NO_2 concentrations are, however, highly variable from year to year and dependent on the occurrence of particular summer or winter episode weather conditions, as discussed in section 6.5. Measured 99.8th percentile NO_2 concentrations were above 200 µg m^{-3} at 5 out of a total of 97 national network monitoring sites during 2001.

7.3 Mapped projections of NO_2 concentrations in 2005 and 2010

7.3.1 Introduction

751. Modelled projections of NO_2 concentrations are subject to considerable uncertainty. This uncertainty can arise from the treatment of dispersion and chemical processes within the models, the meteorological data used, the emissions inventories and projections included and the boundary conditions for the models, such as the regional concentrations of pollutants. A full analysis of the uncertainty associated with the modelled projections from a particular modelling study has not been attempted for this report. Such an analysis would not be practicable, in any case, given current understanding of the factors that influence ambient NO_2 concentrations and the fact that emission projections are necessarily influenced by policy, economic and political factors that are beyond the scope of this report. An indication of the uncertainty associated with the modelled predictions can, however, be provided by an examination of the range of the results obtained from the different studies.

7.3.2 Mapped results of national empirical models

752. Maps of annual mean NO_2 concentrations in 2005 and 2010 at both background and roadside locations have been calculated by netcen for the UK using the empirical modelling methods described in section 5.2.1 and are shown in Figures 7.12 to 7.15. These maps can be compared with the maps for 2001 presented in section 6.4.2. These projections have been derived using the empirical calibration coefficients derived for 2001 and NAEI projections of emissions for 2005 and 2010. These maps have therefore effectively been calculated using '2001 meteorology'. The modelling results in terms of exceedence of 40 µg m^{-3} as an annual mean are summarised in Table 7.7 and can be compared with the analysis for 2001 presented in Chapter 6. The modelled extent of exceedence is broadly consistent with the projection for individual monitoring site locations presented in Table 7.2 above. The greatest decline in the length of major road exceeding 40 µg m^{-3} is between 2005 and 2010. 65% of the length of major roads in London are projected to remain above this concentration in 2005, reducing to 23% by 2010. Background concentrations in central London are projected to remain above 40 µg m^{-3} for a small number of 1 km squares. The number of exceedences at roadside locations outside London is projected to be much reduced by 2010 relative to 2001. There are projected to be no roadside exceedences in Wales or Northern Ireland by 2010.

Table 7.7 Summary of national empirical model results for annual mean NO_2 concentrations in 2005 and 2010 (areas defined by 1 x 1 km background estimates, roadside concentrations calculated for built-up major road links).

				2005			2010		
	Area (km^2)	Number of links	Length of links (km)	Area > 40 µg m^{-3} (km^2)	Number of road links > 40 µg m^{-3}	Length > 40 µg m^{-3}	Area > 40 µg m^{-3} (km^2)	Number of road links > 40 µg m^{-3}	Length > 40 µg m^{-3}
Scotland	77769	435	1310.8 (0%)	0 (16%)	70 (8%)	108 (0%)	0 (3%)	11 (2%)	22
Wales	20694	572	1022.0 (0%)	2 (2%)	11 (2%)	21 (0%)	1 (0%)	0 (0%)	0
N Ireland	13627	124	950.2 (0%)	0 (3%)	4 (3%)	26 (0%)	0 (1%)	1 (0%)	4
London	1591	1888	1767 (5%)	78 (75%)	1407 (65%)	1152 (3%)	48 (35%)	670 (23%)	410.6
Rest of England	128519	6069	10922 (0%)	66 (25%)	1538 (18%)	1941 (0%)	33 (7%)	405 (5%)	5441
UK	242200	9088	15972 (0%)	146 (20%)	3030 (33%)	3250 (0%)	82 (12%)	1087 (6%)	981

753. Figure 7.16 shows the frequency distributions of projected concentrations at the roadside of major roads in 2001, 2005 and 2010 in the UK and in London. The mode of the UK frequency distribution is above 40 µg m^{-3} in 2001 but below in 2005 and well below in 2010. The mode for roads in London is rather higher and is still just above 40 µg m^{-3} in 2005. This analysis indicates that small changes in modelled concentrations would have a large impact on the estimated percentage of road length expected to exceed 40 µg m^{-3} in 2001 and 2005. The

percentage of road length projected to exceed 40 µg m^{-3} in 2010 will be less sensitive to small changes in estimated roadside concentrations, particularly outside London, where the expected percentage exceedence is small.

Figure 7.12 Estimated annual mean background NO_2 concentration, 2005 (µg m^{-3}).

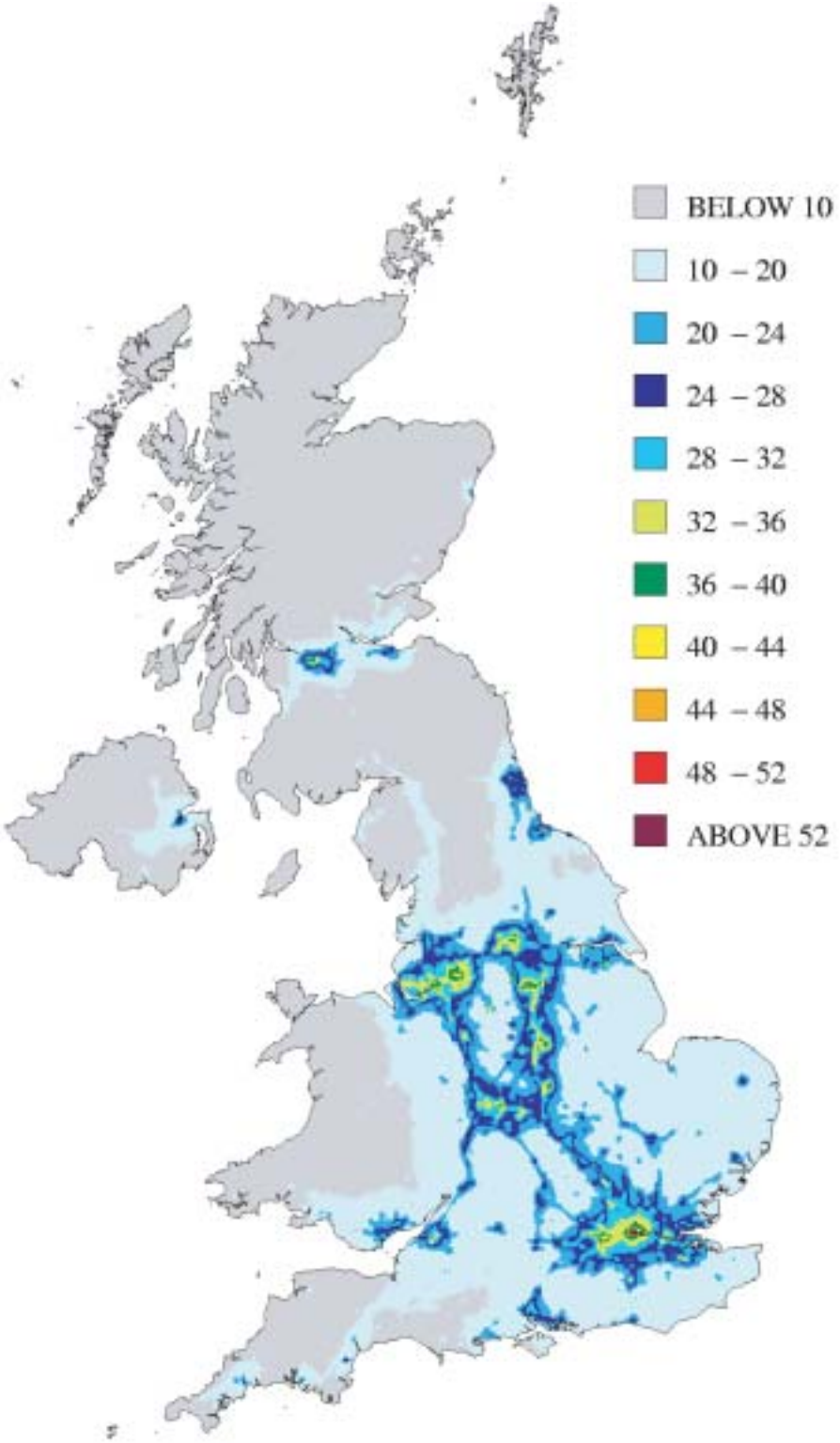


Figure 7.13 Estimated annual mean background NO_2 concentration, 2010 (µg m^{-3}).

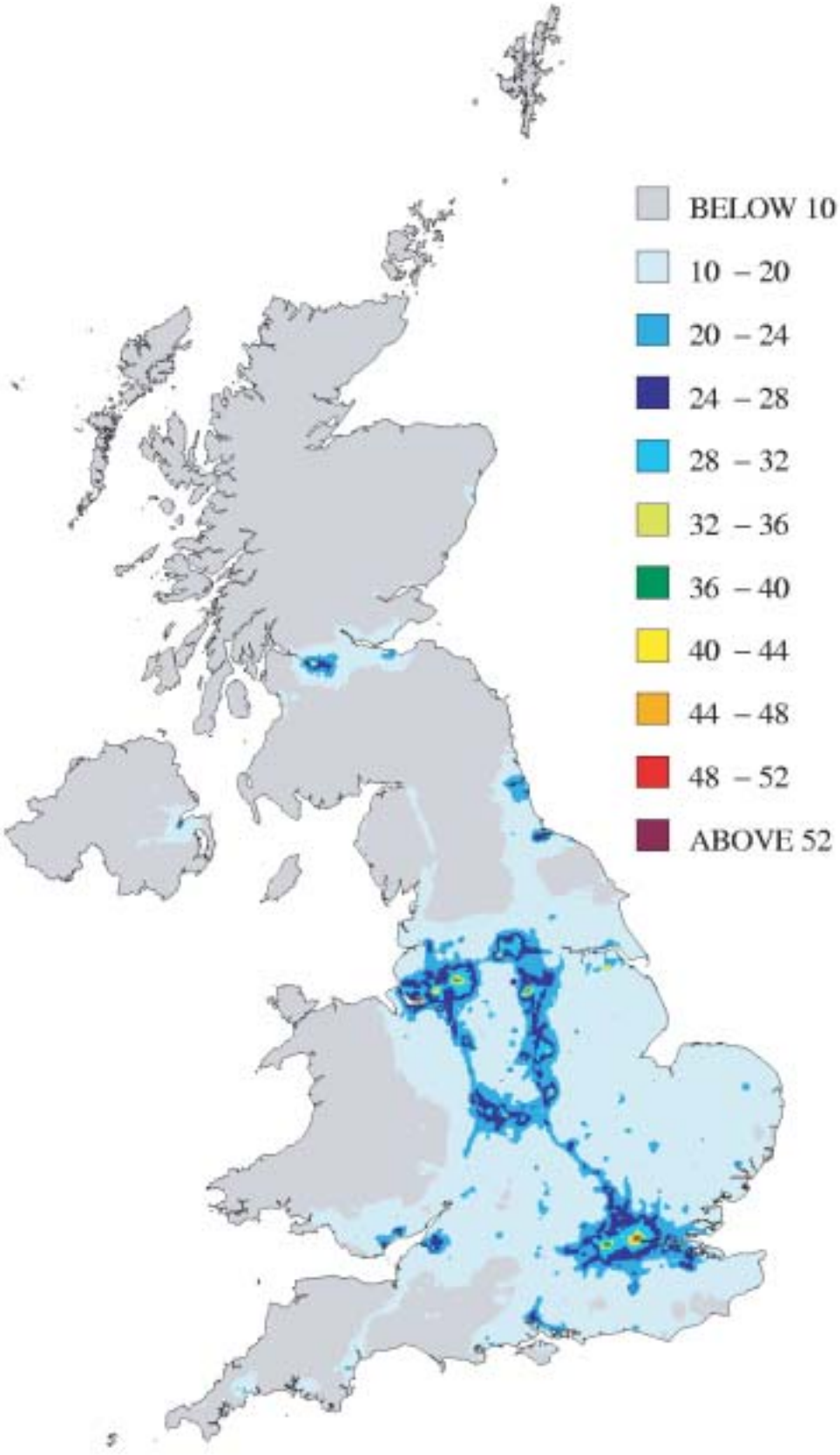


Figure 7.14 Estimated annual mean roadside NO_2 concentration, 2005 (µg m^{-3}).

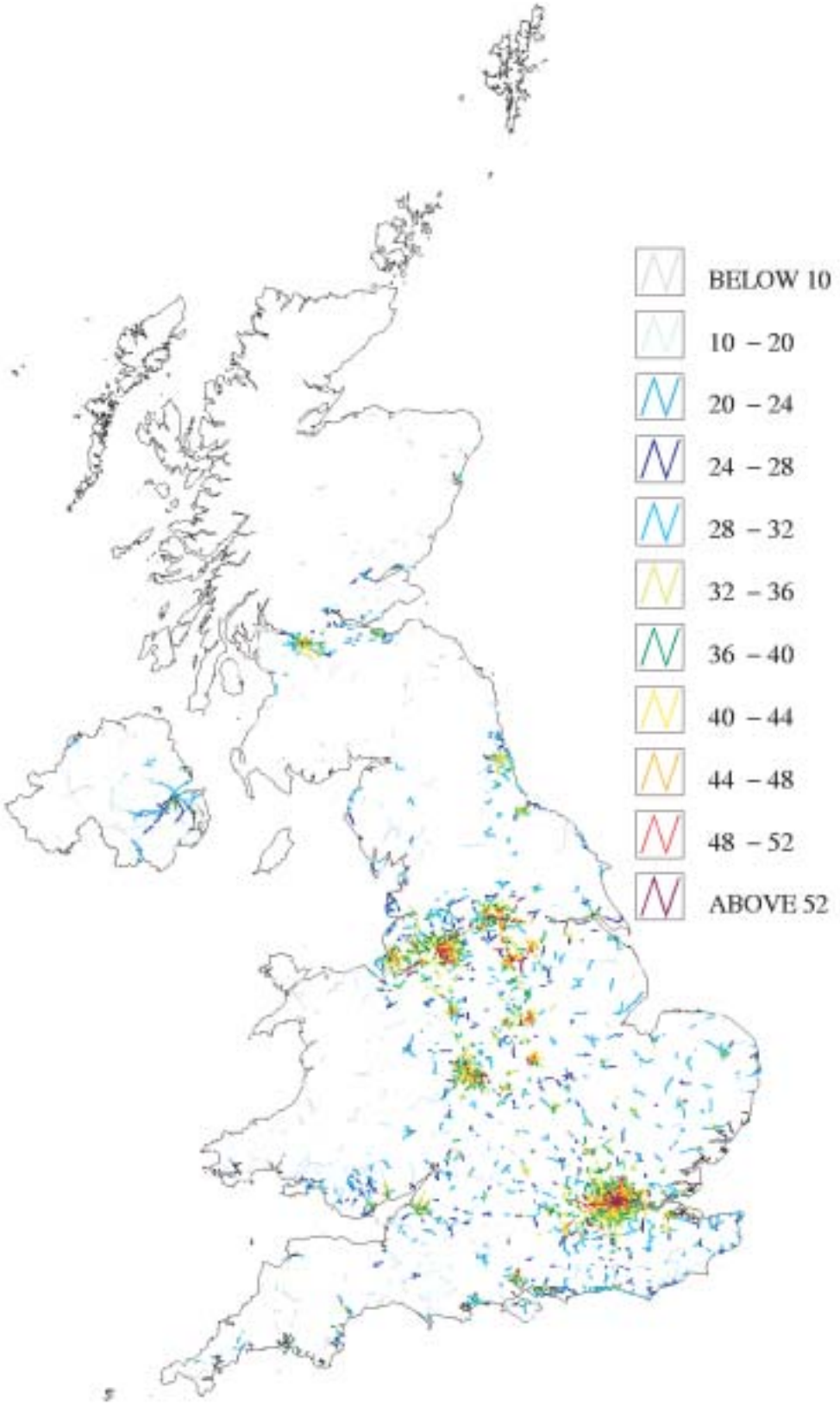


Figure 7.15 Estimated annual mean roadside NO_2 concentration, 2010 (µg m^{-3}).

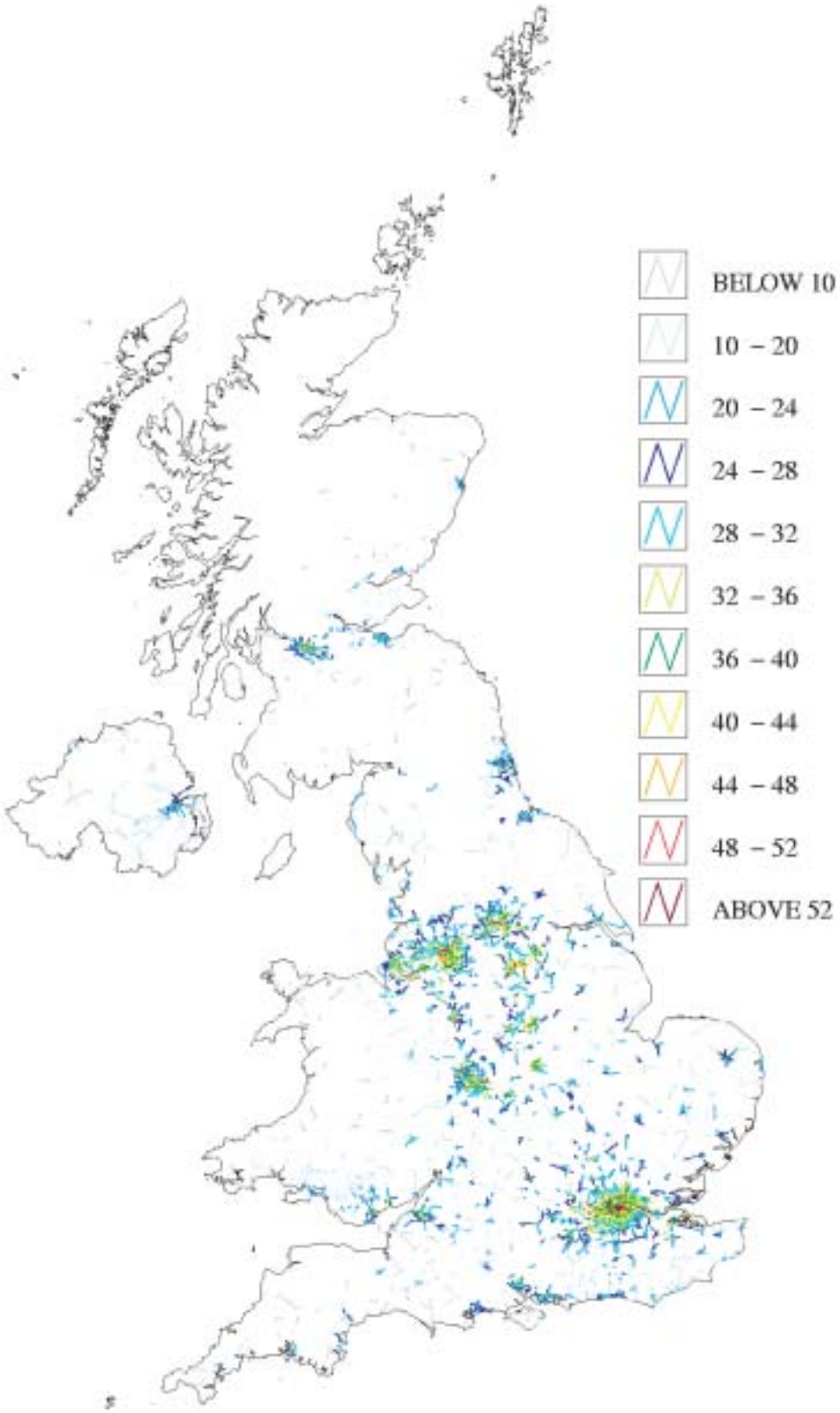
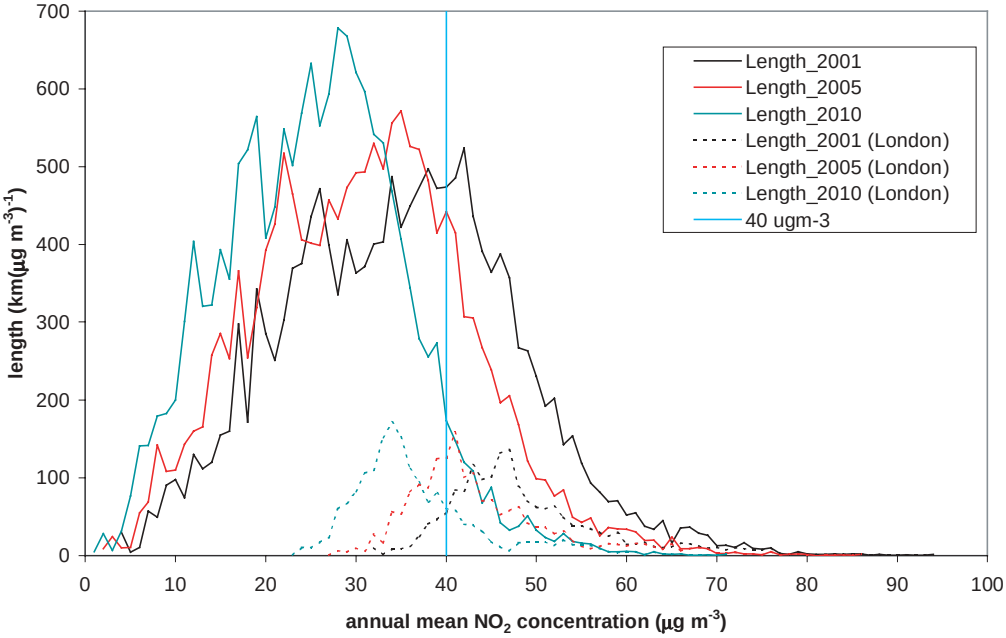


Figure 7.16 Frequency distribution of modelled roadside annual mean NO_2 concentrations from the netcen model.



7.3.3 Detailed modelling results for London

754. Projections of annual mean NO_2 concentrations in London for 2005 and 2010 have been calculated by ERG and by CERC from a 1999 base year using the methods described in the Chapter 5 and LAEI emissions projections. Maps for 1999 and 2001 were presented in the section 5.4.3. The maps for 2005 and 2010 are presented here along with frequency distributions of results and comparisons with the national scale analysis and the modelled concentrations for 2001. Projections of background concentrations from the LRCTM for 2005 and 2010 are also presented and discussed.

755. Figures 7.17 and 7.18 show the ERG modelling results for the London Area. Table 7.8 lists the calculated area of London exceeding the 40 µg m^{-3} for 1999, 2001, 2005 and 2010. These results are somewhat higher than those predicted in the national modelling. The most significant difference is that the ERG calculations relate to the total surface area exceeding 40 µg m^{-3} whereas the national modelling relates only to background areas exceeding this value.

Figure 7.17 Annual mean NO_2 in London for 2005 using ERG model (µg m^{-3}).

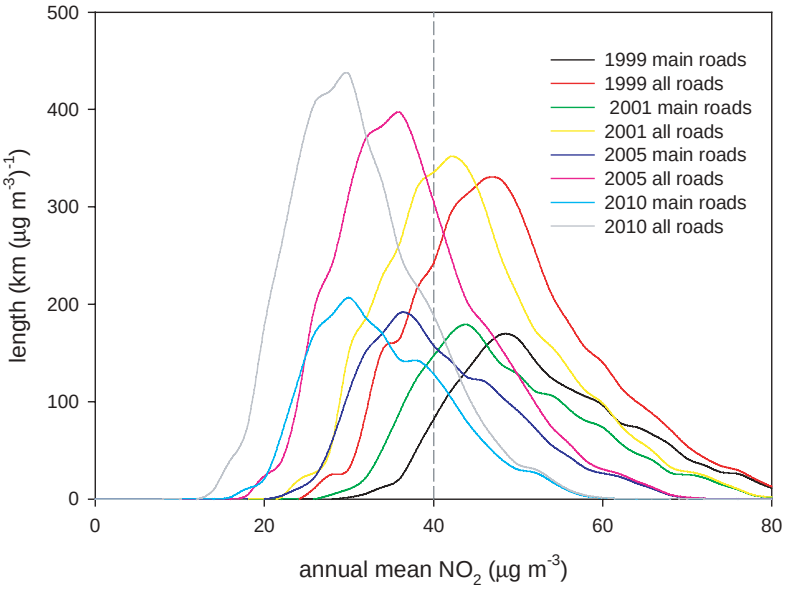
Figure 7.18 Annual mean NO_2 in London for 2010 using ERG model (µg m^{-3}).

Table 7.8 Area and length of road exceeding an annual mean NO_2 concentration of 40 µg m^{-3} in London using the ERG approach.

	km² > 40 µg m⁻³	Length of major road > 40 µg m⁻³ (km and percent)	Length of minor roads > 40 µg m⁻³ (km and percent)	Length of all LAEI roads > 40 µg m⁻³ (km and percent)
Total area/length modelled	1854	1937	2076	4013
1999	627 (34%)	1880 (95%)	1443 (70%)	3323 (83%)
2001	361 (19%)	1627 (84%)	1134 (55%)	2761 (69%)
2005	134 (7%)	1027 (53%)	553 (27%)	1580 (39%)
2010	36 (2%)	500 (26%)	173 (8%)	673 (17%)

756. Estimates of the length of major road (A-roads and motorways) exceeding an annual mean NO_2 concentration of 40 µg m^{-3} have also been made using the ERG model for London. The length of road statistic is somewhat arbitrary because the statistic depends on the distance from the road at which the statistic is calculated. Calculations have been made at a distance of 10 m from the road centreline based on receptor points placed at 100 m intervals along each side of the major roads in the London area. A total major road length of 1937 km has been considered. In 1999 it is estimated that 95% (1880 km) of the road length exceeds 40 µg m^{-3} (84%, 1627 in 2001). By 2005 this decreases to 53% (1027 km, compared with 1152 km from the national model), decreasing to 26% (500 km compared with 410 km from the national model) in 2010. Figure 7.19 shows the frequency distributions for each of the years and highlights 40 µg m^{-3}.

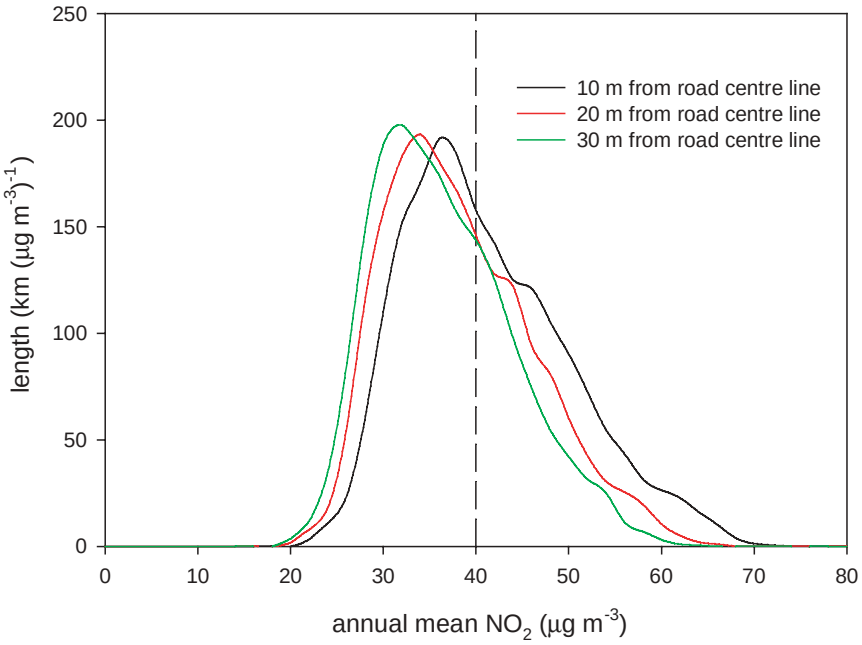
Figure 7.19 Frequency distribution of annual mean NO_2 calculated at 10 m from the road centreline for major and all LAEI roads in London using the ERG methodology.



757. The LAEI considers approximately 4000 smaller road links than the NAEI and it is therefore possible to calculate exceedence statistics for all roads in the LAEI. The total road length in London considered by the LAEI is 4013 km. Figure 7.19 shows the frequency distributions for all roads in the LAEI in addition to major roads only. The mode of each distribution remains similar in each case but the proportion of roads exceeding 40 µg m^{-3} is, as expected, less. In 2005 39% of LAEI roads are predicted to exceed at 10 m, decreasing to 17% in 2010.

758. The ERG estimates of the extent of roadside exceedence depend on the assumptions concerning the distance from the road centreline. Estimates have been made for 2005 at three distances: 10, 20 and 30 m. Figure 7.20 shows the effect of these assumptions. The results are very sensitive to the distance from the road assumed because of the fall-off in concentrations away from roads. At 10 m, 53% of the road length exceeds 40 µg m^{-3}, but this falls to 42% and 34% for 20 m and 30 m from the road centreline respectively. It is likely that the national empirical modelling will typically relate to the 10 m distance from the road centreline on this basis. However, because the national modelling is based on data from roadside and kerbside measurements, which are varying distances from actual road centrelines, there will be some uncertainty in the actual distance.

Figure 7.20 Frequency distribution of annual mean NO_2 calculated at 10, 20 and 30 m from the road centreline for major roads in London using the ERG methodology for 2005.



759. Figures 7.21 and 7.22 show the CERC modelling results for the Greater London Area for 2005 and 2010. The area exceeding 40 µg m^{-3} is calculated to decrease from 68% in 1999 to 32% in 2005 and 13% in 2010. These results are higher than those predicted in the ERG and netcen modelling. Figure 7.23 shows frequency distributions for the percentage of the total area of Greater London derived from the CERC model results. A frequency distribution for roadside concentrations is shown in Figure 7.24 all roads in LAEI and in Figure 7.25 for major roads only. The mode of the all LAEI roadside concentrations is at approximately 40 µg m^{-3} in 2005. The CERC modelling results in terms of the area and length of road exceeding 40 µg m^{-3} are listed in Table 7.9.

Table 7.9 Area and length of road exceeding an annual mean NO_2 concentration of 40 µg m^{-3} in London using the CERC approach.

	km² > 40 µg m⁻³	Length of major roads > 40 µg m⁻³ (km and percent)	Length of minor roads > 40 µg m⁻³ (km and percent)	Length of all LAEI roads > 40 µg m⁻³ (km and percent)
Total area/length modelled	1574	1746	1910	3656
1999	1074 (68%)	1719 (98%)	1591 (83%)	3250 (89%)
2005	504 (32%)	1378 (79%)	893 (47%)	2271(62%)
2010	205 (13%)	857 (49%)	410 (21%)	1267 (35%)

Figure 7.21 Annual mean NO_2 in London for 2005 using CERC model (µg m^{-3}).

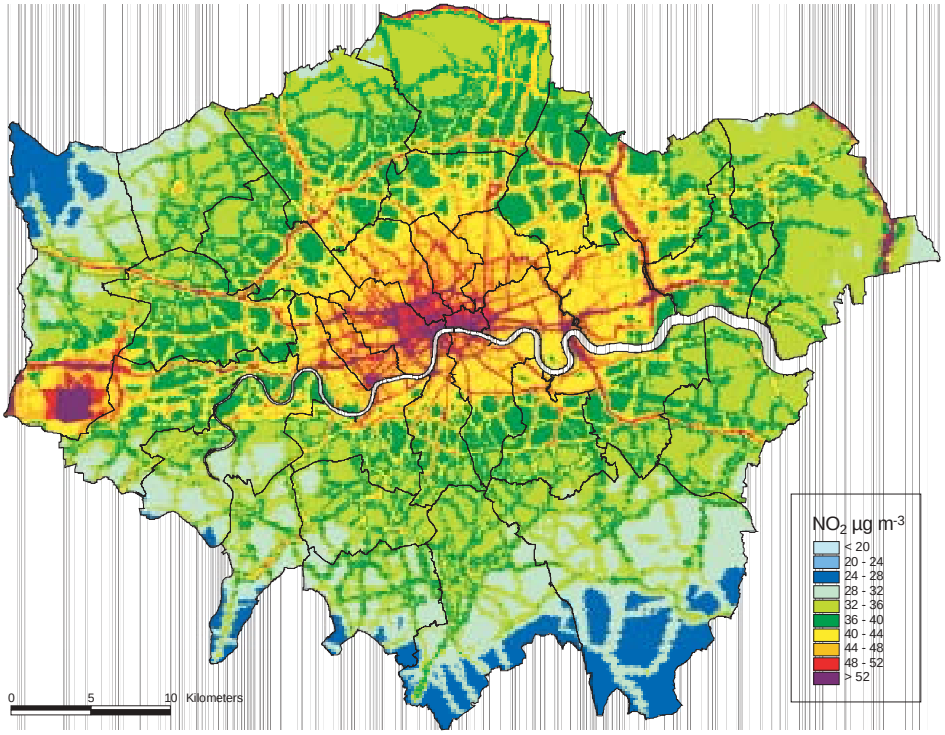


Figure 7.22 Annual mean NO_2 in London for 2010 using CERC model (µg m^{-3}).

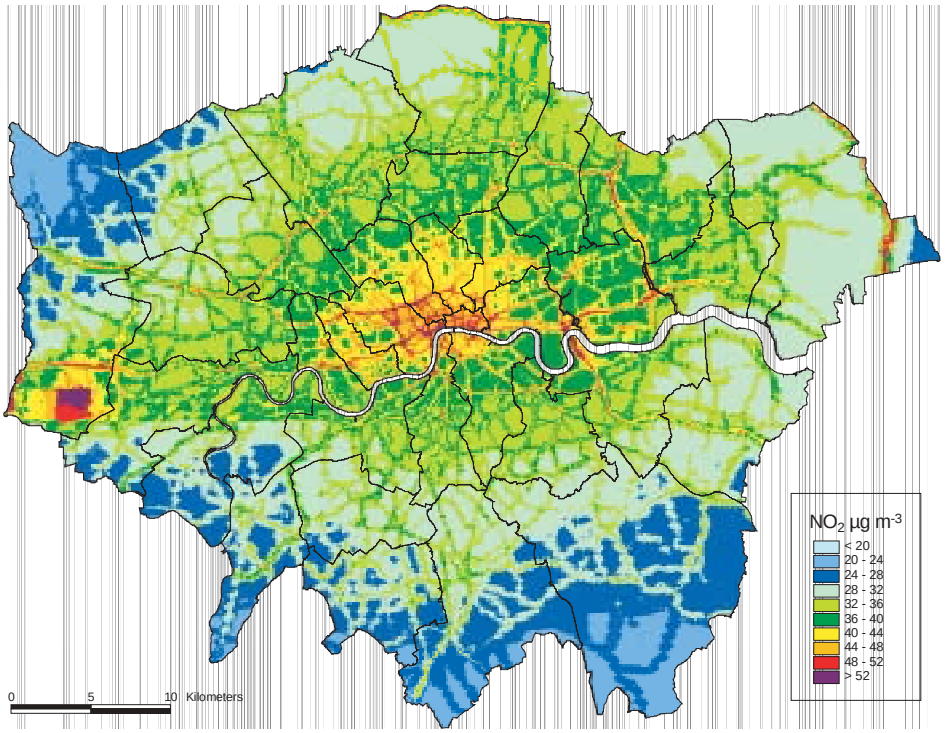


Figure 7.23 Frequency distribution of annual mean NO_2 concentration across the area of Greater London derived from CERC model results.

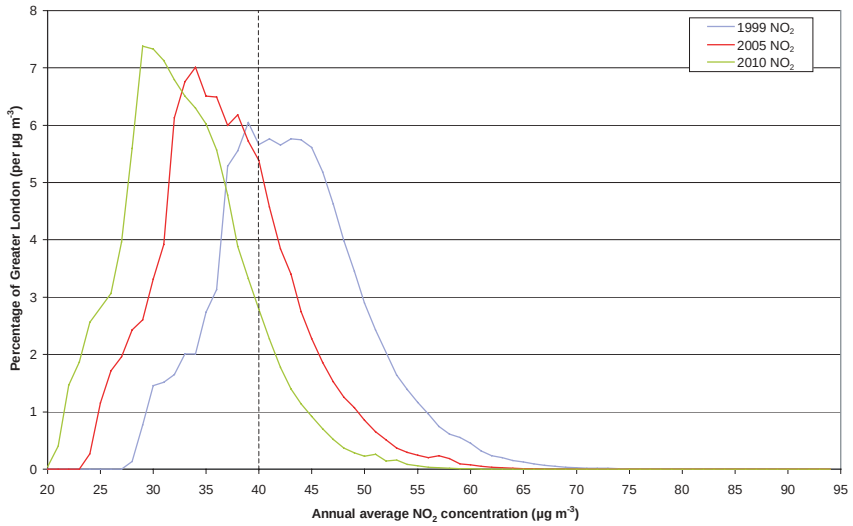


Figure 7.24 Frequency distribution of annual mean NO_2 concentration for all LAEI roads in London using the CERC model.

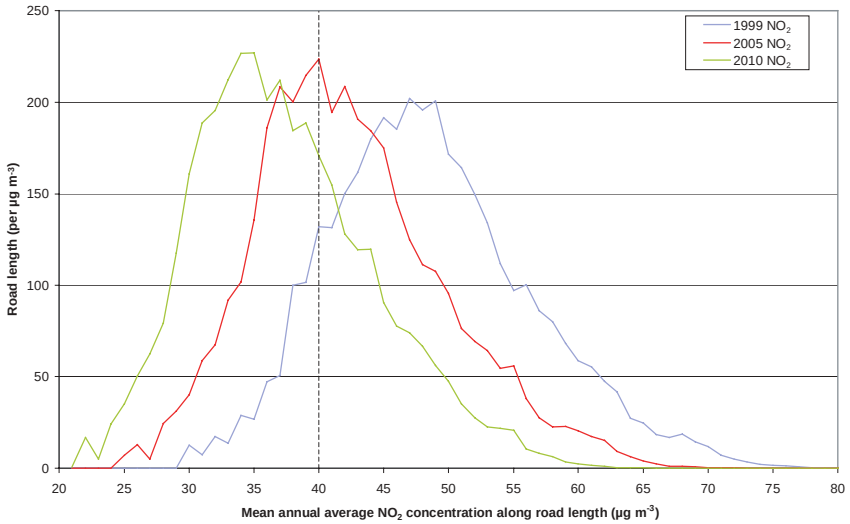
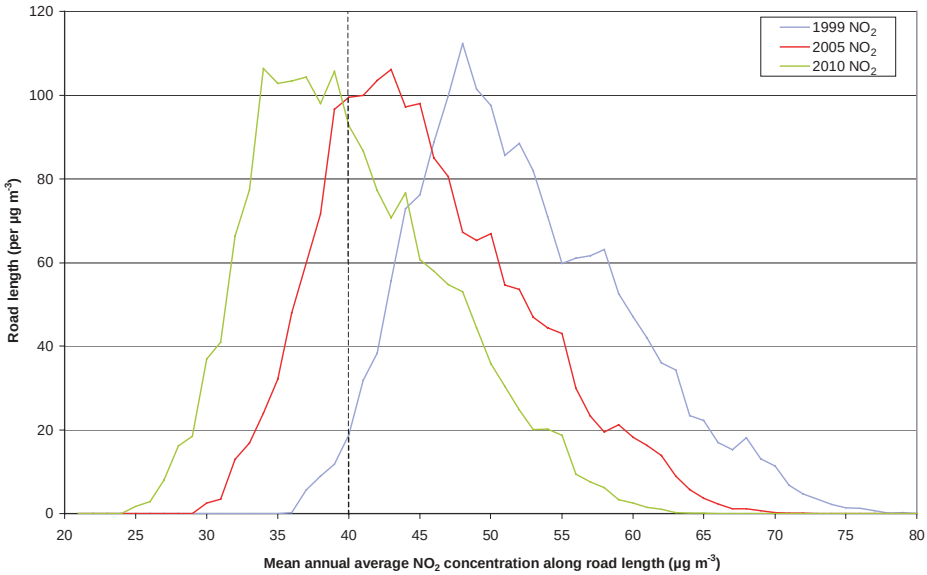


Figure 7.25 Frequency distribution of annual mean NO_2 concentration for major roads in London using the CERC model.



760. The LRCTM (see section 5.4) has also been used to predict background NO_2 concentrations in London. The LRCTM model has been used to test the assumptions inherent in projecting NO_2 concentrations into the future and to examine the impact of policy measures on NO_2 concentrations in London up to the years 2005 and 2010. The concern here has been about the extent to which the empirical models are able to address quantitatively the future NO_2 air quality situation because they necessarily have been built using contemporary NO_2 and NO_x air quality data.

761. The spatial distributions of the annual mean NO_2 concentrations across London have been determined using the LAEI NO_x emission inventories for 2005 and 2010 for comparison with the map for 1999 presented in section 6.4.3. These distributions are plotted out in Figure 7.26 for a substantial area of the London conurbation covering over 1500 km_2 of north and central London and its outskirts. The mean annual mean NO_2 concentration for this selected area was found to be 39.5 µg m^{-3} with 1999 NO_x emissions, 35.8 µg m^{-3} with 2005 emissions and 33.7 µg m^{-3} with 2010 emissions. The reduction in annual mean NO_2 concentrations amounted to 9% for 2005 and 15% for 2010 whilst the reduction in annual mean NO_x concentrations were a factor of two higher at 21% and 31%, respectively. NO_x concentrations fell at a slightly lower rate compared with NO_x emissions because of the contribution to emissions from the south-east region generally and from long range transport from Europe. Both these terms had been held constant in the LRCTM between 1999 and 2010. Mean NO_2 concentrations fell at a significantly lower rate compared with NO_x concentrations because the NO_2 vs. NO_x split changes with NO_x concentration. As NO_x concentrations fall, the fraction of the NO_x that is present as NO_2 increases so that NO_2 concentrations always fall less quickly compared to NO_x concentrations and NO concentrations fall more quickly. This behaviour found in the LRCTM model results explains the origins of the non-linear relationship found between NO_2 and NO_x concentrations which is the basis of the empirical modelling approaches described Chapter 5.

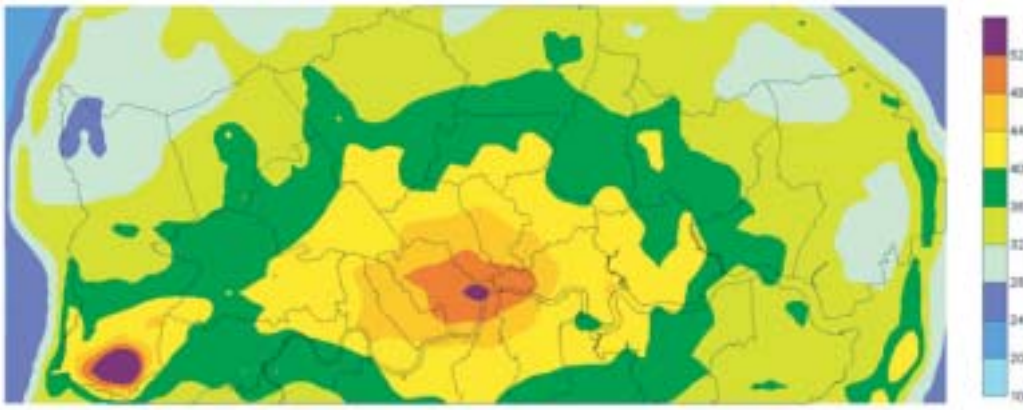
762. The highest annual mean NO_2 concentrations in the LRCTM model results are found in the area between Heathrow Airport and the M25 as is shown in Figure 7.26. With 1999 NO_x emissions, the maximum annual mean NO_2 concentration was found to be 67.1 µg m^{-3} and this decreased by 7% to 62.2 µg m^{-3} with 2005 emissions and by 14% to 58.0 µg m^{-3} with 2010 emissions. Over central London, the maximum annual mean NO_2 concentrations was

found to be 57.4 µg m^{-3} and this decreased by 8% to 52.7 µg m^{-3} with 2005 emissions and by 13% to 49.8 µg m^{-3} with 2010 emissions.

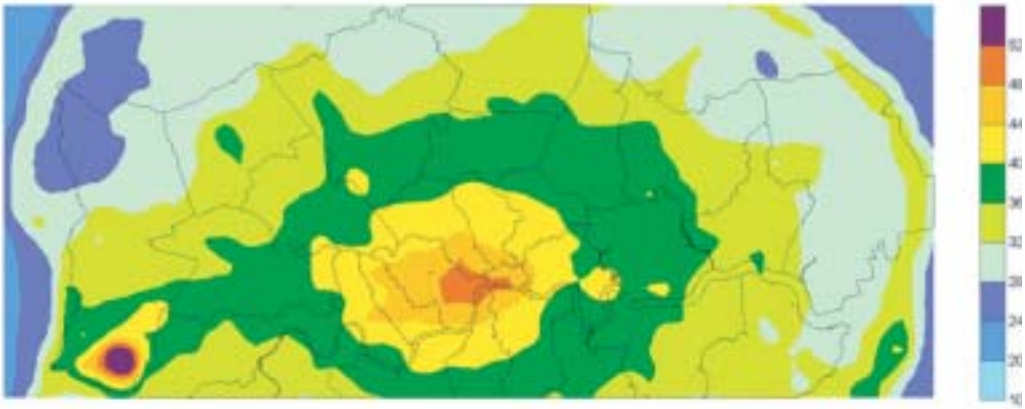
763. The area of exceedence of 40 µg m^{-3} shrinks dramatically from 44% of the area modelled in 1999 to 20% in 2005 and 10% in 2010. A significantly greater reduction in NO_x emissions would be required if exceedences are to be eliminated altogether in central London. In viewing Figure 7.26 account should be taken of the coarse resolution of the LRCTM model. This means that the plotted annual mean concentrations give a reasonable reflection only of likely annual mean NO_2 concentrations in urban background and suburban locations. The model is not able to describe the NO_2 concentrations likely to be experienced in roadside and kerbside locations in 2010. This consideration reinforces the conclusion that significantly greater reductions in NO_x emissions will be required compared to those currently contemplated, if exceedences of 40 µg m^{-3} are to be eliminated by 2010.

Figure 7.26 The spatial distributions of the annual mean NO_2 concentrations (µg m^{-3}) predicted with the LRCTM model with:

a) 2005 LAEI NO_x emissions



b) 2010 LAEI NO_x emissions



7.3.4 Comparison of the different model predictions for London

764. The areas modelled in each of the studies are different and thus the percentages of the total areas modelled exceeding 40 µg m^{-3} presented in the previous section are not directly comparable. Table 7.10, however, shows a comparison of the model results for London for concentrations in background locations for the three studies for which the model domains include the whole of Greater London. The area modelled using the LRCTM does not cover the whole of Greater London and Table 7.11 therefore provides a comparison for the area that is common to all four studies. Figure 7.27 shows the location of this common model domain in

relation to that of the CERC, Met Office (LRCTM) and netcen studies. The ERG model domain is similar to that of CERC but extends slightly outside Greater London.

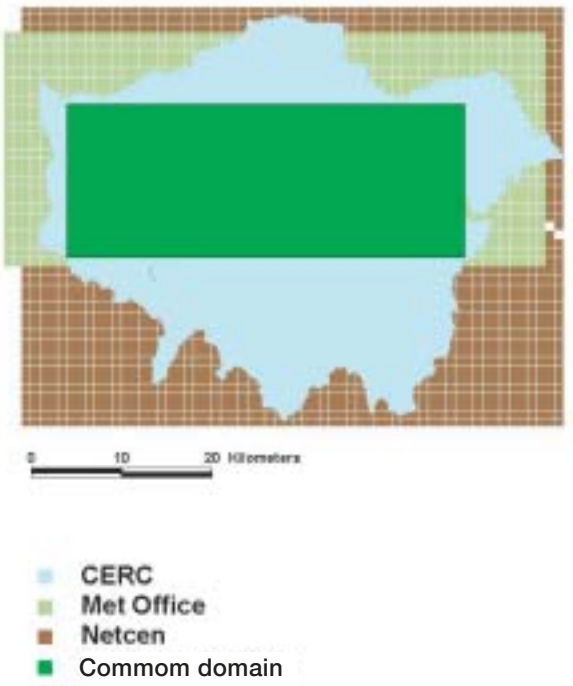
Table 7.10 Comparison of the percentage of the area of Greater London predicted to exceed an annual mean NO_2 concentration of 40 µg m^{-3} (total area modelled = 1574 km^2).

Model	Locations modelled	Base year	1999	2001	2005	2010
Netcen	background	2001	–	12	5	3
ERG	all	1999	38	21	10	3
CERC	all	1999	68	–	32	13

Table 7.11 Comparison of the percentage of the area of the common model domain predicted to exceed an annual mean NO_2 concentration of 40 µg m^{-3} (total area modelled = 748 km^2).

Model	Locations modelled	Base year	1999	2001	2005	2010
Netcen	background	2001	–	22	10	6
ERG	all	1999	65	39	18	5
CERC	all	1999	88	–	55	24
LRCTM	background	1999	75	–	38	20

Figure 7.27 The areas of London modelled in the different studies.



765. The largest percentages of exceedence are predicted by the CERC and LRCTM models. All of the model results show a reduction in the area above 40 µg m^{-3} between 1999/2001 and 2010 but with exceedences remaining in central London and in the vicinity of Heathrow. The area of exceedence at Heathrow predicted in the netcen model is, however, much smaller than predicted in the other three models.

766. Table 7.12 shows a comparison of the lengths of roads in London predicted to exceed an annual mean NO_2 concentration of 40 µg m^{-3} for the different model results (but note that the exact length of road modelled varies between the different studies). The netcen and ERG results for major roads are very similar to each other in both 2001 and 2010, although the netcen results are somewhat higher for 2005. The percentage of minor road length predicted to exceed the 40 µg m^{-3} is considerably less than for major roads in both the ERG and CERC model results. This suggests that the majority of possible roadside exceedences in 2010 are likely to be confined to major rather than minor roads. This is an important result because it suggests that the national scale modelling of concentrations for major roads only should provide a reasonable approximation of the likely exceedences in 2010 for all roads. The CERC results, however, suggest that a greater percentage of roads in London are at risk of exceeding 40 µg m^{-3} in 2005 and 2010 than indicated by the other two models.

Table 7.12 Comparison of the percentage of the length of road in London predicted to exceed an annual mean NO_2 concentration of 40 µg m^{-3} at the roadside.

Model	Road network	Road length modelled (km)	Base year	1999	2001	2005	2010
Netcen	major roads	1767	2001	-	90	65	23
ERG	major roads	1937	1999		84	53	26
ERG	minor roads	2076	1999		55	27	8
ERG	all LAEI roads	4013	1999		69	39	17
CERC	major roads	1746	1999	98	-	79	49
CERC	minor roads	1910	1999	60	-	47	21
CERC	all LAEI roads	3656	1999	89	-	62	35

767. There are clearly important differences between the modelled predictions of annual mean NO_2 concentrations in 2005 and 2010 from the different models and these differences highlight the uncertainties associated with modelled predictions of future air quality. All of the model results show a significant reduction in the areas and lengths of roads above 40 µg m^{-3} between 1999/2001 and 2010. The estimates of the extent of background exceedence in 2010 range from 3% of Greater London for the netcen and ERG modelling to 13% for the CERC modelling (between 5-6% of the common model domain for the netcen and ERG modelling to 20-24% for the CERC and LRCTM modelling). The predicted area exceeding 40 µg m^{-3} statistic is very sensitive to small changes in concentration. A sensitivity analysis of the calculated area above 40 µg m^{-3} for the ERG predictions for 2005 shows that the area changes by a factor of about 2 for a 10% change in predicted concentrations. The predictions of the extent of roadside exceedence in 2010 range from 23-26% of major roads for the netcen and ERG modelling to 49% for the CERC modelling.

768. It is important to attempt to understand the reasons for these differences between the model results. The factors that may influence the different model results include:

- the source apportionment of 'current concentrations';
- the emission inventory;
- the emission projections;
- dispersion modelling methods;
- the treatment of sources outside London;
- the treatment of the conversion of NO_x to NO_2.

7.3.5 Source apportionment and emissions inventories

769. The netcen modelling is based on the NAEI inventory and projections, while the remaining studies all used the LAEI inventory and projections. A comparison of the source apportionment of annual mean NO_x concentrations between the netcen analysis presented in this report and a similar study by CERC (Blair *et al.*, 2003) shows that the results of the two studies are broadly consistent. This suggests that both the emission inventories and the source apportionment of current NO_x concentrations, and thus the general treatment of dispersion, are reasonably consistent in these two studies. Maps of annual mean NO_x derived from the CERC and netcen studies for both 1999/2001 and 2005 and 2010 are also reasonably consistent, which suggests that the relative declines in emission in the two inventories over the period from 1999/2001 to 2010 are consistent.

770. The NO_x concentrations predicted for 2005 and 2010 using the ERG approach, however, show much greater declines from the 1999 concentrations than suggested by the other studies (Carruthers *et al.*, 2002). The source apportionment of current concentrations between local road traffic and other sources within the ERG model is derived from a multiple regression with measurements (see section 5.2.3.2). Non-road traffic sources therefore make a much smaller relative contribution to current concentrations of NO_x in the ERG model compared with road transport. The modelled decline in concentrations of NO_x in the ERG model is therefore steeper than in the other studies. This is in contrast to the other models, in which the relative contribution from the non-traffic sources is greater. This affects the projections of NO_x concentrations because the non-traffic emissions are not expected to show the same decline as the traffic emissions between 1999/2001 and 2010 (see Chapter 2).

7.3.6 The treatment of dispersion

771. The LRCTM predicts the largest area of exceedence and highest concentrations in the Heathrow area and the netcen model predicts the lowest concentrations in this area. This is likely to be due to a combination of differences in the treatment of the dispersion from aircraft sources and differences between the emission projections within the NAEI and LAEI. The NAEI was used for the netcen projections and the LAEI was used for the other three projections. Aircraft sources have been modelled in the same way as all other sources within the LRCTM, with rapid mixing into the boundary layer. The height of the aircraft sources has been taken into account in the other studies. The greater assumed height of the majority of the emissions from aircraft in the other three studies leads to lower modelled ground level concentrations per tonne emitted, than the modelled concentrations for sources close to the ground such as traffic.

7.3.7 Sources outside London

772. The treatment of sources outside the model area is also important and can have an important influence on the area or length of road predicted to exceed 40 μg m^{-3}. The influence of regional O_3 concentrations is discussed below. All of the models also include contributions to NO_x concentrations in London from regional concentrations in the south east of England and these range between 13 to 19 μg m^{-3}, as NO_2 in 1999. The regional NO_x concentrations have been held constant between 1999 and 2010 in the LRCM modelling. Regional NO_x concentrations have been assumed to decline in line with changes in UK total NO_x emissions in the netcen and CERC studies, leading to a reduction of approximately 30% between 1999 and 2010. Regional NO_x concentrations have been assumed to decline in line with changes in NO_x emissions in London in the ERG study, leading to a reduction of almost 50%.

7.3.8 Chemistry

773. The different treatments of the conversion of NO_x to NO_2 in the different models is likely to be an important cause of the differences in predicted NO_2 concentrations. The CERC ADMS Urban and LRCTM calculations derived NO_2 from NO_x on an hourly basis using a simplified chemical reaction scheme while both the netcen and ERG approaches applied empirical relationships to estimates of annual mean NO_x concentrations. The more deterministically based models might be expected to provide a more accurate description of the chemistry of NO_2 formation, however both these models and the more empirically based models are far from being complete descriptions of all the physical and chemical processes taking place in the ambient air.

7.3.9 Treatment of direct NO_2 emissions

774. The different modelling approaches also take account of direct NO_2 emissions in different ways. The empirical models implicitly include the contribution made by direct NO_2 emissions for the current day. There will be uncertainty in the use of these methods when making forward projections if the proportion of direct NO_2 emissions changes; in addition it is difficult to take account of the detailed spatial variation in the proportion of the direct emissions that is NO_2. Conversely, although the deterministic models can specify the proportion of primary NO_2 in NO_x sources they are limited by uncertainties concerning direct emissions of NO_2. They have assumed a uniform NO_2 emission from traffic of 5% of NO_x by volume. Material presented in this report suggests that direct emissions could be higher in locations with a high proportion of slow-moving diesel vehicles for example, central London. For this reason, more of the NO_2 in the deterministic approaches may be chemically derived than is implicit in the empirical models. It is possible that these approaches will respond more slowly to reductions in NO_x compared with the empirical approaches.

7.3.10 Findings from the LAQM process

775. All local authorities in the UK have carried out a review and assessment of air quality in their area. This represents the first round of what are to be regular reviews and assessments to be completed every three years (Defra, 2003). The first round was a three-stage process, examining the likelihood of an exceedence of one or more of the objectives for the 7 regulated pollutants. The third, more detailed, stage was required most commonly for nitrogen dioxide, against the annual mean objective. In many cases the detailed assessment included automatic monitoring for NO_x using a chemiluminescence analyser, for periods ranging from 1 to 12 months. The results from these studies, all of which were focussed on road traffic sources, have been collated and analysed (Laxen *et al.*, 2002). The focus of the analysis was on the influence of distance from the edge of the road, with the data examined in three groupings: single carriageway roads outside of major conurbations; dual carriageway roads outside of

major conurbations; and all roads in major conurbations. Data from national network sites were included, to provide a more comprehensive data set. The findings are summarised in Table 7.13 in terms of distances within which likely exceedences of the annual mean NO_2 objective might occur. An exceedence was judged likely if the 1999/2000 concentration was above 46 µg m^3. It is clear that exceedences are more likely:

- in major conurbations, rather than outside; and
- alongside single carriageway roads, rather than dual carriageways and motorways, outside major conurbations.

Conversely, exceedences are unlikely for locations:

- more than 9 m from the kerb of single carriageway roads outside major conurbations; and
- more than 5 m from dual carriageways and motorways outside major conurbations.

The finding that exceedences outside of major conurbations are likely to be confined to a narrow strip close to the road is consistent with the rapid fall-off in concentrations with distance from the kerb as seen in section 6.3.2.

Table 7.13 Likely exceedences of annual mean NO_2 objective in 2005 identified from monitoring near to roads (from Laxen *et al.*, 2002).

Location	Distances from kerb with exceedences[a]	Exceedences as proportion of number of near road sites[b]	Exceedences as proportion of all sites[c]	Total number of sites in analysis
Outside Major Conurbations – Single Carriageway Roads	0–9 m	36%	24%	59
Outside Major Conurbations – Dual Carriageways and Motorways	0–5 m	40%	12%	17
In Major Conurbations – All Roads[d]	0–35 m	81%	72%	18

a Outside this distance range no likely exceedences were identified.
b Proportion of sites within the distance range in previous column.
c Proportion of all sites (these were all within 100 m of the road, mostly within 50 m).
d The M25 was counted as being in a major conurbation.

7.4 Key issues for projections

7.4.1 Introduction

776. The projections presented here have been derived from a combination of base case emission inventory projections and our best estimates of the response of ambient concentrations to changes in emissions. The base case emission projections are based on an analysis of current national and international policies and their likely effect on future NO_x emissions. A full analysis of the uncertainties in the modelled projections of concentrations in 2005 and 2010 has not been carried out. The range in the results for London from the different models shows that the uncertainties are quite significant. It is clear, however, that exceedences of 40 µg m^{-3} in 2005 and 2010 are likely, but the exact extent of likely exceedence is uncertain. There are two issues that have not been incorporated into the detail of the base case projections. These are the possible impacts of an increase in hemispheric background O_3 concentrations and an increase in the proportion of NO_x emitted as primary NO_2. They have some potential to offset the

predicted decreases in NO_x emissions over the next ten years or so, resulting in smaller reductions in ambient NO_2 concentrations than suggested by the base case projections.

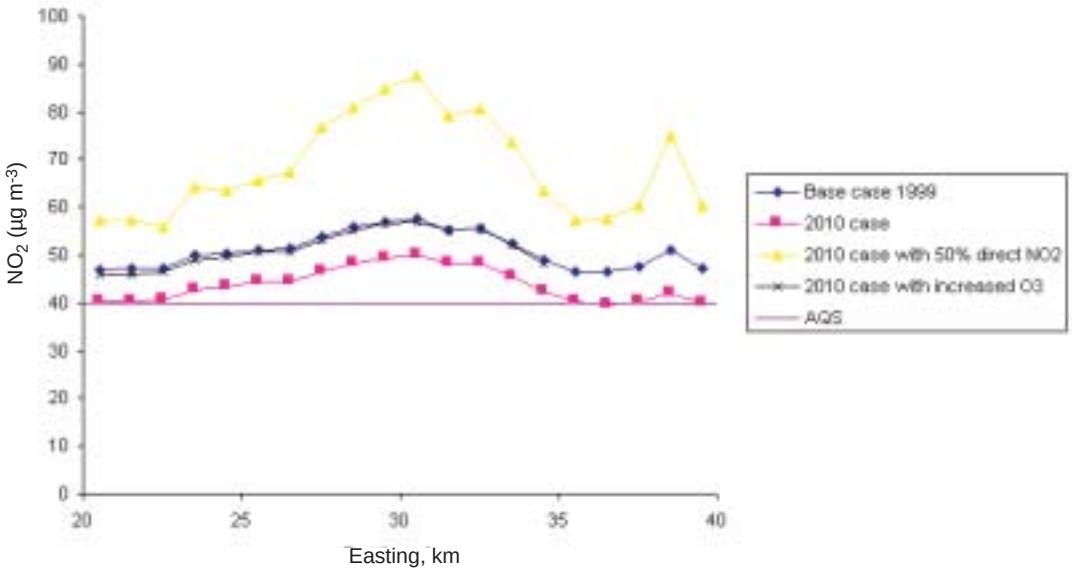
7.4.2 Policy impacts of other influences on future NO_2 air quality

777. Empirical models can only address those changes in future NO_2 air quality that are driven by NO_x emission changes because they are built from contemporary NO_x and NO_2 air quality data. The LRCTM model has been used to test whether there are other potential factors over and above changes in NO_x emissions that could potentially influence future NO_2 air quality and the exceedences of 40 µg m^{-3}.

778. Figure 7.28 presents the annual mean NO_2 concentrations calculated for an east-west transect through central London using the 1999 LAEI NO_x emissions inventory as a base case and with the corresponding 2010 inventory. The transect covers the region of annual mean NO_2 above 40 µg m^{-3} and exceedences in central London which is apparent in Figure 7.26. Annual mean NO_2 concentrations decrease at all points along the transect with 2010 compared with 1999 NO_x emissions.

779. Figure 7.28 also shows the results of two sensitivity cases for 2010 that cannot be easily investigated with empirical models. The first sensitivity case addresses the issue of any increase in the direct emissions of NO_2 in the future. The second sensitivity case addresses what happens if baseline O_3 concentrations continue to rise in the British Isles and increase the capacity of urban atmospheres to convert NO into NO_2.

Figure 7.28 Annual mean LRCTM model NO_2 concentrations along a transect through central London with 1999 and 2010 NO_x emissions, showing the impact of increased O_3 baseline concentrations and of increasing direct emissions of NO_2 .



7.4.3 Increasing direct emissions of NO_2

780. The first sensitivity case assumed that the fraction of NO_x emitted directly as NO_2 changed from 5% by volume in the base case to 50% by volume in the 2010 case for all sources in the inventory. Under these conditions, NO_2 concentrations along the transect then rise significantly above those in the 1999 case and a significant gap opens up between the future NO_2 concentrations in 2010 and 40 µg m^{-3}, see Figure 7.28.

781. The results of this model sensitivity case suggest that it is important to quantify the direct emissions of NO_2 from diesel-engined cars, buses and goods vehicles in the contemporary fleet and in the future. It is also particularly important to determine the influence of catalytically-regenerative diesel particle traps on the direct emissions of NO_2 from the buses to which they have, and will be, fitted in the near future. It should be noted however, that the 50% of all NO_x emissions emitted directly as NO_2 should be considered as an extreme worst case sensitivity test rather than a realistic scenario.

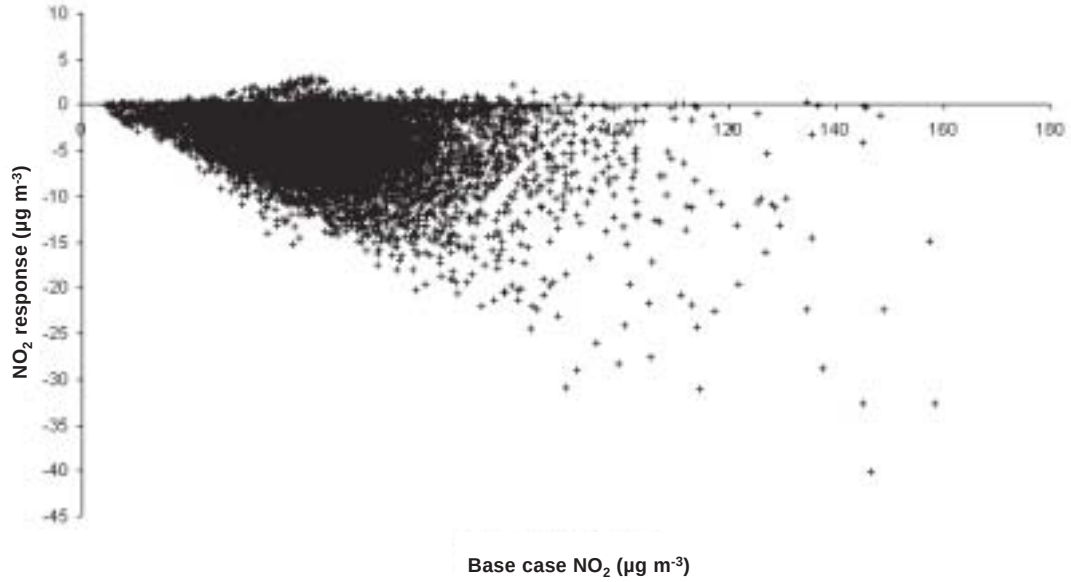
7.4.4 Increasing hemispheric O_3 baseline concentrations

782. The second sensitivity case assumed that baseline O_3 concentrations may rise significantly in the future and that they continue to rise at the same annual rate of increase as that observed historically for background air masses at Mace Head, Ireland during the 1990s. The assumed increase varies by month of the year and is highest in the winter and lowest in the summer, as described in section 6.6.2. The average increase is approximately +1 µg m^{-3} (+0.5 ppb) O_3 per year. Under these assumptions, an additional 2010 case was modelled with both decreased future NO_x emissions and increased O_3 baseline concentrations. Under these conditions, future NO_2 concentrations remained close to 1999 levels, despite the significant reduction in NO_x emissions, see Figure 7.28. It appears that increasing O_3 baseline levels could increase the oxidising capacity of London's atmosphere, enough to offset any improvements anticipated from the reduction of NO_x emissions by the year 2010.

783. In attempting to summarise these results for the 2010 cases compared with the base case, it becomes apparent that there is a less than linear relationship between annual mean NO_2 concentrations and London-wide total NO_x emissions. That is to say, if London-wide total NO_x emissions decrease by x% between 1999 and 2010, then annual mean NO_2 concentrations tend to decline by less than x%. This less-than-linear relationship between NO_2 and NO_x was investigated using the LRCTM model.

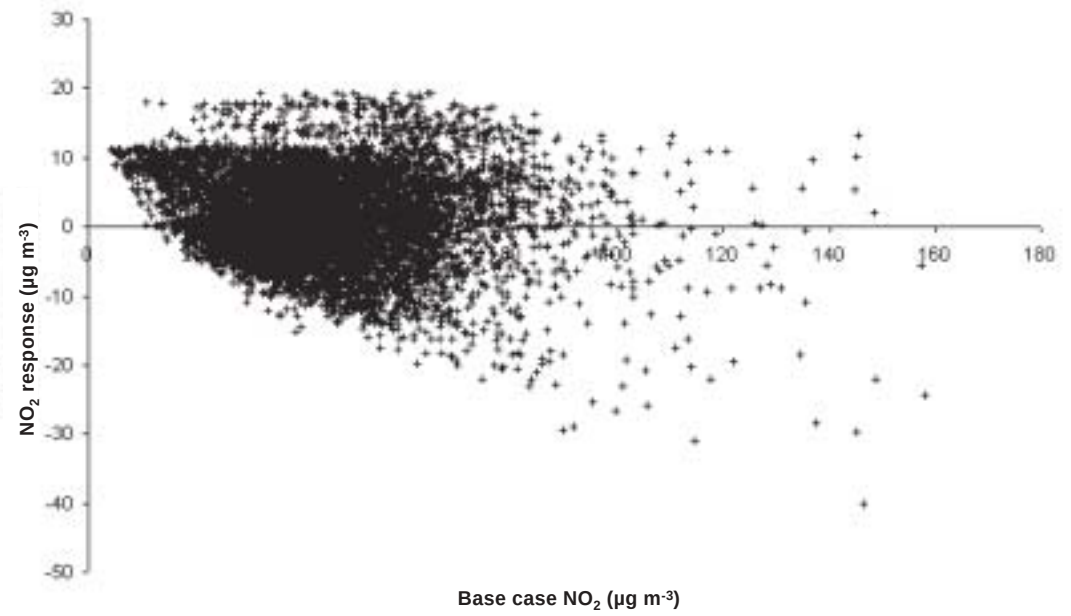
784. Figure 7.29 presents the NO_2 responses for each hour at a location in central London, expressed as 2010 case minus 1999 case so that a NO_2 decrease shows up as a negative value in the plot. Each NO_2 response was plotted out as a scatter plot against its respective base case NO_2 concentration. At each NO_2 concentration level in the base case, there was a large variation in NO_2 response which varied over the range from zero up to about 20%, despite there being about a 38% reduction in NO_x emissions overall. For some hours, there was no apparent NO_2 response to the reduction in NO_x emissions. These are the hours in which NO_2 formation is entirely O_3-limited. Decreasing NO_x emissions then makes no difference to NO_2 formation. For those hours close to the upper-limit surface, NO_2 concentration responses are about 20% for a 38% reduction in emissions, representing an efficiency of about one half to two-thirds. Here NO_2 formation is entirely NO_x limited. Decreasing NO_x emissions then makes a direct difference to NO_2 formation but the efficiency is not unity because for every 2 µg m^{-3} decrease in NO_x as NO_2 (1 ppb), NO_2 decreases by about 1.2 µg m^{-3} (0.6 ppb) and NO decreases by about 0.5 µg m^{-3} (0.4 ppb) because of the photostationary state relationship.

Figure 7.29 Scatter plot of the hourly LRCTM model NO_2 concentration responses against the base case NO_2 concentration for changing NO_x emissions between 1999 and 2010.



785. Figure 7.30 presents the corresponding NO_2 responses to decreasing emissions between 1999 and 2010 and increasing baseline O_3 in 2010. The influence of the increased oxidation capacity has been dramatic and NO_2 concentrations in some hours have increased despite the reductions in NO_x emissions. Overall the decreases in NO_2 concentrations in the NO_x-limited hours have been compensated by the increases in NO_2 concentrations during the O_3-limited hours. Annual mean NO_2 concentrations are thus left more or less unchanged from 1999 to 2010.

Figure 7.30 Responses to NO_x emission reduction and increased baseline O_3 of each hourly mean LRCTM model NO_2 concentration plotted against the base case NO_2 concentration.



786. On this basis, it is concluded that urban NO_2 concentrations in London are surprisingly sensitive to increases in the hemispheric O_3 baseline concentrations in the air masses as they impinge on the London region. This conclusion is entirely derived from model calculations and as yet is unsupported by observations. It is important then to examine the available NO_x-NO_2-O_3 monitoring records from long running sites to establish whether there has been any influence from increasing O_3 baseline levels in NO_2 levels. If such a relationship between hemispheric O_3 and urban NO_2 can be discerned from the observations then it may be necessary to take into account hemispheric O_3 trends in planning future NO_x emission reductions in urban areas. The limited analysis of measured NO_x, NO_2 and O_3 concentrations at West London and Glasgow City Chambers presented in section 6.6.3 suggests that the impact of changes in hemispheric baseline O_3 levels may be variable across the UK, with a greater impact in Glasgow than in London, although the analysis is confounded by changes in summer episode O_3 concentrations.

7.4.5 ADMS-Urban calculations of the impact of increased O_3 concentrations

787. The possible impacts of increasing concentrations of hemispheric O_3 on NO_2 concentrations in London in 2010 have also been estimated using ADMS-Urban. The estimated monthly average increases in O_3 concentrations listed in Table 7.12 in Chapter 6 were added to each hourly background O_3 concentration input into the model for the relevant month. This increased the annual mean regional O_3 concentration in 2010 from 61.52 µg m^{-3} to 73.72 µg m^{-3} (30.76 ppb to 36.86 ppb)

788. The increase in regional O_3 concentration results in an increase in annual mean NO_2 concentration of 4.4 µg m^{-3} (2.3 ppb) averaged across the 23 sites modelled and 3.6 µg m^{-3} (1.9 ppb) at the 14 background sites. The corresponding increases in modelled O_3 concentrations are 7.2 µg m^{-3} (3.6 ppb) averaged over all site sites and 8.3 µg m^{-3} (4.1 ppb) at background sites. While the increase in total input oxidant concentration (NO_2 + O_3) is conserved in both the LRCTM and ADMS-Urban calculations, the partitioning of the increase in oxidant between NO_2 and O_3 is different. For the same 12 µg m^{-3} (6 ppb) increase in input O_3 concentrations the resulting average increase in annual mean NO_2 ranges from about 3.8 µg m^{-3} (2 ppb), for the ADMS-Urban calculations for background sites, to about 6.7 µg m^{-3} (3.5 ppb) for the LRCTM calculations. This difference is likely to be due to the different treatment of dispersion and mixing within the two models since the chemical schemes adopted are similar. The results of these two studies confirms that an increase in hemispheric O_3 concentrations could have an important impact on projected annual mean NO_2 concentrations in 2010 and that this is clearly an important area for further research.

Chapter 8

Conclusions

789. The Expert Group has examined monitoring data for 212 sites across the UK, which show that the annual mean NO_2 concentrations have exceeded 40 µg m^{-3} by a wide margin in recent years. This value of 40 µg m^{-3} is both the UK objective and the EU limit value, although the former is to be achieved by 2005, while the latter is to be achieved by 2010. Many of these observed exceedences are found in London. They have also been reported in other conurbations, but because the density of monitoring sites is much lower than in London, the full extent of the exceedences is difficult to gauge from observations. The Local Air Quality Management process operated by local authorities has also identified current exceedences in smaller towns, especially for locations alongside narrow congested town centre roads, where houses can be close to the kerb. Examination of the European Environment Agency air quality database has shown that current NO_2 concentrations exceed 40 µg m^{-3} at many locations throughout Europe, and thus the situation in the UK is not unique. Direct comparisons with other European cities cannot, however, be made because of differences in approaches to siting of monitoring stations in the various countries. Whilst the hourly mean objective value of 200 µg m^{-3} per year (with 18 allowed exceedences) is occasionally breached, it represents a much less challenging target for air quality management than the annual mean objective.

790. The Expert Group has examined a hierarchy of modelling tools to quantify the spatial distribution of the annual mean NO_2 concentrations from NO_x emission inventories. The general level of agreement found between models and observations is good and confirms that the available NO_x emission inventories give an accurate picture of actual NO_x emissions and that two main processes control the annual mean distribution of NO_2 in urban areas. These two processes are the oxidation of emitted NO to NO_2 by O_3 transported in from the surrounding rural areas, and direct emissions of nitrogen dioxide by vehicular traffic. The general level of agreement found between model and observation at roadside, kerbside and urban background sites away from the immediate influence of roads, argues strongly that models are able to provide a reasonable description of the fall-off in annual mean concentration with increasing distance from roads. On this basis, the Expert Group was able to confirm that exceedences of 40 µg m^{-3} annual mean NO_2 are widespread throughout the UK. Exceedences are unlikely to be limited to the London conurbation and may also be found in all major conurbations, in all the devolved administrative regions of the UK and along all the heavily-trafficked arterial roads.

791. The widespread exceedences of 40 µg m^{-3} NO_2 as an annual mean remain, despite a decade of decreasing NO_x emissions. Running mean NO_x concentrations have declined by up to 3% per annum at urban background sites during the late 1990s. However, simultaneous running mean NO_2 concentrations in London show significantly lesser downward trends or no trend at all. The Expert Group has explained this important difference in the behaviour of NO_x and NO_2 with time through oxidant limitations on chemical production of nitrogen dioxide and increased direct emissions of NO_2. Despite the reduction in NO_x emissions, concentrations of NO in pollution episodes still reach levels at which the thermal oxidation of NO by O_2 plays an important role in producing NO_2, as it did in the December 1991 London episode.

792. The assumption that the relationships in the empirical models between NO_x and NO_2 imply cause and effect relationships has been examined. Using physically-based process models, the Expert Group has been able to show that the empirical relationships between NO_x and NO_2 are exactly those expected if oxidation of NO by O_3 and direct emission of NO_2 are indeed the

two major sources of urban NO_2. However, empirical models are only valid for the range of conditions experienced during their derivation, and changes in, for example, background O_3 concentrations will require model reformulation, and imply that the current models will probably not be reliable in 2010.

793. Despite continuing decreases in urban NO_x emissions projected through to the years 2005 and 2010, modelling studies reviewed by the Expert Group still predict continuing exceedences of the annual mean objective and limit value for NO_2 beyond the relevant dates. Inevitably, these models contain a number of simplifications and inadequacies. They are driven with input data which themselves contain approximations and are subject to uncertainties. Much reliance has been placed on dispersion models and empirical relationships between NO_x and NO_2. Where possible they have been verified and validated against observations but this has been difficult outside of the London conurbation because of the more limited availability of high quality monitoring data with long enough time series.

794. The Expert Group remains convinced that, on the basis of current projections of traffic volumes and vehicle sales and predictions of the reduction of vehicle NO_x emissions on a kilometre travelled basis as new control technologies are introduced, some exceedences of the annual mean objectives and limit values for NO_2 will remain in the years 2005 and 2010 respectively. These will be less widespread than at present, but nonetheless still appreciable. Crucial to these predictions are the assumptions about traffic growth, rate of turnover in the vehicle fleet and NO_x emissions from new vehicles in the future. If future traffic flows exceed expectations, or emission control technologies fail to deliver anticipated reductions, continued exceedences will be more widespread. On the basis of current evidence, heavy duty diesel vehicles emitted 43% of NO_x emissions from UK road transport in 2000, but this conclusion is based on poorly characterized emissions. Levels of NO_x and of direct NO_2 emissions from these vehicles need to be determined through the continuation of robust emission research programmes focusing on both current and future vehicle technologies.

795. NOx emissions are primarily in the form of NO, but there is evidence for significant amounts of NO_2 emitted directly from the tailpipe of diesel vehicles, with levels possibly as high as 25% of total NO_x emissions. Current evidence suggests that increasing the diesel car penetration rate in the UK fleet would lead to a small increase in NO_x emissions from road traffic in urban areas, but a more significant increase in primary NO_2 emissions. An increase in diesel car sales in 2010 from 22% of new car sales (close to the current rate) to 30% would increase urban UK road transport emissions of NO_x in 2010 by 0.7% and NO_2 emissions by 3%. In an extreme case, where diesel car sales increased to 50% of new car sales, urban UK road transport emissions of NO_2 in 2010 would be increased by 6%.

796. Progress in the Government's Ten Year Plan for transport and other transport policies will need to be monitored regularly if the UK is going to reduce NO_x emissions sufficiently to meet the National Emissions Ceiling Directive target for 2010. The Government's recently proposed National Emission Reduction Plan for implementing the Large Combustion Plant Directive will help ensure emission reductions for stationary combustion sources are realised, but levels of activity in the power generating and industry sectors and effectiveness of abatement measures adopted will need to be monitored to ensure the reductions do occur. Uncertainties in the emission projections, and the sensitive drivers that are used to derive them, will need to be considered when progress towards meeting the NECD targets is reviewed.

797. The Expert Group is aware that the local air quality management process being undertaken by local authorities is leading to the development of local air quality action plans to deal with hot-spots. These measures are welcomed by the Expert Group and should help reduce NO_2 concentrations at critical locations. However, because of the devolved nature of this local authority work, the Expert Group has been unable to form a view on the extent to which these measures will contribute to meeting the objectives and limit values.

798. There are reasons to believe that the current projections for future urban NO_2 concentrations may be optimistic. If northern hemisphere baseline O_3 concentrations continue to rise and influence rural O_3 concentrations in the UK, then the relationships between urban NO_2 and NO_x concentrations will alter, resulting in higher than expected future annual mean NO_2 concentrations. The Expert Group were unable to establish clear evidence for or against this hypothesis based on historic monitoring data. There is a clear need for developing new predictive models able to allow for changes in background O_3. Furthermore, if catalytically-regenerative particulate traps that are being retrofitted to diesel powered vehicles significantly increase direct emissions of NO_2, as indicated by studies carried out in the USA, there will be further breaches of the air quality objective and limit value. The Expert Group was unable to find any measurements of direct emissions of NO_2 from vehicles retro-fitted with catalytically-regenerative traps in the UK and were hence unable to form a considered view on whether this is likely to become a problem. However, given the limited number of diesel vehicles in the national fleet which are likely to be retrofitted with these types of regenerative traps, the problem is unlikely to be widespread. It may be more acute in certain areas where local fleets operate which have been targeted with the retrofitting of CRTs in order to control local particulate emissions. Central London, where a significant number of buses have been retrofitted, may be an example. In the future manufacturers of new vehicles and engines will be required to meet increasingly stringent limits on total NO_x as well as on particulate emissions for Euro IV type-approval. Already, particulate trap technology exists which includes downstream NO_2 emission control.

799. The Expert Group has given careful consideration in this report to the processes involved in the emission, formation, dispersion and removal of NO_2, that ultimately determine exposures of the general population to NO_2. However, the Expert Group is only too aware that in this analysis, NO_2 should not be considered in isolation. Traffic sources emit a number of pollutants in addition to NO_x and of particular concern is the emission of particulate matter. Measures taken to reduce particulate matter emissions may increase public exposure to NO_2, particularly if they focus on the important role of the particle emissions from diesel-engined vehicles in contributing to the exceedence of the air quality objectives for PM_{10}. Increasing direct emissions of NO_2 from diesel vehicles retro-fitted with particle traps would lead to increased airborne concentrations of NO_2.

800. NO_2 should not be considered in isolation from other pollutants. In developing air pollution controls, there may therefore be trade-offs between different pollutants, and it is a matter of concern that much of local air quality management is currently driven by exceedences of one air quality objective: the annual mean of 40 μg m^{-3} for NO_2. The Expert Group feels that a more flexible and holistic approach to air quality management might deliver more effective control strategies.

Chapter 9

Research recommendations

801. Research requirements have been identified in the following areas:

802. A better understanding of vehicle behaviour and of instantaneous emissions from traffic at specific locations like road junctions and areas, where modelling emissions by the more simplistic average speed approach is inadequate. Refined estimates of the effects of instantaneous traffic activity (speed/load/rates of acceleration).

803. Provision of robust NO_x emission factors and the fraction of NO_x emitted as NO_2 for current and future road vehicles that can be used in inventories and dispersion models. Emphasis should be placed on measurements of emissions of NO_x and primary NO_2 from heavy duty diesel vehicles meeting current and future emission standards.

804. Measurement of primary NO_2 emissions from other ground-level combustion sources, particularly other transport and machinery types using diesel engines (for example, rail locomotives, construction plant , non-road mobile machinery) and domestic burner and combustion appliances.

805. Investigation of the effects of aircraft emissions at major airports on ground level NO_2, including measurements of emissions and dispersion modelling.

806. Assessment of the effects of domestic emissions on urban background concentrations of NO_2, including forward projections.

807. Development of a better understanding of the effects of meteorology on NO_2 concentrations, including: (i) investigation of the effect of urban environments on meteorological fields; (ii) measurements of meteorological parameters above and below the urban canopy; (iii) assessment of the significance of the choice in models of input meteorological data (station and year), via modelling sensitivity studies; (iv) Coordinated and co-located measurements of air quality, meteorology and detailed traffic activity and better quality control of those weather data which are already collected at urban air quality monitoring stations; (v) evaluation of remote sensing techniques to allow local monitoring of meteorological parameters to be extrapolated to other locations within the urban boundary layer.

808. Research into the use of other modelling approaches, that have not been used extensively in this report for the assessment of NO_2 concentrations, is required. These approaches include computational fluid dynamics (CFD) for the consideration of small spatial and temporal scales, for example, close to roads where the meteorology can be influenced by buildings, and Eulerian approaches for the urban to regional scale. One important application of such models is in helping to build the understanding required to carry out a scientific assessment of the empirical and deterministic models used extensively in this report.

809. Investigation of the determinants of NO_2 concentrations at roadside hotspots, including meteorology, mixing of O_3 from the urban canopy, and chemical kinetics.

810. Further assessment of the contributions of free radical-driven oxidation processes to NO-to-NO_2 conversion in polluted urban environments.

811. Further comparisons of the national empirical model and dispersion models in cities other than London, to confirm the applicability of the conclusions from London elsewhere. Implementation of this recommendation may be difficult, however, because of the more limited extent of hourly continuous monitoring in other major conurbations.

812. Support for national empirical modelling via improved provision of automatic NO_2 measurements, of known high quality, outside London and especially in Scotland, Wales and Northern Ireland. Specific requirements include roadside monitoring data in the West Midlands and greater co-location of rural NO_x and O_3 measurements.

813. Further investigation of the interactions between trends in O_3 and NO_2

814. Further modelling of the relationship between the northern hemisphere scale increase in O_3 and urban scale NO_2 problems. Remote background O_3 is rising as shown by the monitoring data for the Mace Head site in Ireland and the Strath Vaich site in the Highlands of Scotland. There is uncertainty regarding the influence of these rising levels once they have reached urban areas.

815. Modelling studies on the effects of possible increases in the proportion of primary NO_2 emissions on the exceedence of annual mean NO_2 targets.

816. Investigation of various aspects relating to the spatial characteristics of NO_2 concentrations, including: (i) the spatial characteristics of air quality episodes; (ii) the influence of interpolation errors in modelling procedures; and (iii) the influence of particular siting and sampling characteristics on interpolated surfaces. Developments are needed in methodologies for the wide application of interpolation procedures to policy work.

817. Better collection and availability of detailed information on site characteristics, including grid references to 1 m resolution and distance from kerb to enable more extensive GIS and other data analysis and verification of model results.

818. More studies on the decline in NO_x and NO_2 concentrations away from the kerb of major roads in both rural and urban areas, including: (i) long-term studies using chemiluminescent automatic monitors, and; (ii) measurement of both NO_x and NO_2 concentrations for at least one month in the summer and one month in the winter, to aid understanding of seasonal influences.

819. Research on the effectiveness of local air quality management measures on the abatement of NO_2 exceedences.

820. Development of a more holistic approach to air quality management that reflects the trade-offs between abatement strategies for NO_2 and for other pollutants.