2 Road Transport Sector (National Policies)

2.1 Introduction

2.1.1. This chapter evaluates the air quality policies that have been implemented over the past decade in the **road transport sector**, focusing on European wide emission limits (Euro standards) and fuel standards. It assesses the policies in terms of their cost effectiveness in achieving air quality improvements, and their benefits to health, as well as the man-made and natural environment. The study also aims to provide information on which policies have been successful and which have not, and to investigate how the response to legislation can sometimes be different to that anticipated.

2.1.2. The study approach has been to consider:

- The emission reductions of individual policies and combined policies, compared to a scenario of no policies, the so called 'no abatement' scenario. The 'no abatement' scenario assesses *what would have happened in the absence of the policies* (that have since been implemented). It is based on the conditions in 1990, but takes account of the economic/activity growth over the period;
- The progress towards the UK/EC air quality objectives/limit values from these policies, compared to the 'no abatement' scenario;
- The health and non-health benefits achieved by the policies, including the monetary benefits, compared to the 'no abatement; scenario[16];
- The ex ante and ex post costs of the policies;
- The wider economic costs (ex ante and ex post) of the policies;
- The comparison of the costs and benefits of different policies.

2.1.3. The study has considered the following policies:

- ***Unleaded petrol***, which went on sale in 1986 and was compulsory for new vehicles after 1st April 1988 in the UK. Leaded fuel was phased out at the end of 1999.
- ***Euro I technology***, which was mandatory from 1993 for new cars and heavy vehicles (and 1994 for light goods vehicles). There was also an accompanying change in fuel quality for petrol and diesel (fuel directive 93/12/EEC).
- ***Lower sulphur diesel fuel***, which was introduced for diesel for road transport, such that fuel containing less than 0.05%, or 500 ppm, sulphur was mandatory after 1st October 1996, in accordance with standard EN 590.
- ***Euro II technology***, which was mandatory for new vehicles from 1996 – 1998 (1996 for heavy vehicles, 1997 for cars and 1997-8 for light goods vehicles depending on size).
- ***Euro III technology***, which was mandatory for new vehicles from 2001 – 2002 (passenger cars and heavy vehicles in 2001, light goods vehicles in 2002).
- ***Changes in the sulphur content of fuel*** (along with changes to benzene content), which was reduced in 2000 to 150 ppm for petrol and 350 for diesel (fuel directive 98/70/EC).

[16] Note that because scientific understanding of risks to health from air pollution has developed enormously in recent years, an assessment now of the benefits to health of *the same* ambient pollution would be different, in important respects, from a corresponding assessment several years ago. These changes contribute to differences between *ex-post* and *ex-ante* estimates of the benefits of policy changes.

- ***Ultra-low sulphur fuel***, which was due to be introduced in 2005 and reduced the sulphur content to 50 ppm for petrol and diesel. The UK implemented this policy early, in 2000 to 2001, through the introduction of duty differentials.
- ***Euro IV technology***, which is mandatory for new vehicles from 2006.

The relationship between policies and pollutants is summarised in the table below.

Table 2-1. Pollutants covered, by policy, in the study.

Policy	NO_X	PM_{10}	CO	VOC	1,3 But	Benz.	B[a]P	CO_2	SO_2	Lead
Unleaded petrol										✓
Euro I cars	✓	✓	✓	✓	✓	✓	✓	✓		
Euro I all vehicles	✓	✓	✓	✓	✓	✓	✓			
Lower S diesel fuel		✓							✓	
Euro II	✓	✓	✓	✓	✓	✓	✓			
Euro III	✓	✓	✓	✓	✓	✓	✓			
Change S content		✓							✓	
Ultra-low S fuel		✓							✓	
Euro IV	✓	✓	✓	✓	✓	✓	✓			

2.1.4. The analysis for the transport sector has been undertaken over the period 1990 – 2020. We stress that the data from 1990 – 2001 represents the estimated actual emissions, as recorded and reported in the National Atmospheric Emissions Inventory (NAEI, 2003). We can undertake an ex post evaluation on this data, and compare it to the expected ex ante predictions. The data for 2002 – 2020 is based on our current best estimate of the likely out-turn (i.e. in fact this is an ex ante forecast)[17]. Where possible, all data has therefore been split into the period 1990 – 2001 (actual) and 2002 – 2020 (projected).

2.1.5. The 'no abatement' scenario assumes that vehicles would otherwise conform (today and in the future) with pre-Euro 1990 standard vehicle emission standards and pre-1990 fuel types. However, the 'no abatement' scenario adjusts 1990 emissions upwards over the period to 2020, based on the actual and predicted increases in vehicle km (by vehicle type) throughout the period. This is important because a large growth in transport activity has occurred over the last decade (from 1990 to 2000, UK road transport activity rose from 423 billion km to 484 billion km), and this trend is predicted to increase further through to 2020.

2.1.6. The year 1990 was fixed as the starting point for the analysis for the study in the Invitation to Tender. However, it is noted that a number of significant measures affecting emissions were already planned or in place at this point, for example, relating to unleaded petrol. The study has included these policies as part of the overall air quality evaluation, though the benefits analysis has only comprised the period post 1990.

2.1.7. While the analysis includes the main policy initiatives, we highlight that we have focused on the major technical driven policies. We have not considered some wider marketing or information programmes in the transport sector.

[17] We stress that this analysis was consistent with the best available information at the time and was based on the 2001 NAEI inventory. The emissions baseline for has subsequently been updated.

2.1.8. However, the study has undertaken an additional analysis of local (urban) transport measures in improving air quality. This analysis has assessed the ex ante and ex post costs and benefits of these measures, and compared them to the effectiveness of national transport policies. The analysis has been based on a review of measures in cities across the UK and Europe. The data from these studies have been applied to an urban case study (Sheffield), to try and assess the comparative costs and benefits of the measures. This analysis is presented separately to the main national analysis in this document.

2.2 Emission Reductions of the Policies

2.2.1. The emission reductions in the UK from the introduction of all the above policies (all Euro standards and all fuel quality standards) are shown below, relative to the 'no abatement' scenario. The first figure shows the estimated emissions reductions to date (i.e. the ex post analysis to 2000). The second figure also includes the projected emissions reductions through to 2020 with all policies in place.

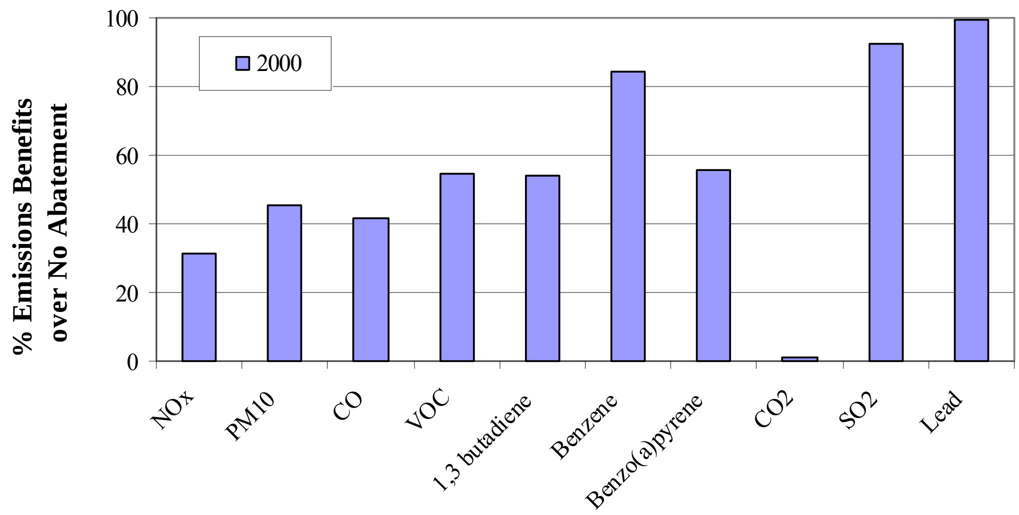


Figure 2-1. Actual Emission Reductions from the Road Transport Sector Relative to the Predicted Out-Turn in the Absence of Policies ('No Abatement')

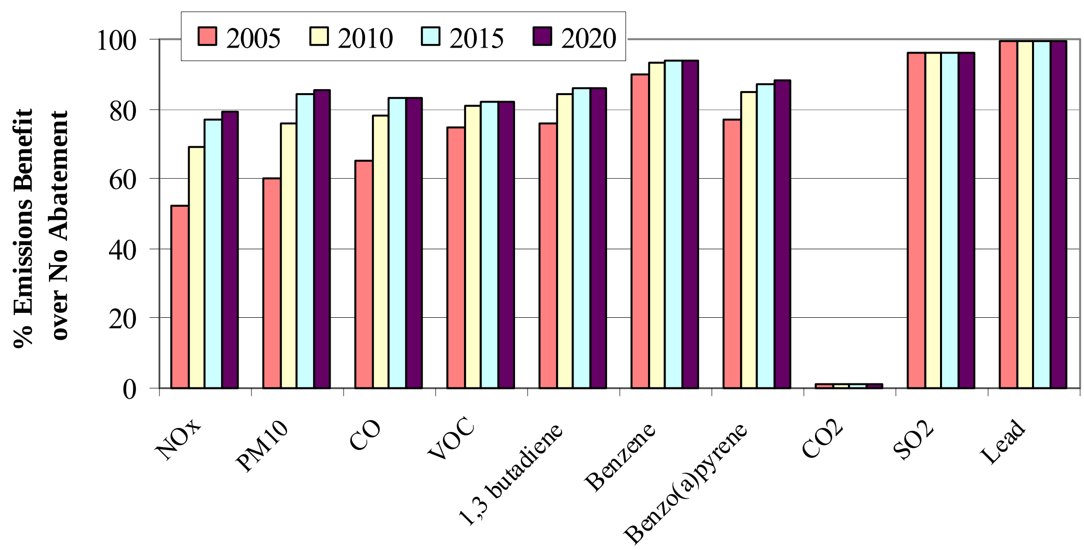


Figure 2-2. Forecast Emission Reductions from the Road Transport Sector Relative to the Predicted Out-Turn in the Absence of Policies ('No Abatement')

2.2.2. The conclusions are:

- The greatest emission reductions (relative to a 'no abatement' scenario) have been achieved by fuel-based standards. These have already led (by 2001) to a 99% reduction in lead emissions, a 96% reduction in SO_2 and a 84% reduction in benzene from the transport sector. The large emissions reductions achieved obviously reflect the reduction in the lead and sulphur content present in fuel. The use of duty differentials (economic instruments) has been extremely successful in the rapid uptake of cleaner fuels, as seen in the rapid reduction in leaded petrol use and higher sulphur diesel over the evaluation period[18].
- The command and control legislation introduced from Europe (vehicle emission standards – the 'Euro' standards) has also been extremely effective in reducing emissions of all regulated air pollutants. The reductions achieved by 2001 are more modest than for the fuel quality standards above, due to the time needed for replacement of the vehicle fleet (and because fuel standard include removal from the fuel, either completely or largely, of pollutants or pollutant precursors). Nonetheless, significant emissions reductions have occurred over the last decade from euro standards, with reductions of 36% for NO_X, 48% for PM_{10}, 42% for CO and 55% for VOC, relative to the no abatement scenario.
- Significant further improvements are projected over the period to 2010 (increasing to emissions reductions of 69% for NO_X, 76% for PM_{10}, 78% for CO and 81% for VOC, relative to the no abatement scenario). Particularly significant is that major reductions in NO_X and PM_{10} occur during this period. These reductions arise as tougher Euro standards enter into force for new vehicles, and as the older vehicle fleet is retired. Further emissions reductions are also projected to occur post 2010.
- The overall success of different Euro standards (as individual emission reduction policies) depends on the importance given to different pollutants. When all eight regulated pollutants are considered, it is the Euro I standard (for petrol cars) that seems to dominate the reductions. However, when the focus is switched to the two pollutants of most concern for local air quality management, NO_2 and PM_{10}, the reductions arise more evenly from all Euro standards across all vehicles.
- The emission reductions are large when compared to 1990 emissions. This improvement has been achieved against a background of increasing transport activity.
- The policies have had only a small effect in reducing carbon dioxide (CO_2) relative to the 'no abatement' scenario. Moreover, CO_2 emissions from the road transport sector have actually increased over the period (relative to 1990 emissions) due to the large increase in transport activity.

2.2.3. The emission reductions of the individual policies have also been assessed. The analysis of reductions in SO_2 emissions from different fuel quality policies is shown below, in total emissions (left) and as % emission reduction relative to the 'no abatement scenario' (right). The reductions match the drop in the sulphur content of fuel with the successive standards.

2.2.4. The analysis shows that:

- The greatest improvement in SO_2 emissions from road transport occurred from the first phase of sulphur reductions in 1996 for diesel. This policy achieved around a 60% reduction when compared to a 'no abatement' scenario, matching the large reduction in sulphur content from this policy.

[18] The study has not evaluated a counter-factual scenario for command and control legislation as an alternative for achieving fuel quality standards.

- Additional reductions in SO_2 arose from the introduction of the 2000 and 2005 fuel quality standards, with cumulative reductions on top of low diesel sulphur of 78% (2000 fuel quality) and 96% (2005 fuel quality) of the actual emissions of SO_2 from transport compared to a ‘no abatement’ scenario.
- Because the 2005 fuel quality was introduced early in the UK, by 2001 (i.e. the period reflecting the actual ex post out-turn), the policies in place have achieved a 96% reduction in SO_2 emissions relative to the no abatement scenario. There are no additional policies in the period 2001-2020.

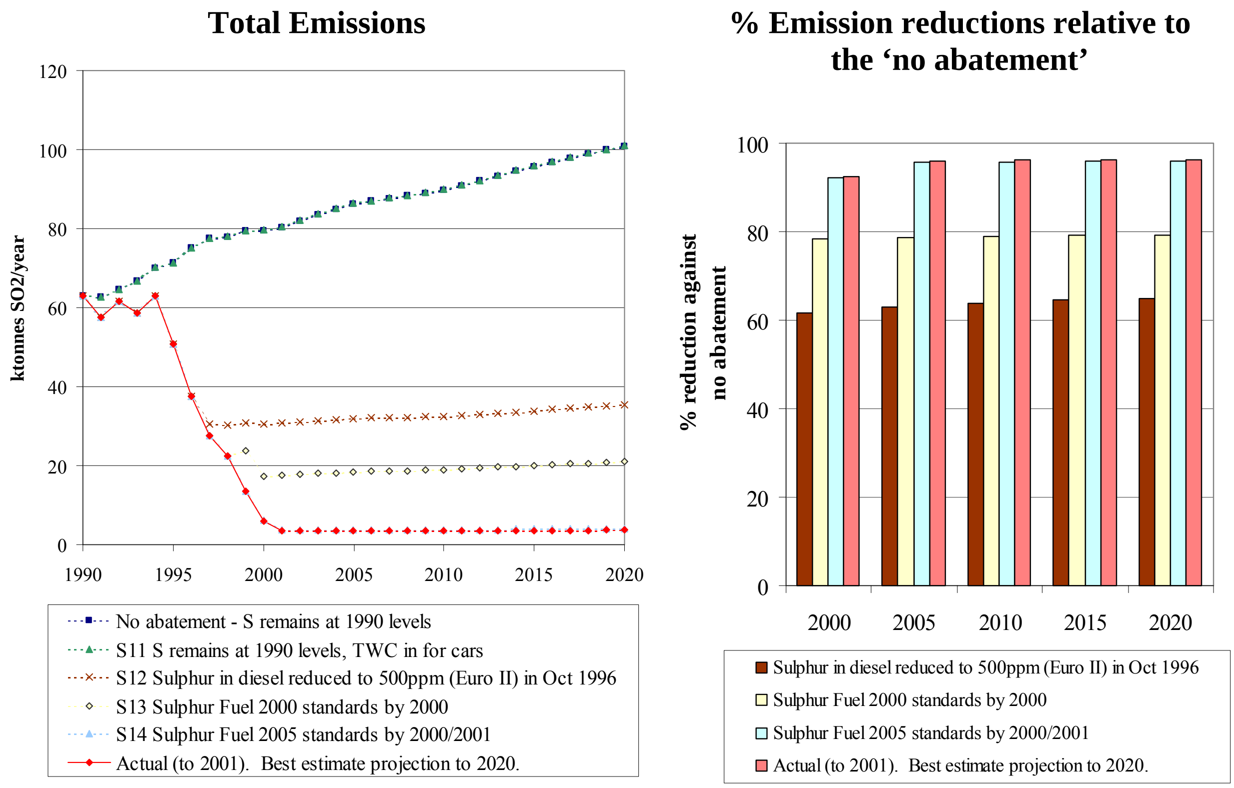


Figure 2-3. Effect of Fuel Quality Policies on UK Road Transport SO_2 Emissions
Actual data (to 2001 ?? Why ‘to’?). Projections 2002 – 2020.

2.2.5. The contribution of the individual Euro standards (Euro I to IV) in reducing vehicle emissions has also been assessed. The absolute emission reductions from PM_{10} and NO_X (as the two primary pollutants of most concern) are shown below with PM_{10} on the left and NO_X on the right. It is stressed that the pattern is different between the two pollutants, because of the detrimental impact of Euro 1 technology on NO_X emissions from diesel vehicles (note the data summarises UK emissions, a slightly different picture emerges for urban areas). The figures include sulphur reductions in 1996 for diesel, and also the introduction of 2000 and 2005 fuel quality standards. The base (actual) line includes Euro IV technology. The graphs show that:

- By 2001, with all policies in place, there has been a 36% reduction in NO_X and a 48% in PM_{10}, relative to the no abatement scenario.
- By 2010, this is projected to further increase to a 69% reduction in NO_X and a 76% reduction in PM_{10}, relative to the no abatement scenario
- The use of the latest emission factors demonstrates that the effects of policies on NO_X emissions are complex. A large proportion of the improvements seen are from the

introduction of Euro 1 technology to petrol vehicles (around a 30% improvement relative to the 'no abatement'). However, the updated emission factors indicate that Euro I emission standards were detrimental for NO_X emissions from heavy diesel vehicles. This spreads the reductions of NO_X reductions more evenly over Euro I to IV standards. The analysis here predicts that the total reductions of successive technical standards are a 30% reduction for Euro I, increasing to 40% with the addition of Euro II, 60% with the addition of Euro III and 70-80% with the addition of Euro IV, relative to the 'no abatement' scenario.

- A different pattern emerges for PM_{10}. The effect of introducing Euro I technology to petrol vehicles was small (7%). Instead the largest reductions arise from the introduction of Euro I technology to diesel vehicles (30%), but there are also progressive improvements projected from later Euro standards (compared to the 'no abatement' scenario, the total reductions increase to 50% with the addition of Euro II, 65-70% with the addition of Euro III and 75-85% with the addition of Euro IV).

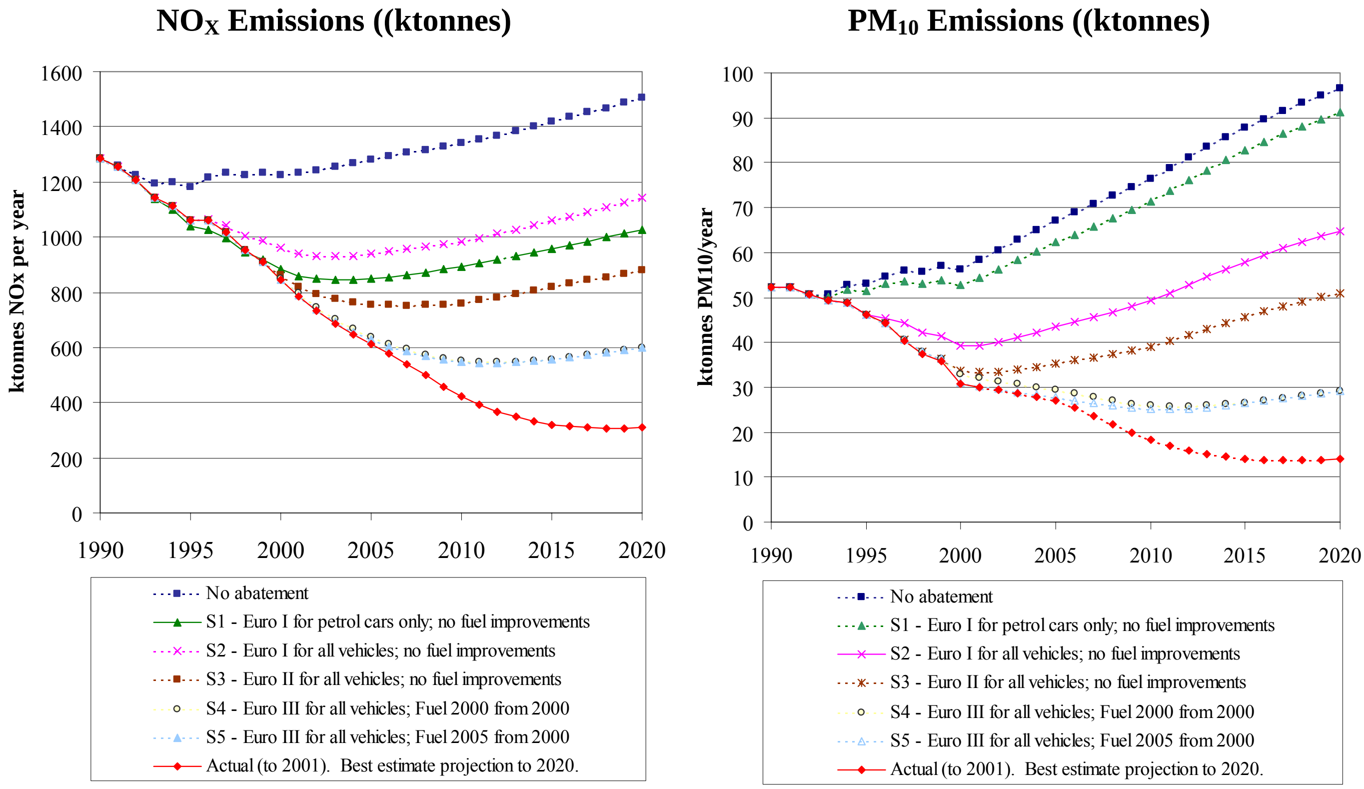


Figure 2-4. Effect of Euro Standards on UK Road Transport NO_X and PM_{10} Emissions
Solid lines represent actual data (to 2001). Dotted lines represent projections.

2.2.6. The emission reduction of each Euro standard (Euro I to IV) for other regulated pollutants (CO, VOCs, benzene and 1,3-butadiene) varies significantly from NO_X and PM_{10}. The emissions reduction relative to the 'no abatement' scenario for these pollutants is shown in the figures below for the years 2000, 2010 and 2020. The analysis shows that:

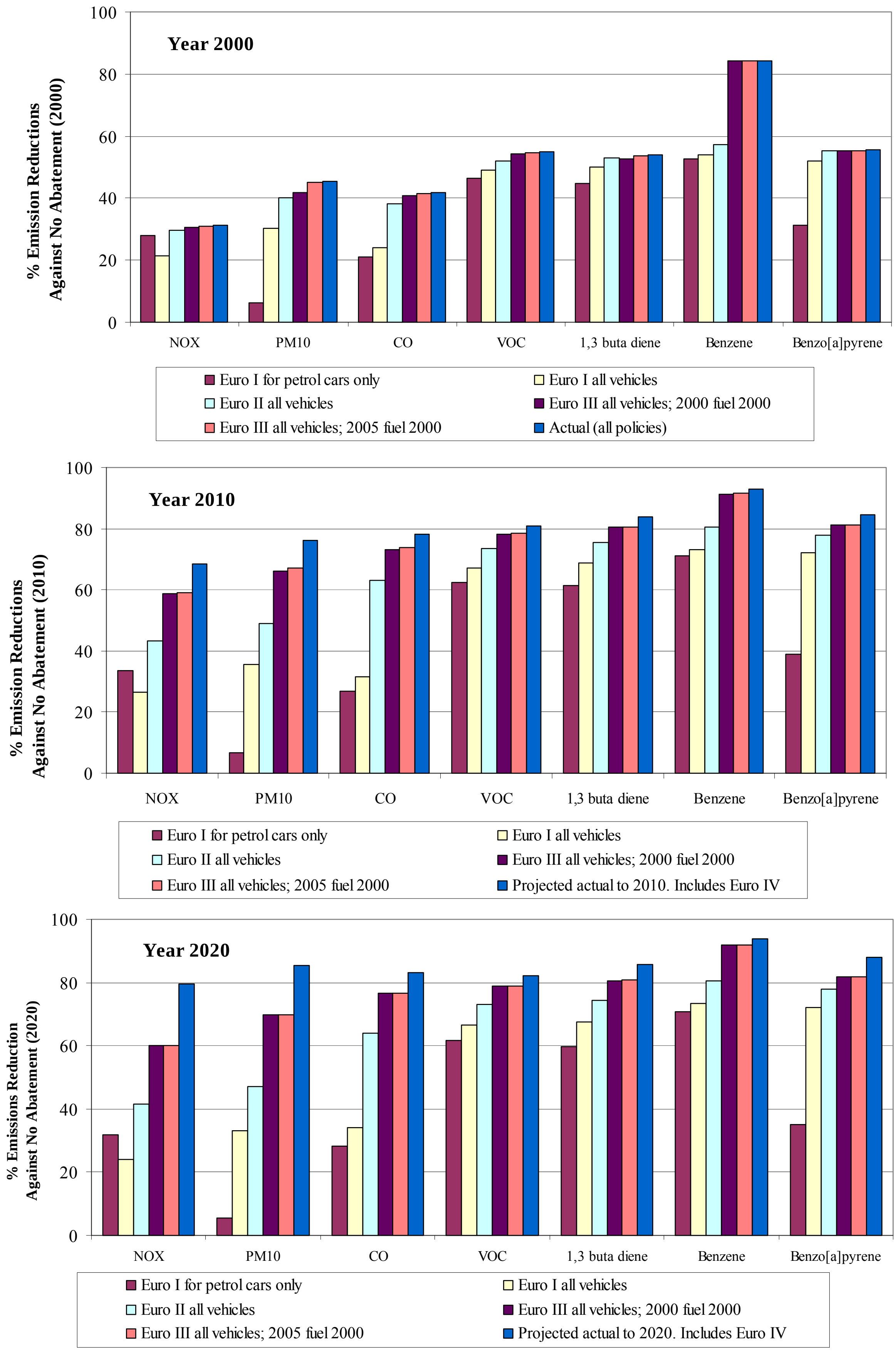


Figure 2-5. Effect of Euro Standards as a % Reduction of Emissions Relative to the 'no abatement'. 2000 Actual Data. 2010 and 2020 Projected.

- The greatest single emissions reduction has been achieved by the Euro I emission standard. For many pollutants, the greatest single reduction has been achieved by the Euro I standard for cars alone - this is the case for VOCs, 1,3-butadiene and benzene where the reductions of Euro I to petrol cars has led to a 60% reduction relative to the 'no abatement' scenario. For CO, the greatest reductions have come from the introduction of Euro I technology to petrol cars, and Euro II technology (the approximate reduction was 30% for Euro I and 60% for Euro I and II relative to the 'no abatement' scenario).
- These conclusions are important, because when all emissions are considered, it is the Euro I standard (for petrol cars) that seems to dominate the reductions. However, when the focus is switched to the two pollutants of most concern for local air quality management, NO_2 and PM_{10}, the reductions arise more evenly from all standards across all vehicles.
- Because of the introduction dates (Euro IV does not enter into force until 2006), and the long lifetime of vehicles, there are significant emission reductions projected in the period 2001 – 2010, and also further projected emission reductions in the period 2010 – 2020.

2.2.7. This pattern is slightly different to that anticipated at the start of the study. The previous evaluation (undertaken in 2001 with the 'old' emission factors) showed a much greater emission reduction attributed to Euro I overall in reducing NO_X emissions, and lower emission reduction from later Euro standards. The new emission factors therefore show more reductions for later Euro standards. This mitigates against the expected effect of diminishing returns, i.e. that as emission standards are tightened, it becomes progressively more difficult to get large emission reductions at reasonable cost. Note it is stressed that the Euro III and Euro IV factors are not based on measurement data (whereas values for Euro I and II are), and there are therefore some uncertainties in these conclusions and the predicted out-turns.

2.3 Air Quality Benefits

2.3.1. The legislation is also projected to lead to benefits in progress toward the UK and EU air quality targets (objectives/limit values). The projected benefits are shown below for PM_{10} and NO_2 in 2005 and 2010 - the relevant dates for the legislation. The approach used for air pollution modelling is consistent with the UK air pollution mapping project (Stedman *et al* 2001). The maps show the estimated concentrations at background and at roadside across the UK, with the 'no abatement' scenario on the left, and with all policies in place on the right. Note for other sectors (e.g. electricity, domestic, industry), the emissions and their contribution to air quality are based on actual and predicted data with all policies in place – therefore a comparison of the maps shows the incremental difference for air quality in the UK from policies in the transport sector alone. The maps show the very large reductions in the air pollution concentrations that are predicted to occur (from the projected emissions reductions) as a result of transport policies. The methodology for producing the maps is outlined in the box below.

Analysis of Air Quality

The starting point for the analysis has been the spatially disaggregated National Atmospheric Emissions Inventory (NAEI). The baseline methodology for the analysis can be found at the NAEI website (http://www.naei.org.uk) and is consistent with that reported in the UK Emissions of Air Pollutants (2001 data analysis). The detailed methodology is not repeated here. The baseline emissions profiles were recalculated for the 'no abatement' (without policies) scenario, as set out in the main text. We stress that this analysis was consistent with the best available information at the time – the emissions baseline for both the transport and ESI have subsequently been updated.

These emissions were used as the input into the pollution modelling, and the emissions from transport or the ESI combined with all other UK PM_{10} sources (including secondary particulates) to calculate the pollution maps for the UK (annual average PM_{10} concentration), output at a $1km^2$ resolution. The modelling approach used for the analysis of impacts is consistent with that used for other PM_{10} analyses presented in the AQ Evaluation report and with previously published work[19]. Contributions to ground level PM_{10} concentrations are influenced by emissions from point sources, area sources, secondary particles and coarse particles. Emissions from point sources specifically were modelled using two atmospheric dispersion modelling techniques. For large PM_{10} sources, (sources with >100 tonnes PM_{10} emission per annum) impacts of emissions were modelled using the ADMS 3.1 dispersion modelling package. For smaller point sources, (sources with <100 tonnes PM_{10} emission per annum), impacts were modelled using a dispersion matrix approach. A similar approach was followed for the analysis of NO_2 and SO_2. This process was followed to assess air pollution concentrations for the baseline (with policies) and the no abatement scenario (without policies).

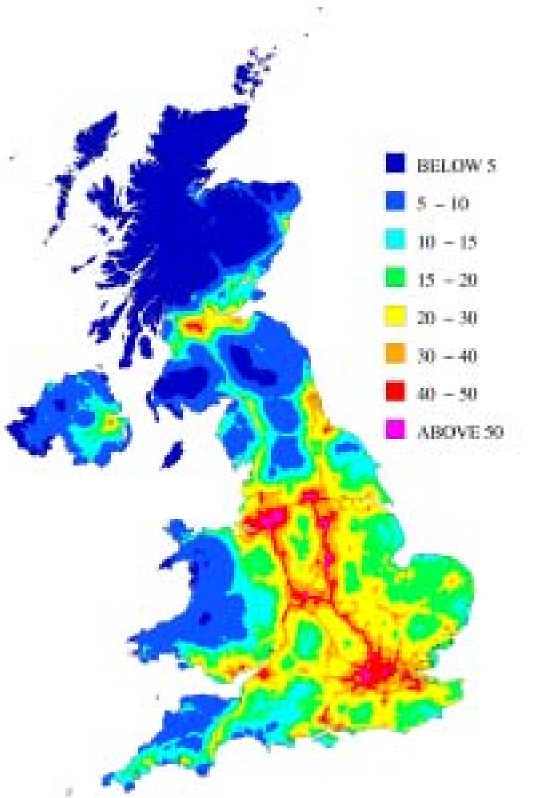
The pollution model outputs were combined with population data within a GIS (geographical information system) to provide population weighted PM_{10} concentrations. This was combined, in turn, with concentration-response functions to estimate the health impacts, and with monetary endpoints to calculate the economic values for total PM_{10} related air pollution for the UK (see later sections).

Maps were generated for 2001, 2004/2005, and 2010. The model was calibrated with 2001 measurements, and reflects the meteorological conditions found in this year. The model was run using 2001 emissions to produce a map of 2001 concentrations. For future years we updated the emissions by the appropriate projection factors and then ran using the 2001 model for the projected emissions. The 2005, 2010 concentration maps are therefore based on 2001 base case model. Note 2001 was a fairly average year in respect of meteorological conditions.

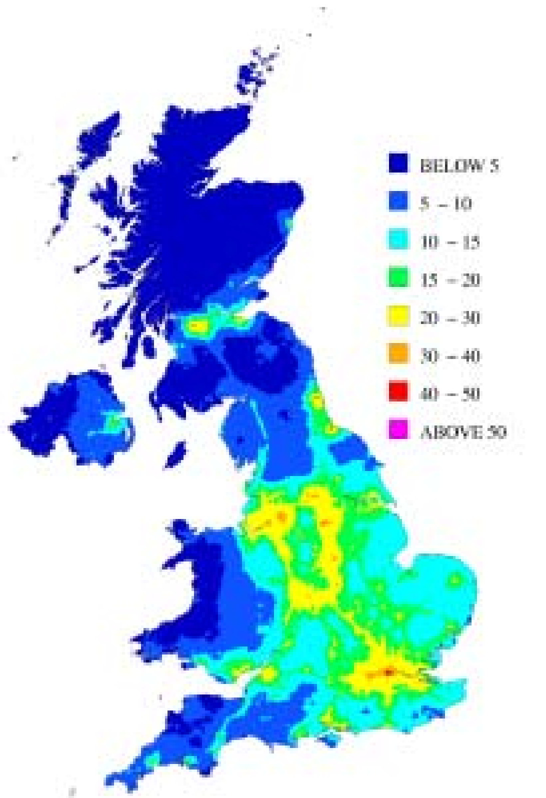
It was not possible to generate pollution maps for all years from 1990 to 2010. Instead, the detailed analysis in 2001, 2005 and 2010 was used to derive scaling factors. The health impacts and monetary benefits were calculated in detail for each year, and combined with emissions estimate to produce unit pollution costs (£/tonne pollutant) for the 'no abatement' and 'baseline' (with policies) scenarios for the three years.

These impacts per tonne, and costs per tonne values, have then been used to estimate the benefits in intermediate years and also from intermediate scenarios– note these intermediate scenarios are expressed in terms of emissions and so there is an assumption about linearity (discussed later). For other pollutants (CO, SO_2, lead, benzene, butadiene, and benzo(a) pyrene), previous air quality modelling maps and analysis (e.g. within the IGCB analysis, the ExternE project or the GARP project) have been used to estimate the health effects of pollutant emissions.

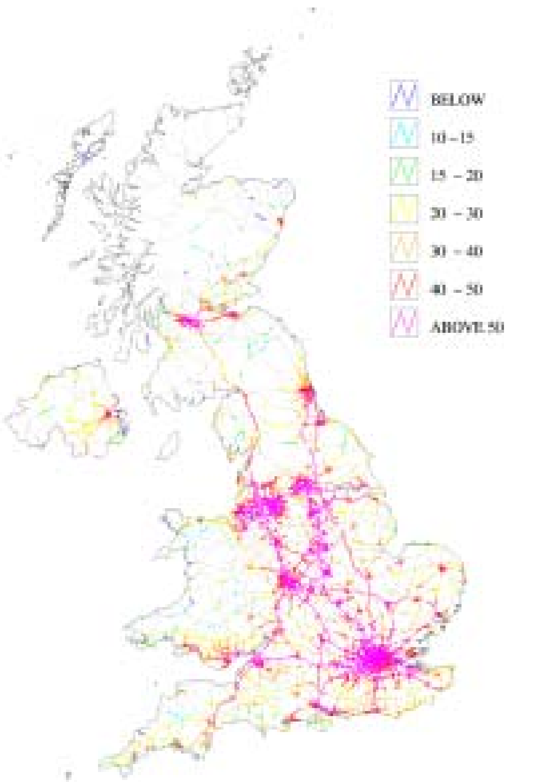
[19] Stedman JR, Bush T and Vincent K. UK air quality modelling for annual reporting 2001 on ambient air quality assessment under Council Directives 96/62/EC and 1999/30/EC. A Netcen report to the Department for Environment, Food and Rural Affairs, The Scottish Executive, Welsh Assembly Government and the Department of Environment for Northern Ireland. AEAT/ENV/R/1221 Issue 1 September 2002.



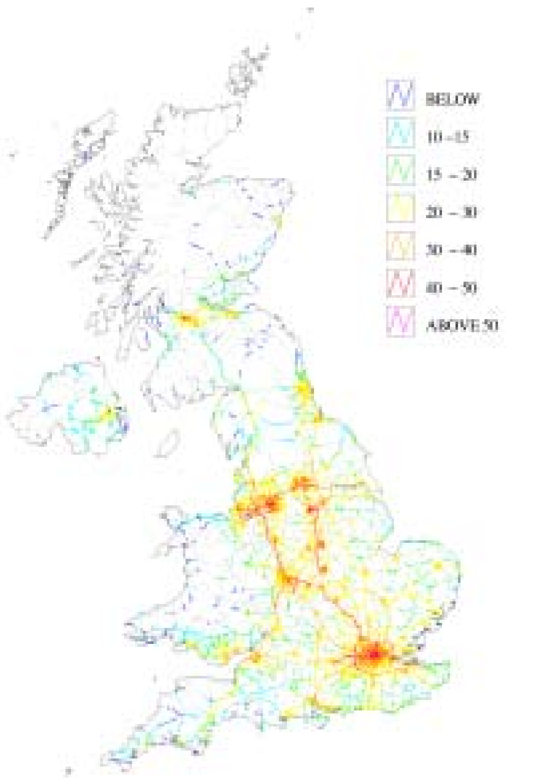
Projected Annual Mean Background NO_2 'No Transport Abatement' (2010), μgm^{-3}



Projected Annual Mean Background NO_2 All Policies (2010), μgm^{-3}

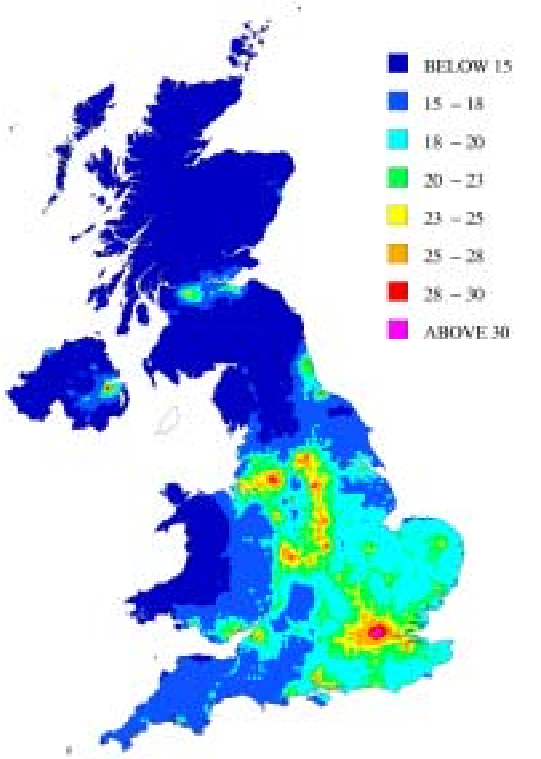


Projected Annual Mean Roadside NO_2 'No Transport Abatement' (2010), μgm^{-3}

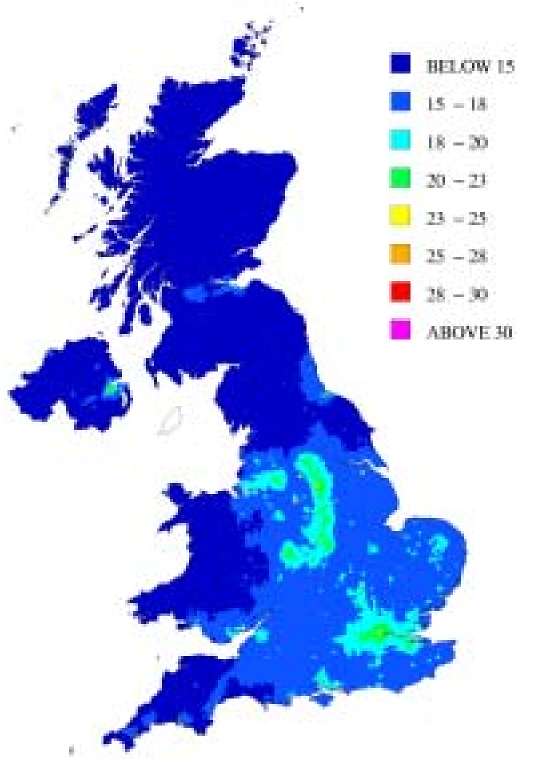


Projected Annual Mean Roadside NO_2 All Policies (2010), μgm^{-3}

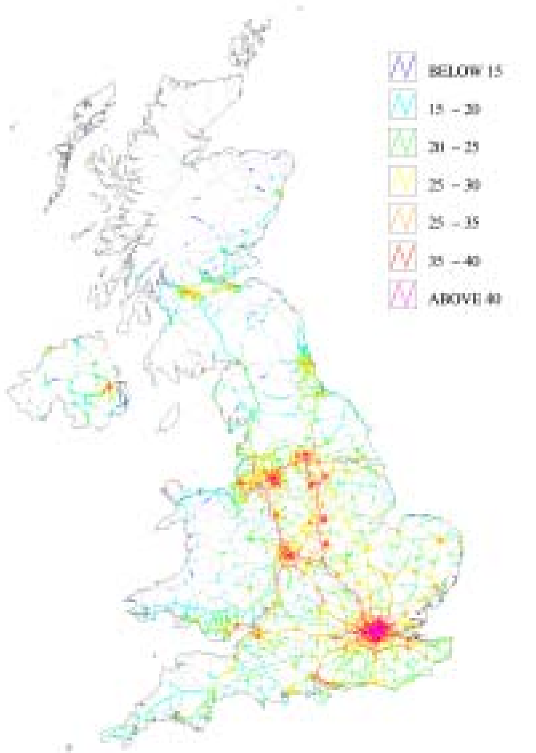
Figure 2-6. Estimated NO_2Air Quality Improvements from Road Transport Policies



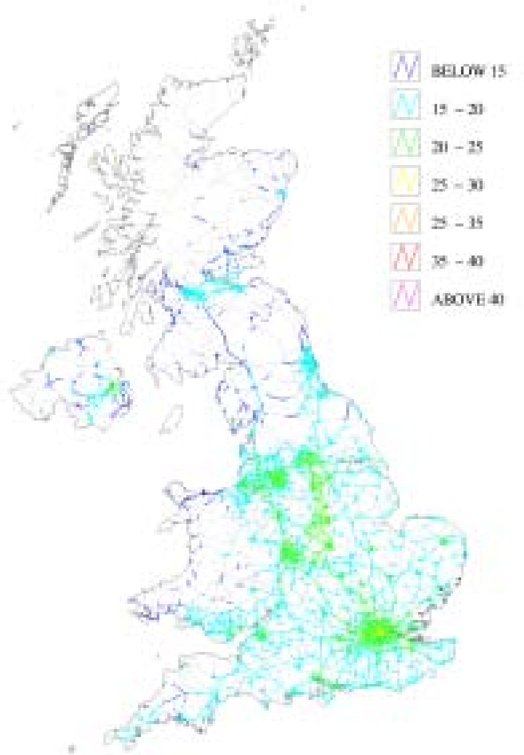
Projected Annual Mean Background PM_{10} No Transport Abatement (2010), μgm^{-3}



Projected Annual Mean Background PM_{10} All Policies (2010), μgm^{-3} (gravimetric)



Projected Annual Mean Roadside PM_{10} No Transport Abatement (2010), μgm^{-3}



Projected Annual Mean Roadside PM_{10} All Policies (2010), μgm^{-3} (gravimetric)

Figure 2-7. Estimated PM_{10} (gravimetric) Improvements from Road Transport Policies (including primary and secondary PM_{10}).

2.3.2. The exceedence data for the key NO_2 objective/limit value (40µg/m^3 annual mean) in the UK are summarised in the Figure below. This shows the exceedences for the predicted out-turn with all policies in place (the baseline), and the 'no abatement' out-turn (no policies in place) for the years 2001, 2005 and 2010. Exceedences have been measured in terms of road length >40µg/m^3 (left hand side) and area > 40µg/m^3 at background locations (right hand side).

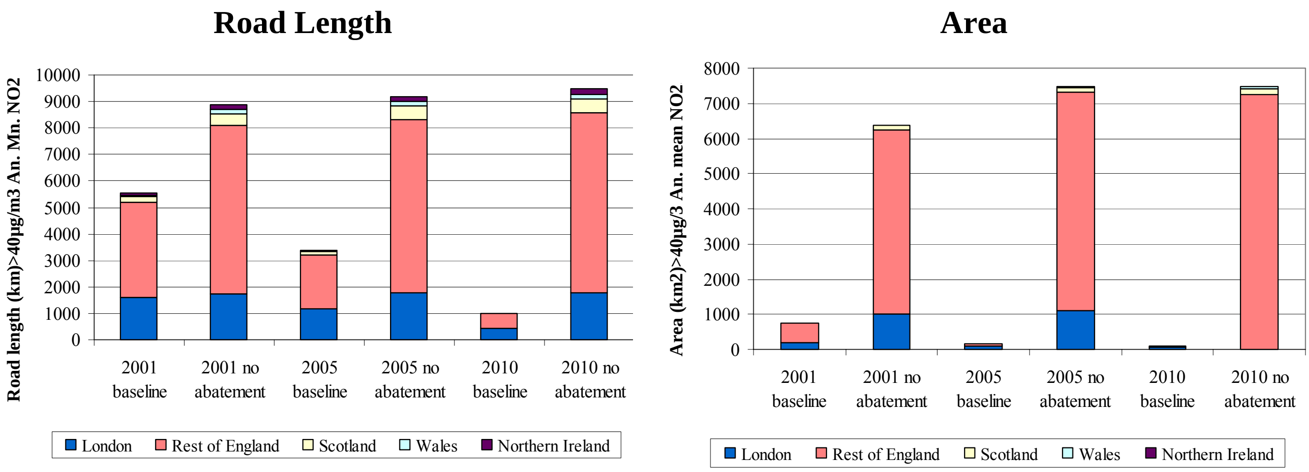


Figure 2-8. Estimated Exceedences of NO_2 Annual Mean (road length and area) with ('baseline') and without ('no abatement') policies in the Road transport sector. Data for 2001 Actual. Data for 2005 and 2010 Projected.

2.3.3. The analysis shows that the expected out-turn (in the absence of the policies) would have led to much higher levels of exceedences. With all policies in place, the exceedences are reduced significantly (especially by projections for 2010). In summary:

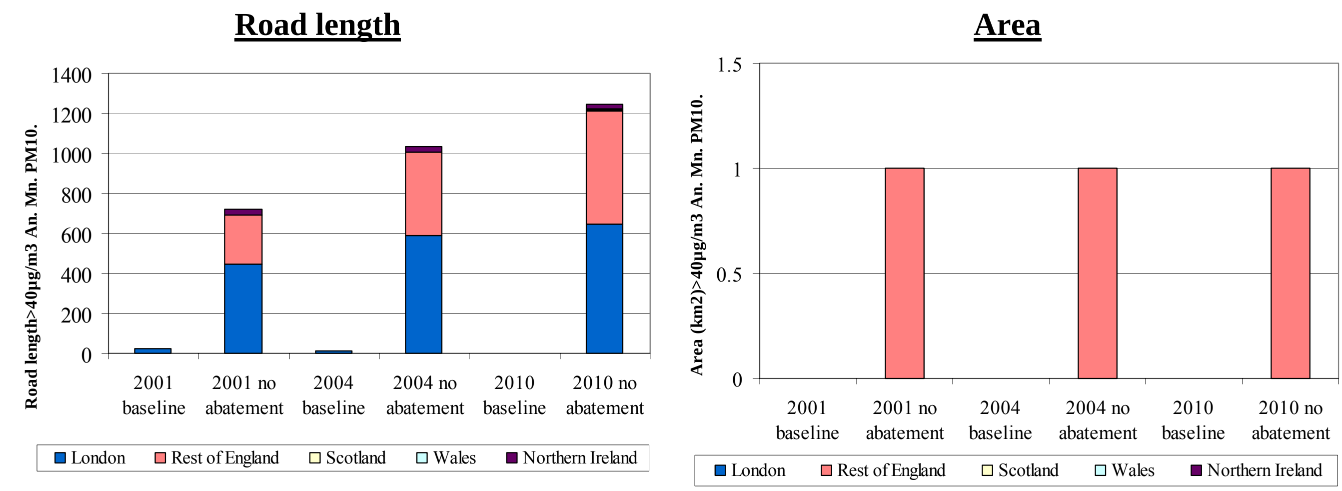
- The population exposed to annual mean concentrations > 40µg/m^3 NO_2 under the 'no abatement' scenario is estimated to be 17,262,000 in the UK in 2010.
- With transport policies implemented, the population exposed to concentrations above the objective is projected to fall to 350,800, a 98% reduction on the 'no abatement' out-turn.
- While the impact of individual policies has not been modelled, the impacts of different policies can be seen in the data, as by 2001, only the Euro I standard (introduced ~1993) and Euro II standard (introduced from 1996-7) would be affecting the transport fleet. This shows that for background areas, these earlier policies have had large benefits.

2.3.4. There is a difference in the pattern of data for road length and background exceedences shown in the graphs above. As expected, the predicted improvements with all policies in place (the baseline) have had a greater effect in reducing background exceedences of NO_2, than in reducing roadside exceedences. This is because the concentrations at background are very much closer to the objective level. It is therefore easier to achieve the objective at these locations (measured purely in terms of reduced exceedences). In contrast, because the concentrations are higher at roadside locations, there are a greater proportion of roads that remain above the objective. The right hand graph (area) shows that by 2010, only a very small area is predicted to exceed the objective (mostly in London, though this is an area with high population density).

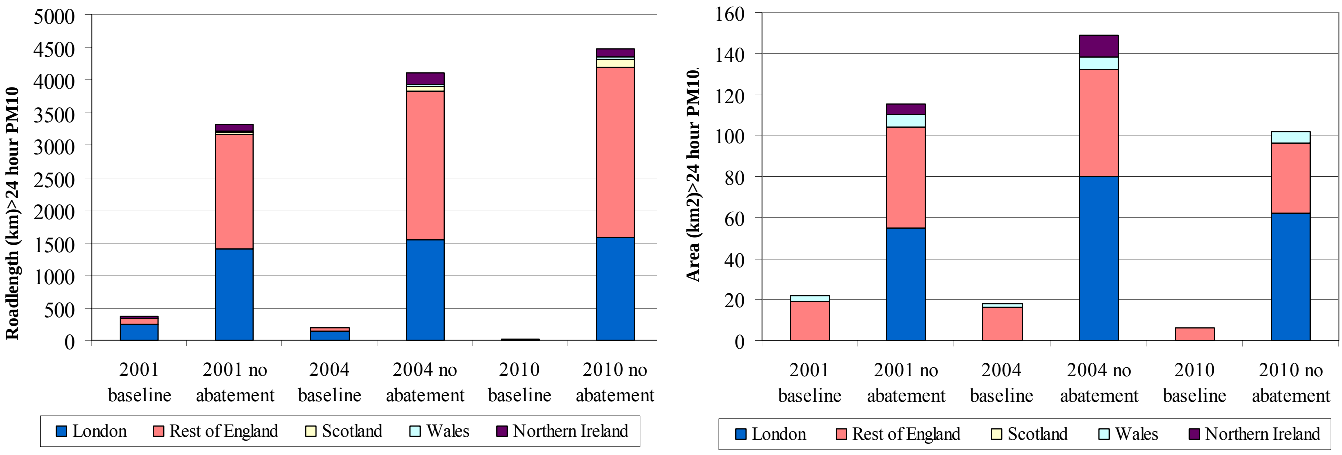
2.3.5. This analysis provides important information for future policies. It indicates that the benefits of future national policies, in terms of reducing background exceedences, will be low, as most background areas will already have achieved the objective with current policies. Any further improvements in reducing NO_2 nationally will thus have most effect in reducing exceedences at the roadside (where human exposure is less of an issue). As an objective exists for NO_2, and assuming it is based on a threshold, then the health benefits of future national policies (targeted specifically at reducing exceedences of air quality targets) will also be low, because no benefits would be expected below the threshold. In this case, the most cost-effective policies would be to reduce remaining background areas above the objective would probably be through local, targeted policies (e.g. in central London), rather than nation wide initiatives.

2.3.6. However, the situation is somewhat less clear if benefits and cost-effectiveness are assessed in terms of health rather than exceedences. This is because even when annual average NO_2 is lower than 40μg/m^3 (the air quality target), there may still be benefits to health from further reductions below this level. As discussed later, assessing the health benefits of reduced NO_2 is not simple, for two reasons. Many of the quantifiable benefits of NO_2 reductions are indirect, i.e. they occur through consequent changes in secondary particles (nitrates) and ozone, and may occur in communities distant from where the NO_X reductions occur. For these reasons, it is best to assume that there is no threshold for the benefits to health of reducing NO_X from traffic, even though arguments for a threshold can be made if health effects are considered purely in terms of NO_2 as a gas. Note there is some evidence and an increasing belief that NO_2 may be a current marker for pollutants, or aspects of pollutants, not otherwise measured directly – notably the number of fine particles (though NO_2 may not be the causal part of this air pollution mixture). These and related issues are discussed in detail in recent publications of the World Health Organisation (WHO, 2003, 2004).

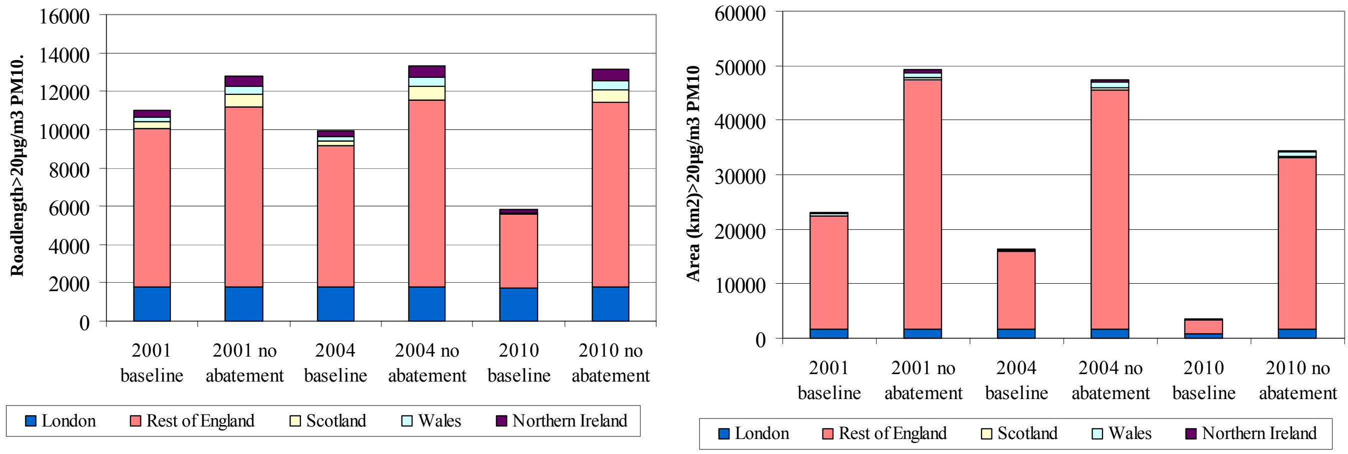
2.3.7. The patterns for PM_{10} and the relevant air quality objectives are shown in the Figure below. The estimated exceedences of the key PM_{10} objective/limit values are shown below with all policies in place (the baseline) and without transport policies (the 'no abatement') for the out-turn in 2001, 2004 and 2010 for roadside locations (left hand column) and background locations (right hand column). Clearly, under all scenarios, the number of exceedences increases as a stricter target is applied, across the three concentrations shown: annual mean 40μg/m^3, equivalent 31.5μg/m^3 and 20μg/m^3, respectively. The increase in background area exceedences between the latter two values is especially marked. Note the pattern of future projected exceedences under the 'no abatement' scenario is different to NO_2 above. The length of road that exceeds the objectives increases in future years under the 'no abatement' scenario, but at background locations (right hand column), there is a drop from 2004 to 2010 (except for the 40 μg/m^3 objective, where there is already effective compliance) because secondary and long-range particles are still reducing. This is because the modelling assumes that European emissions reduce as projected with all European policies, so that the only differences between the graphs are for UK transport policies.



PM_{10} Annual Mean 40µg/m^3 (gravimetric)



PM_{10} 24 Hour Mean (Equivalent Annual Mean 31.5µg/m^3) (gravimetric)



PM_{10} Annual Mean 20µg/m^3 (gravimetric)

Figure 2-9. Estimated Exceedences of PM_{10} Objectives (including primary and secondary PM_{10}), for road length and area, with ('baseline') and without ('no abatement') policies in the Road transport sector
Data for 2001 Actual. Data for 2004 and 2010 Projected.

Note the scale of the graphs below is different - this is important for interpreting the first two objectives, in relation to the small background area that exceed the objective (right hand column, first two graphs).

2.3.8. With the policies implemented (baseline) there will be a significant estimated reduction in both roadside and background exceedences of the objectives. For example, they are likely to go a long way towards ensuring compliance with the standard for PM_{10} 24-hr mean (equivalent annual average 31.5µg/m^3), though the reduction in the exceedences of the annual mean 20 µg/m^3 standard at roadside is modest until 2010 (bottom left hand graph). There has is also a significant reduction in the estimated population exposed above the objective.

- The population exposed to annual mean concentrations above the objectives under the 'no abatement' scenario is projected to be 9,300 (40µg/m^3), 530,000 (31.5µg/m^3) and 37,677,000 (20µg/m^3 PM_{10}) in the UK in 2010.
- With all transport policies implemented, the population exposed to concentrations above the objective is projected to fall to 0 (40µg/m^3), 7,000 (31.5µg/m^3), and 9,972,000 (20µg/m^3 PM_{10}). This is a 73% to 100% reduction on the 'no abatement' out-turns.

2.3.9. Considering the link between PM_{10} and health, it is widely accepted that there is no safe population threshold for PM_{10}, and so health impacts occur below the objective. The best working assumption is that there are *pro rata* health benefits in reducing concentrations below the objective[20]. This indicates that national level policies would still be very beneficial with respect to PM_{10} and its health effects.

2.3.10. The analysis also includes site-specific modelling to assess the impact of individual policies (i.e. Euro I to IV) for a number of specific locations (including urban road-side and urban background locations). This provides information on the change in exceedences with individual policy measures. This has shown some interesting results. For example, after 2010, there may actually be an increase in NO_2 concentrations at some urban background sites, as the gains made from the introduction of the Euro I and II standards are reversed from the growth in traffic. At these sites, the site specific analysis show that abatement measures associated with Euro III and IV standards are required to enable the NO_2 40µg/m^3 limit value (LV) to be achieved by 2010. There is therefore a strong justification for the successive Euro standards – even though the earlier Euro standards have led to large emissions reductions of the key pollutants. For PM_{10}, it is the introduction of the Euro I standard for all vehicles that enables the objective to be met at most locations. The introduction of the Euro I standard for cars (not all vehicles) has little overall impact and of a greater importance is the Euro I standard for diesel cars, LGV and HGV emissions. At the Marylebone Road monitoring location, the emissions abatements due to the Euro III standard and the Fuel 2000 package are the projected minimum required to achieve the UK annual mean standard for PM_{10} 40µg/m^3. However, by around 2010, gains made in reducing PM_{10} concentration under the Euro I and II standards are beginning to be reversed as growth in traffic volume out-weighs abatement technology. Again, this provides support for later Euro standards (e.g. Euro III and IV).

2.4 Health and Economic Benefits of the Policies

2.4.1. Air pollution has a number of important impacts on human health, as well as on the natural and man-made environment. These include impacts of short-term and long-term exposure to air pollution on our health, damage to building materials, effects on crops (reduced yield) and impacts on natural and semi-natural ecosystems (both terrestrial and aquatic). The impacts from air pollution on these receptors are described in the box below.

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[20] We argued earlier that this is probably the case for NO_2, as a marker of a transport mixture and as a precursor to ozone and nitrates. The no-threshold argument for PM_{10} is more strongly established and better accepted.

Box 2.1. Analysis of Health and Non-Health Benefits

Studies of air pollution episodes (such as the London smog episodes of the 1950s) have shown that very high levels of ambient air pollution are associated with strong increases in **adverse health effects**. Recent studies also reveal smaller increases in adverse health effects at the current levels of ambient air pollution typically present in urban areas. The health effects associated with short-term (acute) exposure include premature mortality (deaths brought forward), respiratory and cardio-vascular hospital admissions, exacerbation of asthma and other respiratory symptoms. The evidence for these effects is strongest for particles (usually characterized as PM_{10}) and for ozone. For these pollutants the relationships are widely accepted as causal. Recent studies also strongly suggest that long-term (chronic) exposure to particles may also damage health and that these effects (measured through changes in life expectancy) may be substantially greater than the effects of acute exposure described above. These health impacts have major economic costs because of the additional burden they impose on the health service, the lost time at work, and the pain and suffering of affected individuals. The approach adopted here uses concentration-response functions that link given changes in air pollution to health endpoints, which are then valued. Further details are given in Box 2.2.

Air pollution also impacts on other receptors. The effects of atmospheric pollutants on **buildings and other materials** provide some of the clearest examples of air pollution damage. Air pollution is associated with a number of impacts including acid corrosion of stone, metals and paints in ‘utilitarian’ applications; acid impacts on materials of cultural merit (including stone, fine art, etc.); ozone damage to polymeric materials, particularly natural rubbers; and soiling of buildings. SO_2 is the primary pollutant of concern in building corrosion, primarily from dry deposition, but also from the secondary acidic species in the atmosphere. The approach for quantifying and valuing these impacts for ‘utilitarian’ buildings is based on previous impact pathway analysis in the EC’s ExternE Project (1998: 2001), which links the ‘stock at risk’ of building materials to exposure-response functions. Impacts are monetised using repair and replacement costs, based on critical thickness loss. The key source of data for this part of the assessment is the UNECE ICP on Materials (UNECE ICP Materials (2003). While a similar approach could, in theory, be applied to historic and cultural buildings, there is a lack of data on the stock at risk, and also the relevant valuation of building damage. The analysis of building soiling is concerned with the deposition of particles on external surfaces and the dis-colouration of stone and other materials. Although soiling damage has an obvious cause and effect, the quantification of soiling damage is not straightforward. The approach here has been to quantify and value urban emissions of particles, based on a simplified approach using cleaning costs, with an upward adjustment for amenity loss. The analysis of ozone damage to materials has not been included in this study.

Ozone is recognised as the most serious regional air pollutant problem for the **agricultural sector** in Europe at the present time. Quantification of the direct impacts of ozone on agricultural yield has used an approach from the EC ExternE project. The valuation of impacts on agricultural production combines estimated yield loss by world market prices as published by the UN’s FAO. Some air pollutants other than ozone have been linked in the literature to crop damages (e.g. SO_2, NO_2, NH_3), but generally at higher levels than are currently experienced.

Air pollution also can impact on **natural and semi-natural ecosystems.** These effects, and the issues with valuation are discussed in a later box in the electricity generation chapter.

Health benefits: Quantification and Valuation Approach

2.4.2. The following sections detail the issues with quantification and valuation of health impacts for different pollutants. Box 2.2 provides the main background on the quantification of the health impacts of air pollutants used in the study. The main health outcomes quantified in the study are:

- Short-term (acute) pollution effects - deaths brought forward and respiratory hospital admissions; and
- Long-term (chronic) effects - changes in life expectancy, known as chronic mortality.

The approach to valuation of the three main health impacts is provided in Box 2.3.

Box 2.2. Quantification of Health Effects

Two types of epidemiological study are relevant to the quantification of mortality impacts from health pollution:

- Time series studies, available for assessing the mortality and morbidity impacts of the short-term (acute effects) exposures to PM, SO_2, O_3 etc., which examine associations between daily pollution levels and daily numbers of deaths or respiratory hospital admissions.
- Cohort studies which examine age-specific death rates (technically mortality hazards) in study groups of individuals followed up over prolonged periods. Having adjusted for other mortality risk factors measured for individuals (gender, race, smoking habit, educational status, etc.), differences in age-specific death rates between cities are assessed in relation to average pollution concentrations over periods of several years (chronic effects).

We have based the quantification of health effects on reports of the UK Department of Health's *Committee on the Medical Effects of Air Pollutants (COMEAP 1998: 2001)*). These recommend quantification of deaths brought forward, respiratory hospital admissions, and chronic mortality for particulates (including secondary particulates) and deaths brought forward and respiratory hospital admissions for ozone and SO_2. The IGCB approach (which we adopt here) treats the mortality effects from short-term and long-term exposure as additive. Other implementation studies (e.g. the ExternE project, US EPA) quantify effects of long-term exposure only, to avoid risks of double-counting the effects of PM. For deaths brought forward and respiratory hospital admissions we have quantified health impacts using the functions from time series studies recommended by COMEAP (1998). For particulates, this uses PM_{10} concentration-response functions. Functions have been implemented linearly, without threshold.

Pollutant	Impact Category	% change in rate per µg/m^3
PM_{10}	Deaths brought forward	0.075%
SO_2	Deaths brought forward	0.060%
Ozone	Deaths brought forward	0.060%
PM_{10}	Respiratory Hospital Admissions	0.080%
SO_2	Respiratory Hospital Admissions	0.050%
Ozone	Respiratory Hospital Admissions	0.070%
NO_2	*Sensitivity Only*	
	Respiratory Hospital Admissions	*0.050%*

We have also undertaken some sensitivity analysis, using additional endpoints not recommended for quantification by COMEAP, based on functions that have been used in European cost-benefit studies (e.g. in ExternE). These values are less reliable and so are not included in any of the summary results reported. Details are provided in Appendix 2.

For mortality and long-term exposure to PM, the risk estimates are based on analyses of the American Cancer Society (ACS) cohort by Pope *et al* (1995,) and updated in 2002. The main results give a lower bound estimate of increase in death rates of 0.3%/µgm^{-3} $PM_{2.5}$. The IGCB (2001) used a lower risk estimate (0.1% per µgm^{-3} $PM_{2.5}$), based on the preferred estimate selected by COMEAP (2001) from the HEI reanalysis estimates adjusted for further possible confounders. This is a third of the lower bound risk estimate derived by Pope *et al,* (1995, 2002).

We have applied the 0.1% risk estimate here, and referred to it as the ***central low*** analysis. However, we have also applied the original lower bound risk estimate from the Pope study (0.3%/µgm^{-3} $PM_{2.5}$), as used by the ExternE project in European cost-benefit analysis (EC 1998: 2001) and by the Institute of Occupational Medicine (2003). Where used, this is referred to as the ***central high*** analysis. There is therefore a factor of 3 between the risk factors applied. Note the central high factor is still within the sensitivity range recommended by COMEAP. Use of the central high value is supported by Pope *et al* (2002). Indeed, recent European work by WHO under the CAFE project (Clean Air for Europe) and Long-Range Transboundary Air Pollution is now recommending 0.6%/µgm^{-3} $PM_{2.5}$, based on Pope *et al* (2002), i.e. double the central high estimate used here (note we have used in sensitivity analysis here).

Following IGCB (2001), we have applied the risk estimates for $PM_{2.5}$ directly to the PM_{10} concentrations assessed here. This implicitly assumes that most transport related PM_{10} falls within the $PM_{2.5}$ size fraction (which is the case), but also that the secondary particulates that form as a result of transport related pollution, are also within this size fraction. For implementation, we have used a life-table approach to quantify the change in life years. In order to examine the effect of individual policies in individual years, we have had to use a different approach to the IGCB analysis (2001). The IGCB analysis assessed the benefits of achieving a given air quality objective, and assumed this level was maintained thereafter (e.g. looking at benefits in the population through to 2110). This is not appropriate for assessing marginal changes from specific policies, against a changing background of air quality concentration. Therefore we have used an approach based on the IOM's work, which assesses the net benefits of incremental pollution emissions for a single year and follows the effects of the single-year increment on death rates and then on life expectancy through the population over time.

The approach uses life-tables, and assesses the impacts of a 1 year pollution pulse. For this pulse, the effect of the change was followed up until the population current at the time of the one-year pulse (i.e. the population exposed to the pollution change) had all died. These 1-year pulse implementations were based *only* on the population alive at the time of the pulse – for analysis of that 1-year pulse, no account was taken of new birth cohorts born in later years. When extrapolating the values for emission pulses in future years, we assumed that the starting population was identically the same as the starting population in Year 1. In effect, this means that we included new birth cohorts for every year from Year 1 up to Year N in the starting population of Year N; but ignored – for the analysis of Year N – all new birth cohorts subsequently (N=1,2,…15). Because the starting population was the same in each Year N=1,2,..15, then it was sufficient that we did the analysis only once, using some standard change to the risk, which was then scaled according to the relevant pollution level for that year. Note, however, that discounting was applied for future years.

For the analysis, we have assumed no lag between exposure and effect. This is consistent with recent guidance given by the WHO to the CAFE process. However, COMEAP 2001 gave a range assuming a lag of between 0 and 40 years. This does not affect the number of life years lost, but would affect the monetary valuation due to discounting of longer lags. The values presented in this report therefore underestimate the full uncertainties, by ignoring the full range of lag phases (the economic benefits would be lower if longer lags were assumed). With no lag, and a 1-yr pulse, the *mortality risks* change in Yr 1 only, and then they revert to previous levels. The reason for following up the population over a full lifetime is that the lower mortality risks in Year 1 under a pulse reduction imply:

- fewer deaths in year 1 (i.e. the number of deaths 'saved'),
- also and necessarily a slightly *increased* population in Year 2 and subsequently; and so
- slightly *more* deaths in Yrs 2 and onwards, because of the slightly larger population at risk.

We analyse over a full lifetime to 'track' how all this plays out. Another way of expressing it is that we analyse over a full lifetime to see when the deaths 'saved' in year 1 actually occur later, because necessarily they will occur.

The reduction in the text is shown as the benefit from the pollution change in the individual year (e.g. 2001 for the evaluation period and 2010 for the projected period) compared with the predicted out-turns 'without' policy for that year. The study has used detailed pollution maps for years 2001, 2004/5 and 2010. Values in intermediate years have been interpolated, based on the detailed emissions estimates for individual years.

Note when summing health benefits, the values presented here are total benefits are from emissions in the time period 1990 – 2010 only. They do not include benefits from lower emissions in future years (post 2001 for the evaluation or post 2010 for the projected analysis) from a move to sustained new pollution levels.

2.4.3. For monetary valuation of deaths brought forward by air pollution, the EAHEAP report recommended a wide range of estimates from £2,600 to £1.4 million per death (as a lower and upper bound). We have used the lower bound, adjusted by inflation (£3,100) in our ***central low*** analysis. The EAHEAP report also presented a value of £110,000 as an adjusted value, representing one year with a lower quality of life (see box). We have used this value, in our ***central high*** analysis, because it correlates with the value typically used in European cost-benefit analysis. The study team also considered the use of the upper range presented by EAHEAP (£1.4 million). This was included in a sensitivity analysis (though values are not presented here). The use of this upper value (or similar) was used some years ago in valuing the 'acute' mortality effects of outdoor air pollution, and so might have been used in a formal *ex ante* benefits analysis of some of the policies that were implemented. However, any studies at this time would not have considered chronic mortality. The study team believe that the use of the value of £1.4 million is no longer appropriate for valuing deaths brought forward, not least because it would double count effects with chronic mortality (see box). We stress that the use of this value would have the effect of dramatically increasing the importance of this endpoint in the monetary valuation. We highlight that there are a number of specific valuation studies on mortality from air pollution that have emerged recently.

2.4.4. The valuation of respiratory hospital admissions (RHA) is more straightforward. We have used the values derived in the EAHEAP working group report as the starting point, but taking into account the new empirical study on the valuation of these end-points (CSERGE, 1999). The latter study suggests a value of £1860 to £2538 per case. This is similar to the previous value recommended by EAHEAP (in current prices) of £1700-3550 (with £2625 as a mid-point). The value of £2625 has been used in the analysis below. The value includes resource costs (e.g. NHS costs), opportunity costs (lost productivity) and dis-utility. Note COMEAP, in the quantification report, presents the functions for respiratory hospital admissions as 'brought forward and additional', recognising that some or all of these cases would have occurred in the absence of the additional pollution. As is usual in most HIA work, we have assumed that hospital admissions attributable to air pollution are additional to those that would have occurred anyway, and not simply the bringing forward of admissions that would otherwise still have occurred, but only later. In practice, there is likely to be a mixture of both, but the underlying time series studies are strictly uninformative about the balance between them. We highlight that this assumption does not have a significant impact on the overall economic benefits (because the effects of RHAs are so low compared to the overall values).

2.4.5. Finally, we have monetised the chronic mortality benefits. The IGCB analysis concluded that '*given the uncertainty over the health values to be used…chronic mortality benefits can only currently be presented in quantitative terms (i.e., in terms of life years saved).*' However, for the purposes of this study, we need to progress to valuation. The valuation of chronic mortality (change in life expectancy) is again a subject of continued debate. The quantification (number of years lost) presented above has been quantified using two values for a life year lost. The first, applied to the ***central low*** analysis, is a value of £31,500 per life year lost. This is indicative of the value likely to emerge from the new empirical studies[21]. The second, applied to the ***central high*** analysis, is based on the value of £65,000, used in European cost benefit analysis. The combination of the quantification and valuation approach used for the central low and central high leads to approximately a factor of 6 difference between the low and high estimate for the valuation of life years saved. However, the life years saved includes benefits that happen in the future, from current pollution reductions. When health effects can be valued in monetary terms, as in a full cost-benefit analysis, the Treasury's preferred method is that they are discounted at the same rate as costs but that the future real values attached to health should be inflated to reflect rising real incomes. As we have progressed through to valuation in this analysis, it is appropriate to discount the future benefits over time. The study has used a 1.5 % discount rate as used in the IGCB work (Box 2.3 details the reason for the use of this rate).

[21] The Defra study 'Valuation of Health Benefits Associated with Reductions in Air Pollution', published June 2004, and the NewExt Study 'The Willingness to Pay for Mortality Risk Reductions: An EU 3-Country Survey', to be published by the EC 2004.

Box 2.3. Valuation of Health Effects

The valuation of time-series health endpoints was discussed by the Ad-Hoc Group on the Economic Appraisal of the Health Effects of Air Pollution. (EAHEAP, 1999). The EAHEAP report noted that there were no direct studies of people's valuation of reducing the risk of a death brought forward by air pollution. The valuation estimates were therefore inferred by adjusting a baseline figure obtained from other contexts. Adjustments were based on the expectation that those at risk would take account of their own prognosis, age and health in assessing the values they attached to further reductions in air pollution. The uncertainties in this process resulted in a wide range of estimates from 2,600 to 1.4 million to avoid a death being brought forward by air pollution. It was highlighted that the deaths associated with increases in air pollution are thought to occur in the elderly and among those with pre-existing serious cardio-respiratory disease, and so that life is shortened typically by weeks or months but not years (note the loss of life expectancy is not known precisely). The low value (£2600) has been used here for valuation of deaths brought forward in the ***central low*** analysis. The report also presented some adjusted values based on the assumption – see earlier – that those at risk of earlier death following days of higher air pollution have on average a lower life expectancy (say, in the order of 1 month to 1 year) than average for elderly population (12 years). The value of £1.4 million was therefore adjusted to £120,000 (for one year), and by 0.7 to reflect a lower quality of life (0.2 to 0.7) than average for elderly population (0.76). The use of upper quality of life adjustment gave a value of £110,000. Other studies (e.g. the ExternE study – EC, 1998:2001) have provided a single value, based on an assumption of the period of life lost. This has been used in European cost-benefit analysis, assuming a period of 6 months of life lost, with a value equivalent to £110,000. This value has been used here in ***central high*** analysis.

Note the upper value (£1.4 million) from EAHEAP has not been used here for time series studies (acute effects). Time series studies provide results in terms of changes in the number of daily deaths associated with air pollution. Aggregated over days, these results can be represented as the number of deaths per annum whose immediate life shortening was attributable to air pollution in the preceding days. These are described as the number of deaths brought forward, to indicate that in at least some of these cases, the actual loss of life is likely to be small – the death might in any case have occurred within the same year. There is an issue whether these effects can be added to the results of the cohort studies, i.e. the mortality effects of long-term exposure. In principle, cohort studies should capture the full mortality effects of PM. On that basis, it would involve double counting to add the PM-related mortality effects as estimated from time series studies. In practice, it may be that some aspects of the PM-attributable mortality identified by time series studies are *not* incorporated into the relative risk estimates of the cohort studies. In particular, this may apply to deaths brought forward by only a few days or weeks. Omission of time series estimates would therefore lead to some under-estimation of the total mortality impact. In this report, we have added the time-series and cohort studies, however, in selecting monetary values for the former, we do not believe it appropriate to use the unadjusted value for a death brought forward, as to do so would imply (in our view) a longer period of life lost, and would double count the benefits captured from the cohort studies.

We highlight that there are a number of specific valuation studies on mortality from air pollution that have recently been published. These studies provide values for a life year lost. As an interim position, the indicative value from one of these studies for a life year lost (£31,500) has been used in the ***central low*** analysis. The previous value in use in European cost-benefit analysis (£65,000) has been used in the ***central high*** analysis (e.g. see ExternE 1998:2001). Note the analysis of life years saved includes benefits that happen in the future, from current pollution reductions. As we have progressed through to valuation in this analysis, it is appropriate to discount these future benefits over time. The study has used a 1.5 % discount rate as used in the IGCB work (An Economic Analysis to Inform the Review of the Air Quality Strategy Objectives for Particles, 2001), on the basis of the following statement (reproduced from IGCB, 2001):

'The current Treasury Green Book states that: 'Some costs and benefits, such as for example risk of death or change in health state, might be seen as having a broadly constant utility value over time, regardless of changes in income. If so, then such future costs or benefits could be valued in 'today's' values and discounted at [the pure time preference rate], so avoiding the need to calculate separately a rate of increase in their value over time.' (Page 85, paragraph 17, The Green Book, HM Treasury, 1997). If health effects are measured in quantities (e.g. life years saved) and the value of health effects is increasing over time, discounting the volume of health effects at a lower rate than costs is an acceptable method of taking into account the future value of health effects. The Department of Health recommendation is that health effects are discounted at 1.5%. A rate of 1.5% is used because it is a measure of the pure time preference rate (including allowance for catastrophic risk). This is consistent with guidance from the Treasury Green Book. For the purposes of the analysis presented in this report, future health effects are discounted at 1.5%.'

2.4.6. There are a few additional areas that warrant further discussion. These are presented below by pollutant. The following sections also include discussion of non-health impacts and the additional sensitivity analysis that have been included in the study.

Particulates (PM_{10})

2.4.7. Ambient PM_{10} is a mixture of primary and secondary particulates[22]. Transport emissions lead to both primary and secondary PM_{10}. As part of the analysis here, we have separated out the health benefits of primary and secondary particulates[23]. We have also commented on the potential implications of these different parts of the PM_{10} mixture (i.e. primary and secondary particulates) being associated with health impacts. The analysis has also included effects of PM_{10} on building soiling (only for primary PM_{10}).

SO_2 Emissions (SO_2 as a gas and formation of secondary PM_{10} (sulphates))

2.4.8. The benefits of SO_2 reductions from transport policies have been quantified. SO_2 is associated with direct health effects (deaths brought forward, respiratory hospital admissions) and also with PM_{10} health effects from secondary particulate formation (sulphates). One very recent study has also shown direct associations between long-term exposure to gaseous SO_2 and reduced life expectancy. If quantified, this would appear to be a significant additional benefit. We have however not quantified this, on the understanding that to do so *and to add this to the life expectancy benefits associated with PM reductions* might over-estimate the benefits. However, estimation has been made of the benefits of reduced secondary particles (sulphates), as the evidence for the health benefits associated with reductions in sulphates is fairly strong for two reasons:

- Sulphates are within the PM_{10} size fraction and, although it is widely believed that different constituents of PM_{10} are associated with different toxicities to human health, it is rare that quantification seeks to take this into account. Thus, COMEAP does quantify secondary particulates in the same way as primary PM_{10} (because it applies the PM_{10} health concentration-response functions to all of the PM_{10} size fraction), but it has not specifically commented on the application of PM_{10} health functions to sulphates.
- Several epidemiological studies in the USA and Canada have shown direct relationships between sulphates and various acute and chronic health endpoints, including mortality (reduced life expectancy) from long-term exposures (chronic mortality). However, it does not necessarily follow that there is a causal relationship – it may be that sulphates are a marker (surrogate) for other aspects of the pollution mixture (and that these other parts of the pollutant mixture also change at the same time as reductions in sulphates).

2.4.9. SO_2 is the primary pollutant of concern in building damage, primarily from dry deposition, but also from the secondary acidic species that it forms in the atmosphere. The

[22] Anthropogenic particles (PM) arise from either direct emissions from a source such as a power plant or vehicle (primary) or are formed due to chemical processes (referred to as secondary particles) in the atmosphere. Primary particles typically arise from combustion processes and include carbonaceous particles (soot). Secondary particles form from gaseous species emitted to the atmosphere such as sulphur dioxide (SO_2) and nitrogen oxides (NO_x: $NO+NO_2$), which subsequently react and nucleate to form atmospheric particles. We have assessed the formation of sulphates (SO_4^{2-}) and nitrates (NO_3^-) aerosols and treated these in a similar way to primary particulates, because they generally fall entirely within the PM_{10} size fraction. Secondary particles are formed relatively slowly in the atmosphere and have a long lifetime (i.e. they are a regional pollutant).

[23] Note the modelling approach used for secondary particulate is subject to more uncertainty, the main problem being how much of the secondary particulates in the UK is from UK sources, and how much is imported.

study has quantified and valued these non-health benefits, using an approach consistent with previous IGCB analysis (IGCB, 1998). This is based on the work of the UNECE ICP programme and implemented in the ExternE project (EC, 1998). More details are provided in Appendix 2.

NO_X Emissions (NO_2 as a gas and secondary PM_{10} (nitrates) and ozone))

2.4.10. The benefits of **NO_X reductions** from transport policies are more complex to estimate. The evidence for the direct acute effects of NO_2 at ambient concentrations on health is not strong and COMEAP did not recommend quantification of effects, though a sensitivity function was included (for respiratory hospital admissions). More recent thinking tends to the view that where concentration-response (C-R) relationships have been found, linking NO_2 and health, then NO_2 may be acting as a marker for particle number, which might strengthen the case for its inclusion. There is only uncertain evidence that long-term exposure to ambient NO_2 causes quantifiable adverse health effects. We have, however, included the sensitivity function recommended in COMEAP (see Box 2.2) to assess the potential benefits from NO_2 reductions.

2.4.11. NO_X emissions also have potential health benefits through the reduction in ozone and secondary particulates (nitrates). COMEAP recommended the quantification of the acute health effects of ozone (deaths brought forward and respiratory hospital admissions); there is some equivocal evidence of chronic effects, i.e. from long-term exposure to ozone, but not sufficient for quantification. Ozone is also the main pollutant of concern in crop damages. However, ozone formation is extremely complex and non-linear. There are local and regional scale issues that complicate analysis. To illustrate, a decrease in NO_X emissions does not always lead to a reduction in ozone concentrations at the local or even the regional scale. Although the potential benefits of reductions in NO_X emissions have been quantified at a regional scale, in studies such as ExternE (EC, 2001), this analysis relates to specific time periods, and involves specific background concentrations of other pollutants. It is therefore inappropriate to apply these results to the current study. The ExternE analysis indicated that marginal reductions of NO_X emissions in the UK (within a short-time horizon) would be unlikely to reduce regional ozone concentrations and was actually more likely to increase them. We have not quantified the potential effects of NO_X emissions on ozone here, as it has not been possible to undertake new modelling analysis, and we believe the uncertainties in using previous work is too high for the analysis of NO_X emissions on ozone. This is highlighted as an area warranting future analysis.

2.4.12. NO_X emissions also form secondary particulates (nitrates). The issues with quantification are similar to sulphates, though there are also some significant differences. Nitrates are part of the PM_{10} size fraction, and it would be reasonable (applying a precautionary approach) to treat them as associated with similar PM_{10} related effects as for sulphates above. As noted earlier, COMEAP in its quantification work does not differentiate between the various components of PM_{10} (nor does the US EPA, other than distinguishing $PM_{2.5}$), but neither has COMEAP taken a position on the health effects of nitrates specifically. However, unlike sulphates, there is almost no direct evidence linking nitrates to health effects, partly because it is difficult to measure nitrates reliably on the scale necessary for modern epidemiology, and most analysts (including the ExternE team) remain cautious about the causality of nitrates as part of the PM_{10} size fraction. In the present study, the quantification and valuation of nitrates (as secondary PM_{10}) has been undertaken, based on the detailed air quality mapping work for 2001, 2004 and 2010. However, it is stressed that our confidence in the values is lower than for sulphates.

Benefits from VOC Emission Reductions (Ozone Impacts)

2.4.13. The benefit of VOC reductions occurs because of their role in ozone formation. The role of VOCs to ozone formation is slightly less complex than for NO_X because reductions in VOC nearly always lead to reductions in ozone (at both a local and regional scale). The potential benefits from ozone reductions from VOC reductions have been quantified at a regional scale, using ozone transfer matrices from EMEP modelling undertaken within previous work in the ExternE study (EC, 2001). In addition to health benefits, the analysis has quantified and valued benefits in reducing crop damage (the latter based on ExternE, 2001).

Benefits from Lead Emission Reductions

2.4.14. The study has assessed the potential benefits of lead reductions from the introduction of unleaded petrol. Lead has a number of serious impacts on health, although this too is a controversial area. The earlier environmental economics literature quantified a number of health endpoints including hypertension in adults, coronary heart disease events, mortality (neonatal and adult), and IQ loss in children. This leads to extremely large values – for example, the US unleaded programme was estimated to have annual benefits of $6 billion and total benefits (net present value) of $29 billion (1988 prices) for the period 1985 to 1992 (when compared with net present costs from the policy of only $3 billion (Cannon (1990)). However, there are significant problems with these earlier studies, and recent work has typically only quantified IQ loss in children and qualitatively linked lead to increased blood pressure in adults[24]. The valuation of IQ loss is contentious, and recent reviews in ExternE (e.g. EC, 2001) concluded that valuation was not possible without further underlying research. Nonetheless, it is possible to apply earlier values from the US literature to illustrate the potential benefits from lead reductions from policy in the UK. We have undertaken such an analysis based on lifetime earnings loss per IQ point, and estimated national exposure to lead levels in children aged 0 – 2 years of age. It is stressed that our confidence in the valuation approach is extremely low. Estimated effects from increased blood pressure in adults would also increase these values. More detail on the approach used is presented in Appendix 2.

Sensitivity Analysis: Additional Morbidity Benefits from PM_{10} Emission Reductions

2.4.15. Subsequent communications from COMEAP (2001) added the effects of cardiovascular admissions from particulates as a sensitivity analysis. We have quantified the health impacts using the recommended COMEAP exposure-response functions. The study has also quantified and valued a number of additional acute health effects for morbidity as part of a sensitivity analysis of PM_{10}, using functions reported in a number of EC and US studies (IOM, 2001). Note this sensitivity analysis does not include all functions in the literature, but is restricted to those studies for which the evidence is strongest. The sensitivity has been applied to both primary and secondary PM_{10}. The analysis is split into 'other respiratory cases' (e.g. as recorded by GP visits), 'respiratory symptoms in asthmatics', and

[24] Communication from the Chief Medical Officer also states that 'among adults, there is some evidence of a small increase in blood pressure - for example, an increase in systolic blood pressure of about 1 mmHg, with a smaller increase for diastolic pressure, for a doubling of blood lead from 0.8 to 1.6 µmol/1 (17 to 33 µg/dl[3])' *CMO'S Update* 18. Department of Health. May 1998.

'other respiratory cases' (e.g. restricted activity days) with several health endpoints in each category. It is stressed that these endpoints have not been recommended by COMEAP as reliable enough for quantification, but it is likely that they are related to air pollution. Omitting them probably implies under-estimating effects. Their inclusion leads to very much higher estimated heath impacts, relative to the no abatement scenario. The functions and valuation for the additional morbidity effects are presented in Appendix 2.

Sensitivity Analysis: Carbon Monoxide and Potential Carcinogens

2.4.16. There are a number of additional (potential) benefits that have been quantified as part of the sensitivity analysis. COMEAP quoted studies that showed associations between carbon monoxide (CO) and deaths brought forward and cardio-vascular admissions, but did not quantify because of the problems separating CO from other components of the air pollution mixture and because of the lack of UK studies. The 1998 quantification report did however acknowledge that information on CO was accumulating, and that assessment may be possible in the future. We have therefore included some analysis of the potential effects of CO on cardio-vascular disease in the sensitivity analysis. The sensitivity analysis also includes the quantification and valuation of the potential carcinogenic effects of benzene, 1,3-butadiene, and benzo[a]pyrene quantified using US-EPA risk factors. It is stressed that the UK DoH does not recommend these risk factors for use. The functions and valuation for the additional effects are presented in Appendix 2.

Health Impacts and Uncertainty

2.4.17. It is stressed that there are different levels of uncertainty associated with different pollutants and impacts. This includes uncertainty concerning the exact exposure-response function or valuation used, and wider issues of confidence in the reliability of effects. The study has categorised the pollutants and impacts into confidence bands. These confidence bands represent our views on the reliability of effects (not in terms of concentration-response functions or valuation) and are presented in Table 2-2 below, as high, medium, low, and sensitivity only. These are subjective but informed assessments. The rankings have been used in a later section for sequential uncertainty analysis and sensitivity analysis.

Quantification of Health Impacts from Transport Policies

2.4.18. The air quality improvements, as shown in the detailed pollution maps above, have significantly reduced the population exposed to air pollution, and therefore the potential health impacts of air pollution in the UK. The analysis has quantified how much national transport policies are estimated to have already reduced the main health impacts of concern (to 2001), compared to the 'no abatement' scenario, and how much they are projected to do so in the future (to 2010).

Table 2-2. Impacts and Uncertainty Ranking for Health Impacts from Air Pollution

Pollutant and Impact	Confidence Ranking	Notes
PM_{10} on health Deaths brought forward (DBF), Respiratory Hospital Admissions (RHA) Chronic Mortality (CM). **PM_{10} on building soiling**		Note confidence in effect is high, but some uncertainty over exact valuation of endpoints for acute and chronic mortality (and also on potential double counting from adding DBF and CM effects).
SO_2 as a gas on health (DBF/RHA). **SO_2 and secondary pollutants on building damage** (corrosion)	**High**	Some uncertainty over valuation of endpoint of acute mortality
VOC and impacts on health (DBF/RHA) through formation of **ozone** **VOC and impacts on crops** (yield loss) through formation of **ozone**		Some uncertainty over valuation of endpoint of acute mortality. Note lower confidence in predictions of ozone concentrations presented here (modelling uncertainty).
NO_X and impacts on health (DBF/RHA) through formation of **ozone** **NO_X and impacts on crops** (yield loss) through formation of **ozone**		Some uncertainty over valuation of endpoint of acute mortality Note ozone concentrations from NO_X not included here, because uncertainty too high.
Lead on health (childhood IQ and increased blood pressure)		Valuation methodology high uncertainty
SO_2 as secondary PM_{10} (sulphates) on health (DBF/RHA/CM).	**Medium**	Note confidence in health impacts of secondary PM_{10} is lower than for primary PM_{10}. Some uncertainty over exact valuation of endpoints for acute and chronic mortality
NO_X as secondary PM_{10} (nitrates) on health (DBF/RHA/CM).	**Low**	Note confidence in health impacts of nitrates (as secondary PM_{10}) is lower than sulphates. Some uncertainty over exact valuation of endpoints for acute and chronic mortality
Additional PM_{10} health impacts other than DBF/RHA/CM from European/US literature	**Sensitivity analysis** **(<u>NOT</u> recommended by COMEAP*)**	Confidence low as based on small number of non-UK studies
NO_2 as a gas on health Respiratory Hospital Admissions (RHA)*		Recommended for use as sensitivity only. NO_2 surrogate for other pollutants?
Benzene, 1,3 butadiene and benzo[a] pyrene on health (cancer)		Confidence low as based on US dose-response functions and assume no threshold and low level causality
CO on health		Recommended for use as sensitivity only. Surrogate for other pollutants?

* Respiratory Hospital Admissions (RHA) for NO_2 and Cardiovascular admissions (CA) for particulates were recommended for sensitivity by COMEAP (1998:2001)

2.4.19. PM_{10} is one of the main pollutants of concern. Figure 2-10 shows the estimated health effects in the UK (only) in terms of deaths brought forward (left), with and without the transport sector policies. The difference between the two lines on the left hand graph is the benefit achieved from transport policies, i.e. from reductions in total PM_{10} (both primary and secondary PM_{10}). The values for 2001 are based on the actual data (i.e. they are effectively an ex post analysis). The values for 2005 and 2010 are projected. It is stressed that the benefits include the reduction of primary PM_{10} from vehicle exhausts, but also the reduction in secondary particulates from transport NO_X and SO_2. The analysis shows that transport policies have already (2001) led to a reduction of around 500 in the number of people per year whose life is shortened by pollution in days before death. This is projected to increase to a benefit of 1400 people per year whose life is shortened by pollution by 2010. Recall that these are people with short remaining life expectancy. These benefits (i.e. the 500 to 1400 people) have been attributed to the different components of the PM_{10} pollution mix on the right hand side of Figure 2-10. This shows that these health benefits are dominated by the reduction in primary PM_{10}. Note the benefits in terms of deaths brought forward (and also respiratory hospital admissions) would have been anticipated ex ante.

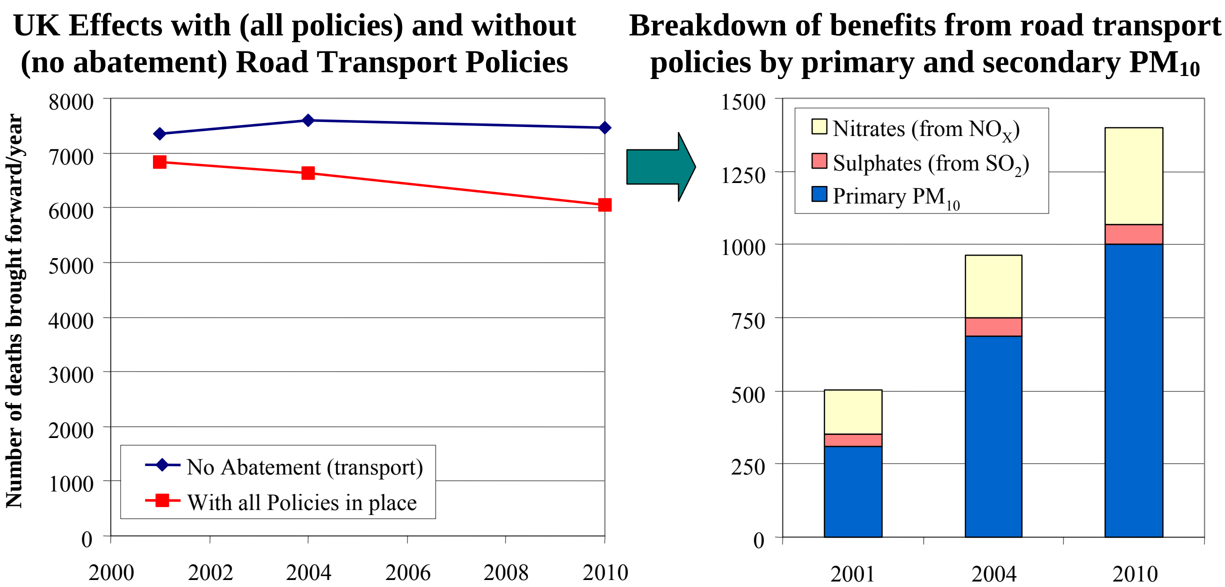

Figure 2-10. Estimated <u>Annual</u> Deaths Brought Forward in the UK from PM_{10} (Data for 2001 Actual. Data for 2004 and 2010 Projected.)

Note that the figure on the left shows the differences between the projected out-turn for the whole UK and the ‘no abatement’ scenario where no transport policies are introduced (but improvements in other sectors do occur).

The figure shows the benefit from the pollution change in the individual year (2001,2005 and 2010) compared with the predicted out-turns ‘without’ policy for that year.

2.4.20. The analysis has also assessed the long-term benefits from transport policies for PM_{10}. Figure 2-11 shows the estimated health effects in the UK (only) in terms of the change in life expectancy (left), with and without transport policies. Note a central low and a central high value are presented. The difference between the two lines on each of the two left hand graphs is the benefit achieved from transport policies. It is stressed that the benefits include the reduction of primary PM_{10} from vehicle exhausts, but also the reduction in secondary particulates from transport NO_X and SO_2. Again, the values for 2001 are based on the actual data (ex post), the values for 2005 and 2010 are projected. The analysis shows that transport policies have already (2001) led to large reduction in the years of life lost. This is projected to increase significantly by 2010. These benefits have been attributed to the different components of the PM_{10} pollution mix on the right hand graph (which obviously follows the pattern for short-term effects above). This shows that these health benefits are dominated by the reduction in primary PM_{10}. Note that life expectancy benefits from reduced long-term exposure to PM are now well accepted, though questions remain about how quickly the benefits follow on from pollution reduction; these benefits would have been considered controversial, or unquantifiable, at the time when earlier policies were being decided (*ex ante* benefits in policy appraisal).

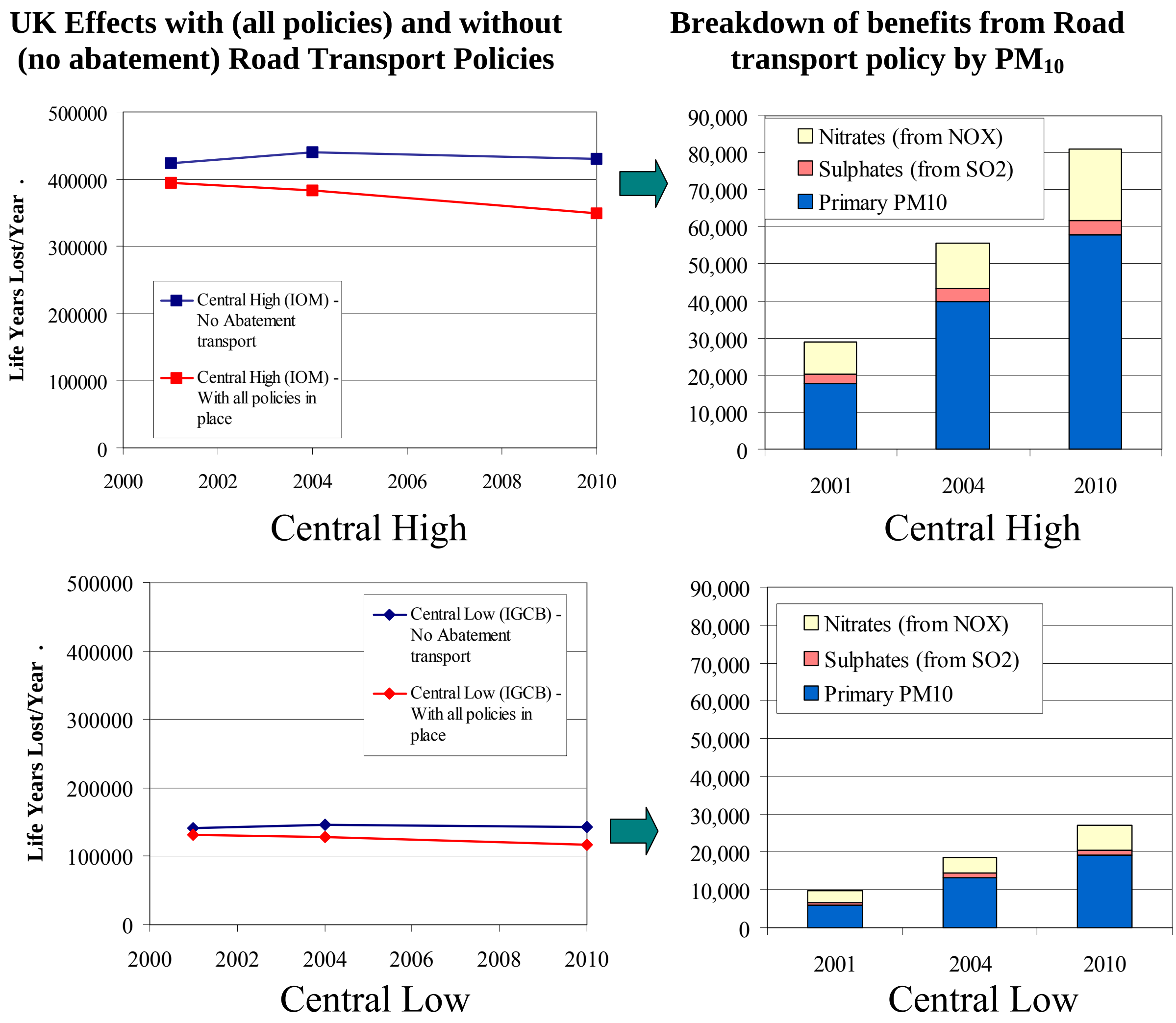

Figure 2-11. Number of Annul Life Years Lost in the UK from PM_{10} concentrations (Data for 2001 Actual. Data for 2004 and 2010 Projected.)

The reduction is shown as the benefit from the pollution change in the individual year (2001, 2005 and 2010) compared with the predicted out-turns 'without' policy for that year.

Note that the figure on the left shows the differences between the projected out-turn for the whole UK and the 'no abatement' scenario where no transport policies are introduced (but improvements in other sectors do occur). The analysis of life years saved is based on exposure to PM_{10} experienced for a 1 year pollution increment. It is based on the life-table approach, following up the population exposed to the 1-year pollution change until all have died, assuming no lag effects. Pollution-related changes to death rates are spread over time but in total are equivalent to changing the death rates for one year only by the estimated risk coefficient (i.e. 0.1% or 0.3% per μgm^{-3} $PM_{2.5}$). Values include benefits from both primary PM_{10} and secondary PM_{10}. The numbers presented are undiscounted. The analysis accounts for the potential differences between PM_{10} measurement techniques (TEOM vs. gravimetric).

2.4.21. The benefits results are summarised in the table below. The analysis shows that while there have been major benefits already (to 2001) from the introduction of policies, much larger benefits are projected to occur by 2010. This is not surprising, as the first Euro standards only appeared in 1993, and that the benefits will increase as older vehicles are retired from the fleet, and as stricter standards apply (post 2001).

Table 2-3. Annual PM_{10} Health Benefits in the UK from All Road Transport Policies: Achieved (2001) and Projected to Occur (2010), relative to the No Abatement Scenario

Health Effect	**Actual annual benefit in 2001**	**Projected annual benefit in 2010**
Deaths brought forward	500	1,400
Respiratory hospital admissions	490	1,370
Life years saved	9,670 (central low) to 29,010 (central high)	26,960 (central low) to 80,880 (central high)

The benefits are the difference between the UK out-turn (with transport policies) and the 'no abatement' scenario (with no transport policies, but with improvements in other sectors, e.g. ESI). The table shows the benefit from the pollution change in the individual year (2001 and 2010) compared with the predicted out-turns 'without' policies for that year. Values include benefits from both primary and secondary PM_{10}. Note analysis of life years saved is based on exposure to PM experienced for a 1-year pollution increment, assuming no lag effects. The numbers presented are undiscounted. Only benefits in the UK are included (no trans-boundary benefits). Central low/high only includes variation in risk factor for chronic mortality.

2.4.22. It is possible to value the above health benefits. The results are summarised in Table 2-4 below. They show the transport policies in place have had very large economic benefits already (by 2001), and again, these are projected to be even greater by 2010. For example, the total benefits from policies in the transport sector, from the reduction in all PM_{10} (primary and secondary), are estimated to be £250 Million to £1587 Million/year (central low to central high), relative to the no abatement scenario. These are the ex post benefits achieved to date (2001). By 2010, these benefits are projected to increase to £697 Million to £4427 Million/year (CL – CH) relative to the no abatement scenario. It is stressed that the life years saved, even when discounted, dominate these benefits, at over 95% of overall benefits.

Table 2-4. Annual PM_{10} Related Economic Benefits in the UK from Road Transport Policies: Achieved (2001) / Projected to Occur (2010), relative to No Abatement Scenario

Health Effect	**Actual annual benefit (2001) £ Million**	**Projected annual benefit (2010) £ Million**
Deaths brought forward	1.6 (central low) to 55.2 (central high)	4.3 (central low) to 153.9 (central high)
Respiratory hospital admissions	1.3	3.6
Life years saved (discounted @ 1.5%)	247 (central low) to 1531 (central high)	689 (central low) to 4269 (central high)
TOTAL	**250 (central low) to 1587 (central high)**	**697 (central low) to 4427 (central high)**

For caveats, see Table 2-3. Note the valuation of future life years saved from annual pollution in 2001 and annual pollution in 2010 have both been discounted (using a rate of 1.5%). 2010 values assume constant prices. The central low and central high values include a variation in the risk factor for chronic mortality, and a range in the valuation of deaths brought forward and chronic mortality.

2.4.23. Note the values above **only include the benefits of air quality improvements in the UK, from the implementation of policies in the UK**. We stress that this is the most relevant metric for the evaluation (and was specified in the study terms of reference). However, it does raise a number of issues.

- Firstly, the implementation of policies in the UK would also lead to a reduction in trans-boundary pollution from the UK to Europe. This would be important in reducing long-distance transport of PM_{10}, secondary pollution precursors, and formation of secondary PM_{10} and ozone. The benefits presented here are therefore a sub-total of the full social benefits of UK emission reductions (and UK policies), because they do not include these additional health benefits in the rest of Europe.
- Secondly, we have not assessed the benefits to the UK from other European countries complying with the same policies. For example, the introduction of the Euro standards in other European countries will have helped to improve air quality levels in the UK over the past decade. Instead we have included these European benefits in both our 'with policies' and 'no abatement' scenarios. If there were a total absence of fuel quality or Euro standards across Europe, the 'no abatement' scenario would actually be much higher than shown here. We highlight that part of the logic of international negotiations (especially for reductions of SO_2) was that collective action would lead to collective benefits. It is clear that there are benefits to the UK from agreeing to European Directives and Agreements, because this reduces the 'imports' of trans-boundary pollution into the UK.

2.4.24. We highlight both these issues as a potential bias within the study[25], and recommend that they be considered in future discussion by the IGCB, and future Regulatory Impact Assessment in Government (i.e. 'exports' and 'imports'). An additional sensitivity analysis has been undertaken here to examine the potential benefits of including trans-boundary benefits from UK pollution to Europe – this increases the benefits of air quality benefits by 25% or more (in terms of economic benefits). We have not been able to assess the potential benefits to the UK from European compliance with the transport policies separately.

2.4.25. The health impacts and economic benefits of all transport policies, for all pollutants, are presented in the following tables. They include the benefits of all transport policies, relative to the 'no abatement' scenario. The analysis is split by pollutant, and classified using the confidence bands outlined above.

- Table 2-5 presents the annual health benefits from transport policies in the UK for the evaluation date (2001) and projected to occur with existing policies (by 2010). This is based on the detailed mapping analysis for the years 2001 and 2010.
- Table 2-6 presents the annual economic benefits from the above analysis, in 2001 and 2010, including health and non-health benefits.
- Table 2-7 presents the total benefits from transport policies in the evaluation period (to 2001) and projected to occur from 2002 to 2010. These values have been calculated by using the detailed mapping and valuation analysis above to estimate the marginal benefits of air quality improvements (expressed as a cost per tonne). The results have been used to estimate the benefits in all years over the evaluation period and projections, based on the

[25] It could therefore be argued that the benefits abroad from UK action, and likewise the benefits to the UK from action in other countries, as part of the same legislation, should be counted in the evaluation. The study team has highlighted these trans-boundary aspects, and several members of the steering group and also the peer reviewer have also raised this issue. Note for the transport sector, even if the UK had not agreed to the Euro standards (but the rest of Europe did), it is likely that cleaner vehicles would still have entered the UK fleet, due to the harmonised nature of the car manufacturing market.

detailed emissions estimates for each year. This approach involves a number of assumptions (notably the linearity of emission reductions to concentrations, and an even distribution across all locations with different policies), but provides a practical approach.

Table 2-5. Annual UK Health Benefits (Cases) from All Road Transport Policies. Benefit achieved (2001) / Projected to Occur (2010), relative to No Abatement Scenario.

Pollutant and Impact	Confidence Ranking	Actual annual benefit as number cases in 2001	Projected annual benefit as umber cases in 2010
Primary PM_{10} on health	High		
Deaths brought forward (DBF)		309	1000
Respiratory Hospital Admissions (RHA)		302	980
Chronic Mortality (CM).		5946 to 17839 (CL-CH)	19272 to 57817 (CL-CH)
SO_2 as a gas on health (DBF/RHA).		Not presented separately	Not presented separately
VOC and impacts on health (DBF/RHA) through formation of **ozone**		Not presented separately	Not presented separately
NO_X and impacts on health (DBF/RHA) through formation of **ozone**		Not quantified	Not quantified
Lead on health Childhood IQ		Not presented separately	
SO_2 as secondary PM_{10} (sulphates)	Medium		
Deaths brought forward (DBF)		42	69
Respiratory Hospital Admissions (RHA)		41	68
Chronic Mortality (CM).		812 to 2436 (CL-CH)	1336 to 4008 (CL-CH)
NO_X as secondary PM_{10} (nitrates)	Low		
Deaths brought forward (DBF)		151	330
Respiratory Hospital Admissions (RHA)		148	323
Chronic Mortality (CM).		2913 to 8739 (CL-CH)	6351 to19053 (CL-CH)
Additional PM_{10} health impacts (includes primary and secondary PM_{10})	Sensitivity analysis (NOT recommended by COMEAP*)		
Cardiovascular admissions (CA)*		287	801
A&E visits for respiratory illness (A&E)		732	2041
GP visits: Asthma		10805	30118
GP visits: Lower respiratory symptoms		526	14688
Restricted activity days		1717960	4788849
Respiratory symp. in adult asthmatics		575860	1605222
Respiratory symp. in child asthmatics		215190	599848
NO_2 as a gas on health* Respiratory Hospital Admissions (RHA)		1196	3198
Potential Carcinogens			
Benzene		9.4	10.2
1,3 butadiene		62	87
Benzo[a]pyrene		4.2	6.6
CO on health		Not presented separately	Not presented separately

* Respiratory Hospital Admissions (RHA) for NO_2 and Cardiovascular admissions (CA) for particulates were recommended for sensitivity by COMEAP (1998:2001).

See text for caveats. The table shows the benefit from the pollution change in the individual year (2001 and 2010) compared with the predicted out-turns 'without' policy for that year. Note numbers only include UK benefits, and do not account for benefits arising outside the UK from the reduction in trans-boundary pollution. CL = Central Low. CH = Central High. This range only includes variation in risk factor for chronic mortality.

Table 2-6. Annual Economic Benefits in the UK from All Road Transport Policies. Benefit achieved (2001) / Projected to Occur (2010), relative to No Abatement Scenario.

Pollutant and Impact	Confidence Ranking	Actual Annual benefit in 2001 £ Million	Projected Annual benefit in 2010 £ Million
PM_{10} on health Deaths brought forward (DBF) Hospital Admissions (RHA) Chronic Mortality (CM). **PM_{10} on building soiling**	High	 1.0 to 34.0 (CL-CH) 0.8 152 to 942 (CL-CH) 7 to 13	 3.1 (CL) to 110 (CH) 2.6 493 to 3052 (CL-CH) 14 to 28
SO_2 as a gas on health (DBF/RHA) *plus* **SO_2 / secondary buildings** (corrosion)	High	34 to 393(CL-CH)	39 to 442(CL-CH)
VOC and impacts on health (ozone) *plus* **VOC and impacts on crops (ozone)**	High	129 to 325 (CL-CH)	174 to 440 (CL-CH)
NO_X and impacts on health (ozone) *plus* **NO_X and impacts on crops (ozone)**	High	Not quantified	Not quantified
Lead on health Childhood IQ	High	42 to 426**	
TOTAL	**High**	**366 (CL)–2134 (CH)**	**726 (CL)– 4075(CH)**
SO_2 as secondary PM_{10} (sulphates) Deaths brought forward (DBF), Respiratory Hospital Admissions (RHA) Chronic Mortality (CM).	**Medium**	 0.1 to 4.6 (CL-CH) 0.1 21 to 129 (CL-CH)	 0.2 to 7.6 (CL-CH) 0.2 34 to 212 (CL-CH)
TOTAL	**Medium**	**21 (CL) – 134 (CH)**	**34 (CL)– 220 (CH)**
NO_X as secondary PM_{10} (nitrates) Deaths brought forward (DBF) Respiratory Hospital Admissions (RHA) Chronic Mortality (CM).	**Low**	 0.5 to 16.6 (CL-CH) 0.4 74 to 461 (CL-CH)	 1.0 to 36.3 (CL-CH) 0.8 162 to 1006 (CL-CH)
TOTAL	**Low**	**75 (CL) – 478 (CH)**	**164 (CL)–1043 (CH)**
Additional PM_{10} morbidity health impacts (includes primary and secondary PM_{10}) Respirator symptoms (CA*/A&E/GP visits) Restricted activity days Respiratory symptoms in asthmatics	**Sensitivity analysis (NOT recommended by COMEAP*)**	 1.4 170 105	 4.0 474 293
NO_2 as a gas on health Respiratory Hospital Admissions*		 4.1	 8.4
Other pollutants on health **Benzene** (cancer) **1,3 butadiene** (cancer) **benzo[a]pyrene** (cancer)		 8.6 56.4 3.8	 9.3 78.8 6.0
CO on health Congestive heart failure		 3.1	 4.8
Total	**Sensitivity**	**352**	**878**

See text and previous table for caveats*. Note the numbers only include UK benefits. CL = Central Low. CH = Central High. This range only includes variation in the risk factor for chronic mortality, and the valuation of deaths brought forward and chronic mortality. Note the valuation of future life years saved from annual pollution in 2001 and annual pollution in 2010 have been discounted at 1.5%. Estimates for 2010 in 2002 constant prices and have not been discounted to allow direct comparison with 2001 data.
** Range reflects valuation literature. We stress that the value for lead in indicative only. All policies fully implemented by 2001. Note also that policies to reduce lead were already in place prior to 1990.

Table 2-7. Economic Benefits from All Road Transport Policies. Total benefit achieved (2001) and Projected to Occur (2010), relative to the No Abatement Scenario.

Pollutant and Impact	Confidence Ranking	Evaluation (ex post benefit) 1990 - 2001 £ Million	Projected benefit 2002 - 2010 £ Million
PM_{10} on health (DBF), (RHA) (CM). *plus* **PM_{10} on building soiling**	High	1248 to 7788 (CL-CH)	3764 to 23487 (CL-CH)
SO_2 as a gas on health (DBF/RHA). *plus* **SO_2 / secondary pollutants on building damage** (corrosion)		180 to 2062 (CL-CH)	335 to 3824 (CL-CH)
VOC and impacts on health (DBF/RHA) through formation of **ozone** *plus* **VOC and impacts on crops** (yield loss) through formation of **ozone**		650 to 1644 (CL-CH)	1447 to 3659 (CL-CH)
NO_X and impacts on health (DBF/RHA) through formation of **ozone** + **NO_X and impacts on crops** (yield loss) through formation of **ozone**		Not quantified	Not quantified
Lead on health childhood IQ		357 to 3662**	
TOTAL	**High**	**2435 to 15156 (CL-CH)**	**5546 to 30970 (CL-CH)**
SO_2 as secondary PM_{10} (sulphates) (DBF), (RHA), (CM).	**Medium**	147 to 934 (CL-CH)	273 to 1732 (CL-CH)
TOTAL	**Medium**	**147 to 934 (CL-CH)**	**273 to 1732 (CL-CH)**
NO_X as secondary PM_{10} (nitrates) (DBF), (RHA), (CM).	**Low**	359 to 2280 (CL-CH)	1116 to 7085 (CL-CH)
TOTAL	**Low**	**359 to 2280 (CL-CH)**	**1116 to 7085 (CL-CH)**
Additional PM_{10} health impacts Respirator symptoms (CA*/A&E/GPv) + Restricted activity days + Respiratory symptoms in asthmatics	**Sensitivity analysis** **(NOT recommended by COMEAP*)**	1905	5593
NO_X as a gas on health Respiratory Hospital Admissions (RHA)*		19	59
Benzene (cancer) **1,3 butadiene** (cancer) **benzo[a]pyrene** (cancer)		37.6 287 19.1	81.0 648 47.1
CO on health		13.8	37.5
TOTAL	**Sensitivity**	**2282**	**6466**

The values represent the benefits from emissions in the time period 1990 – 2010 only. They do not include benefits from lower emissions in future years (post 2001 for the evaluation or post 2010 for the projected analysis) from a move to sustained new pollution levels.

See text and previous tables for caveats */**. Note the numbers only include UK benefits.
CL = Central Low. CH = Central High. This range only includes variation in the risk factor for chronic mortality, and the valuation of deaths brought forward and chronic mortality.

Estimates for 2002-2010 in 2002 constant prices and are not discounted to allow direct comparison with 1990-2001 data.

The values, by uncertainty band, are presented in the Figures below for annual benefits and total benefits for the evaluation period (1990 – 2001) and projected to occur (2002 – 201).

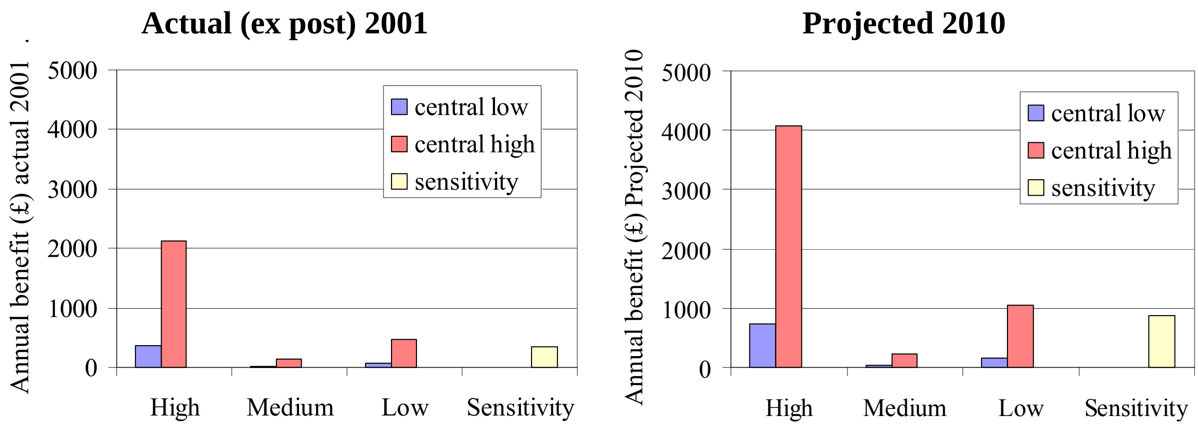

Figure 2-12. <u>Annual</u> Benefits (£Million) of Road Transport Policies Relative to 'No Abatement'. Achieved (in 2001) and Projected to Occur (by 2010), by confidence band

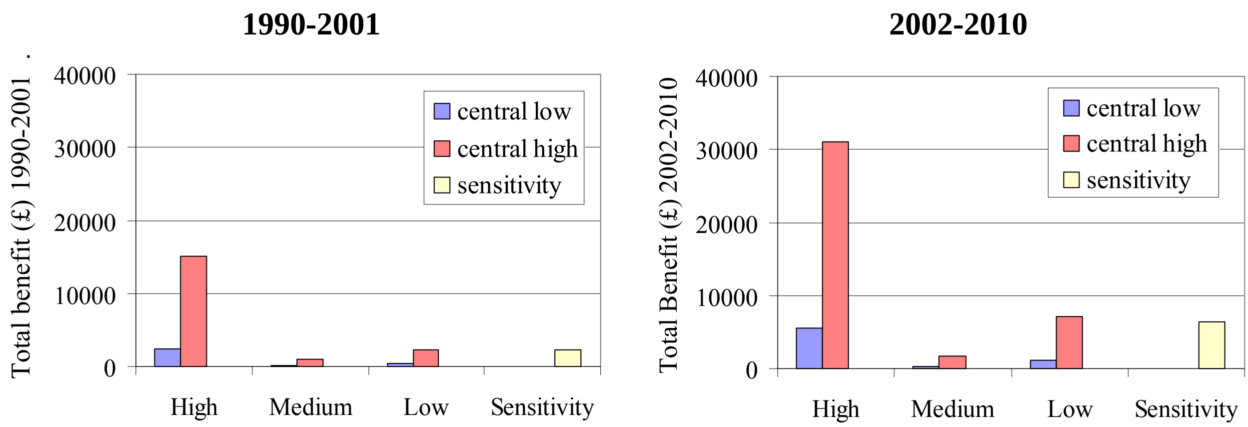

Figure 2-13. <u>Total</u> Benefits (£ Mill) of Road Transport Policies relative to No Abatement. Achieved (1990-2001)/ Projected to Occur (2002-2010), by confidence band

See tables 2-6 and 2-7 for notes.

2.4.26. The transport policies, when compared to the 'no abatement' scenario, show:

- The economic benefits from improvements in air quality in the evaluation period from the policies are very large:
  - The annual benefits in 2001 (for high, medium and low confidence bands) are estimated at £462 million (central low) to £2,746 million (central high).
  - The total benefits in the evaluation period (for high, medium and low bands) are estimated at £2,941 million (central low) to £18,370 million (central high). Note these total benefits are from emissions in the time period 1990 – 2001 only. They do not include benefits from lower emissions in future years (post 2001) from a move to sustained new pollution levels.
- However, in terms of numbers of both health and economic benefits, greater benefits are projected to occur in the period 2002-2010, than have occurred in the period 1990 –2001:
  - The annual benefits in 2010 (for high, medium and low confidence bands – in 2002 constant prices, undiscounted) are projected at £924 million (central low) to £5,338 million (central high).

  - The total benefits in the projected period (for high, medium and low bands – in 2002 constant prices, undiscounted) are projected at £6,935 million (central low) to £39,787 million (central high). Again, these total benefits are from emissions in the time period 2002 – 2010 only. They do not include benefits from lower emissions in future years (post 2010) from a move to sustained new pollution levels.
- For lead, the largest benefits from policies have already occurred. For SO_2, there are also larger benefits in the evaluation period. This has occurred because of the rapid introduction of cleaner fuels through duty differentials for both these fuels.
- The overall benefits are dominated by the vehicle emission standards (Euro standards for new vehicles). Greater benefits are projected from these Euro standards in the projected period to 2010. The delay in benefits is because of the longer time-scale for vehicle replacement in the fleet and because a number of policies (standards) do not come into force until post 2001 (Euro III and IV).
- The banding of impacts into sensitivity categories (high, medium, low) shows that the greatest benefits are associated with the high confidence band. The health and economic benefits are dominated by primary PM_{10} and specifically the improvements to life expectancy (chronic mortality). Nonetheless, the benefits from SO_2 (as a gas), VOCs and lead are also high.
- The medium confidence band (sulphates) is lower in size due to the low absolute emissions of SO_2 (i.e. in tonnes) from the transport sector, even prior to the policies.
- There are significant benefits associated with the low confidence band (nitrates). Note that these effects were estimated as if nitrates have the same toxicity as $PM_{2.5}$ generally.
- We highlight that benefits of the policies (particularly Euro III and IV) also extend beyond 2010, because of the time taken for the entire fleet to comply with the standards.
- The economic benefits of non-health categories (materials and crops) are low in relation to health benefits.

2.4.27. The sensitivity analysis shows:

- The additional impacts assessed are important, particularly in relation to the number of health impacts. Indeed, some of the morbidity benefits identified could exceed over a million avoided impacts each year, as a result of transport policies. They are also significant in terms of economic benefits, though the estimated effects for the sensitivity analysis are much lower in monetary terms than the main analysis.

- The specific effects of NO_2 as a gas, using the COMEAP sensitivity function, shows very low effects in terms of health and economic impacts. This is important because the NO_2 limit value is a strong driver in transport policy. The NO_2 objective is currently being met in the great majority of the United Kingdom, but it will be very difficult to meet the NO_2 limit value everywhere. The benefit assessment alone does not support further action beyond the existing objective for NO_2. This is because NO_2 is probably a threshold pollutant, unlike, for example, PM_{10}. Once the standard has been achieved, there are no additional health benefits from reducing concentrations further. Indeed the there is little justification for the current NO_2 objective when considered in terms of cost-benefit analysis alone. There are however additional benefits from reducing NO_X emissions, the precursor to NO_2. In other words it is not an economically optimal target, set on the basis of cost-benefit analysis, but one that seeks to ensure environmental protection and environmental justice. The NO_2 objective, and further action to reduce NO_X, may be justified in cost-benefit terms when these additional secondary pollutants (nitrates and ozone) and additional impact categories (ecosystems) are included[26]. However, as these are regional pollutants, locally based objective levels are not as relevant. Therefore, future policy might achieve greater overall health and environmental benefits by considering different policy approaches, e.g. by trying to reduce overall population weighted exposure to these pollutants rather than focusing on hot-spots. This is highlighted as a research priority.

- The estimated health benefits of reductions from CO emission reductions, even with all policies (Euro I to IV), are extremely low, when compared to the no abatement scenario.
- The economic benefits from reducing potential carcinogens (benzene, 1,3-butadiene, and benzo[a]pyrene), are potentially important. The potential benefits are dominated by 1,3-butadiene, because of the high underlying risk factor. Again, we stress the uncertainty in these risk factors and highlight that DoH do not recommend quantification.

Benefits of Individual Policies

2.4.28. The marginal benefits of air quality improvements (e.g. expressed as a cost per tonne of pollutant avoided) have also been used to estimate the benefits of individual policies. This is presented in the analysis later on the costs and benefits of specific policies. We have also provided some additional material below, discussing the two major pollutants of concern (PM_{10} and NO_X), as these dominate the overall benefits analysis.

2.4.29. The estimated benefits from reductions in **primary PM_{10} only** (directly emitted from the tailpipe) split by individual policy, are shown in the Figure below, relative to the no abatement scenario. The Figure only shows the benefits under the central high scenario. The central low values would be a factor of 6 lower (approximately), but the relative pattern between policies would be identical. Note the values below only include the benefits of emissions in the UK. The figure also includes the benefits from reduction in building soiling (non-health impacts). The figure shows clearly that the benefits to date (to 2001) are much smaller than those projected – note the timescale extends to 2015, to show the full effect of later Euro standards. In looking at the policies, it is clear that the introduction of the Euro I standard for diesel vehicles had the single greatest economic benefit in the evaluation period to 2001. It is also projected to have greater benefits than later Euro standards. The introduction of Euro III (all vehicles) is also projected to lead to very large benefits.

2.4.30. A different pattern emerges for NO_X emissions in terms of the formation of **secondary PM_{10} (nitrates)** from the policies in the transport sectors. The benefits of the central high scenario are shown in the figure below. Note the figure does not include potential effects (positive or negative) from NO_X on ozone. In contrast to the pattern for primary PM, it is the introduction of Euro I standards for petrol cars that has had the single greatest economic benefit in the evaluation period to 2001. The figure also shows the negative effect of Euro I technology on diesel vehicles. Again, the figure shows clearly that the benefits to date (to 2001) are much smaller than those projected – note the timescale extends to 2015, to show the full effect of later Euro standards.

[26] We highlight that an uncertainty analysis undertaken in the current study has established that there is a lower confidence attached to the health effects of nitrates (secondary PM_{10}), which might further weaken the case for future action for this pollutant. NO_X also has potential benefits in reducing ozone (though ozone formation is complex and reductions in NO_X can lead to increases in ozone, particularly in urban areas).

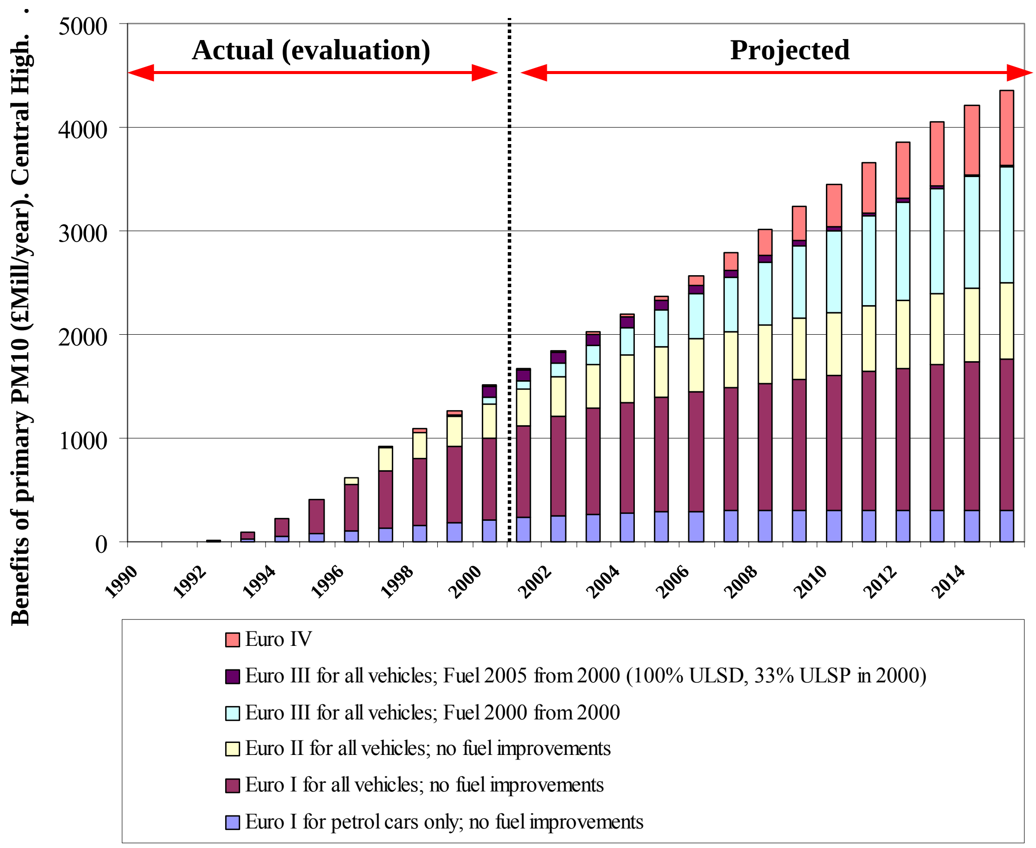

Figure 2-14. Annual Benefits of Primary PM_{10} in the UK from implementation of the Euro standards over the No abatement Scenario. Central High.

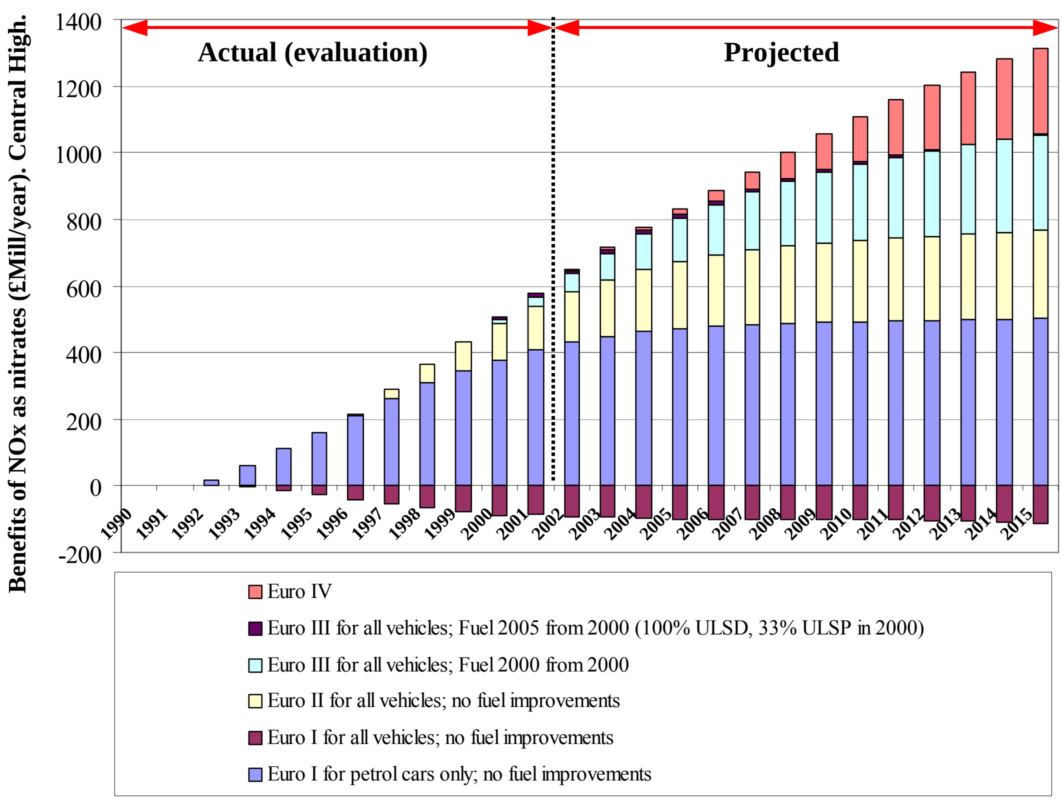

Figure 2-15. Benefits of NO_X (as nitrates only) over the 'No abatement' Scenario from the Euro standards. Central High.

Greenhouse Gas Emissions (Climate Change): Benefits from CO_2 Emission Reductions

2.4.31. The policies introduced in the transport sector have been targeted towards air quality benefits. The potential benefits of policies in reducing **CO_2 emissions** (i.e. improving fuel efficiency) have been assessed here for completeness, though the underlying emission data in this area remain controversial. There is some evidence that CO_2 emissions increased from petrol passenger cars when three-way catalysts were added, though later models are generally thought to have improved fuel efficiency. We have not included the potential benefit of the voluntary ACEA agreement in this study, which is likely to lead to significant CO_2 reductions for light vehicles in future years[27]. We have also not considered the potential effects of Euro IV technology on CO_2 emissions from heavy vehicles. For the freight sector, there does appear to have been improvements in fuel efficiency for larger heavy vehicles (HGVs) over the past decade, though the benefits for vans and buses are less certain. The potential benefits from fuel efficiency improvements, from all policies, across all vehicle classes, have been estimated. Using the illustrative range of £35/tC to £140/tCfor valuation[28], as recommended by the Government Economic Service (GES) working paper (Clarkson, R. & Deyes, 2002), the introduction of all policies has led to an annual benefit of £15 million to 60 million by 2001 (and total benefits in the evaluation period to 2001 of £42 million to 166 million), when compared to the no abatement scenario[29]. These benefits have occurred alongside the improvements in air quality, though we stress that air quality policies are not directly responsible for these benefits, indeed, we do not believe it appropriate to include these benefits in the summary analysis.

Additional health and non-health impacts from air quality

2.4.32. It is stressed that our knowledge of the health effects of air pollution continues to evolve, and there are still potential unknown health effects. It is possible that other endpoints should be included. In particular, there is increasing evidence that particulate air pollution is associated with infant mortality and that some quantification of this effect is both desirable and possible. There are also additional effects suspected in a number of areas, for example, on morbidity and mortality from chronic (long-term) exposure to ozone, and chronic morbidity effects from PM_{10}.

2.4.33. It is also highlighted that not all potential benefits of air quality improvements have been valued (because quantification and valuation is not possible or highly uncertain). Amongst those effects actually or potentially excluded are:

- Impacts on ecosystems through exceedence of critical loads and critical levels (including forests, freshwaters, etc.). This has long been regarded as a serious problem, with potentially significant consequences for ecological sustainability. With respect to acidification, which is linked to emissions of SO_2, NH_3 and NO_X, the problem is worst in areas of northern Europe where the bed rock is hard and weathers too slowly to counteract deposited acidity (e.g. Scandinavia) and much less severe in southern Europe (e.g. Spain, Greece). The most obvious impact of acidification is the loss of fish, particularly salmon

[27] We have not assessed the effect of this measure because it is a voluntary agreement, rather than a policy, and because greenhouse gas mitigation policies have been covered in other recent work by Defra.

[28] We highlight that the Defra value for the marginal social cost of carbon includes effects in the UK and internationally, i.e. in contrast to the air quality analysis above (which is for the UK only). If the analysis of the marginal social cost of carbon in the UK only was used, this would produce a very much smaller value (almost negligible in fact), since the impact on the UK from changes in the UK's own emissions is practically zero.

[29] Note the recommended value of the SCC is the subject of a current review.

and trout, though terrestrial ecosystems are also affected. Problems of eutrophication, caused by emissions of nitrogen-containing pollutants (NO_X, NH_3) are widespread in Europe, with particular hot-spots in a few countries, such as the Netherlands. The most visible effect is one of reducing the viability of rarer species of plant, allowing other species, particularly grasses, to invade land that was previously too nutrient deficient to support them, leading to a loss of species diversity. More detail on the possible importance of ecosystem effects is presented in the ESI chapter (see boxed text on ecosystem impacts and valuation).

- Damage to cultural heritage, such as cathedrals and other fine buildings, statues, etc has not been assessed (only damages to utilitarian buildings). Whilst the effects on historical buildings provided the earliest and clearest demonstration of air pollution effects, its importance has decreased substantially over time, as urban SO_2 levels have reduced. It is unknown whether this reduced rate of deterioration is still important. Analysis is not possible because of a lack of data on stock at risk (e.g. number of culturally important buildings, surface areas, number and size of statues) and repair and maintenance costs.
- Change in visibility (visual range) as a function of particle and NO_2 concentration. Research in the USA suggests that this results in a serious loss of amenity. However, following analysis carried out for EC DG Environment and the UNECE, and resulting debate, it was concluded that the issue is not regarded as being so serious in Europe (possibly because reduced visibility through poor air quality is now less of a problem than it was a few years ago). It has been concluded that the US results are not transferable to Europe, though their inclusion would significantly increase the benefits values above.
- Effects of ozone on materials, particularly rubber.
- Non-ozone effects on agriculture (e.g. through acid deposition, nutrient deposition, etc.).
- Macroeconomic effects of reduced crop yield and damage to building materials.
- Altruistic effects of health impacts.

2.4.34. As a final note, there is one major issue that could alter the benefits analysis presented here, potentially very significantly. This relates to the metric used for particulates. The UK has adopted and uses PM_{10} as the size fraction on which standards for outdoor particles are and will continue to be based. This does not imply a view on causality. While not discounting the coarse fraction (i.e. $PM_{2.5-10}$), EPAQS noted the evidence that $PM_{2.5}$ may be more dangerous, per $\mu g/m^3$, than PM_{10} generally. However, EPAQS noted also that PM_{10} and $PM_{2.5}$ tended to vary together; and so standards for PM_{10}, if applied sensibly, would also lead to effective control of $PM_{2.5}$, i.e. there was no need to change the basis of standards to achieve of $PM_{2.5}$. The use of $PM_{2.5}$ as the relevant causal size fraction in the present analysis would, however, increase the estimated benefits analysis above, because:

- If the coarse fraction (i.e. $PM_{2.5-10}$) of the particle mixture is not implicated in health impacts, then the remaining $PM_{2.5}$ fraction must be responsible for a greater health impact per $\mu g/m^3$ (i.e. as less pollution is responsible for the existing health impact). This would increase the health benefits from transport policies above (e.g. for deaths brought forward and other acute endpoints), because more than 90% of transport particulate emissions are $PM_{2.5}$.
- A similar issue would arise if - as evidence seems to be indicating - the health effects of nitrates or sulphates were discounted as being causal, because again, the remaining $PM_{10}/PM_{2.5}$ must be responsible for a greater health impact per $\mu g/m^3$. Therefore, if nitrate or sulphate effects above were ignored, then the primary $PM_{10}/PM_{2.5}$ benefit would

be much greater. This would be particularly important for the transport sector, which is a major contributor to primary $PM_{2.5}$.

2.4.35. To illustrate the importance of this, we have undertaken a sensitivity analysis, using differentiated weighting factors for different elements of the PM_{10} mixture (primary, secondary as sulphates, secondary as nitrates). In undertaking this analysis, we have tried to be consistent, i.e. if some elements of the PM mixture are more toxic, then others must be less so, in order that the same overall health effects occur from the ambient pollution mixture. Using very crude information on the contribution of primary particles, sulphates, nitrates and the course fraction, we have assumed that primary transport related PM has a toxicity 2.5 times higher than the main analysis above, that sulphates have the same toxicity, and that nitrates have 0.5 times the toxicity.

2.4.36. Applying these factors would change the benefits of the transport policies very significantly. For the total benefits in the evaluation period (to 2001), the benefits from all policies, from use of these different weighting factors for the PM mixture would double the benefits of transport policies. This is shown in the table below. Clearly, this would also affect the individual policies, with a much greater benefit attributed towards policies that targeted primary PM_{10} emissions (i.e. towards diesel vehicles).

Table 2.8. Sensitivity Analysis on the Toxicity of the PM fraction – Benefits from all Policies Achieved in the Evaluation Period for PM (1990 – 2001).

Particulate Fraction	Total benefit (1990 - 2001) Central assumption (£ million)	Total benefit (1990 - 2001) With different Toxicity assumptions (£ million)
Primary PM_{10} from transport	1,248 – 7,788 (CL-CH)	3,073 – 19,375 (CL-CH)
Sulphates	147 - 934 (CL-CH)	147 - 934 (CL-CH)
Nitrates	359 – 2,280 (CL-CH)	180 – 1,140 (CL-CH)
Total	**1,754 – 11,002 (CL-CH)**	**3,400 – 21,449 (CL-CH)**

2.4.37. As a final note, we stress that recent European work by WHO under the CAFE project (Clean Air for Europe) and Long-Range Trans-boundary Air Pollution is now recommending a higher risk factor for chronic mortality analysis. This is consistent with the 0.6%/μgm^{-3} $PM_{2.5}$, based on Pope *et al* (2002)[30]. The use of this higher risk factor would lead to chronic mortality health impacts that are double the central high estimate for chronic mortality presented in this report.

2.5 Economic Costs of the Policies

2.5.1. The study has estimated the costs of national transport policies, looking at both the ex ante (predicted) and ex post (actual) costs. It is extremely difficult to accurately assess the ex post out-turn for transport measures, because it is difficult to accurately predict what would have happened in the absence of the policies. Nonetheless, the analysis here indicates that for the *Euro emission standards*:

[30] see http://www.unece.org/env/documents/2004/eb/wg1/eb.air.wg1.2004.11.e.pdf, and also review and answers (http://www.euro.who.int/document/e79097.pdf) and (http://www.euro.who.int/document/e82790.pdf).

- In nearly all cases, the estimated ex ante costs appear to have been significantly higher than actually occurred (as seen in the ex post cost analysis). There appears to be a consistent over-estimation of ex ante costs by industry throughout the auto-oil process. Comparison of cost estimates of each standard (by technology cost per vehicle) indicates that ex ante estimates fell significantly over time in most cases.
- There has also been a tendency for over pessimistic assumptions with respect to technical progress (e.g. some manufacturers claimed Euro IV emissions standards were not technically possible).
- The costs predicted in appraisals (in regulatory impact assessments) are therefore likely to have been significant over-estimates of the total cost (cost of compliance) to the UK of meeting new legislation in the transport policy area.

Costs of Vehicle Emission Standards

2.5.2. Other analysis (SEI, 1999) indicates that industry estimated (ex ante) the costs of the catalytic converter technology for Euro I technology at £400 to £600 per vehicle. However, a cost survey for UK government, prior to the Directive, revealed likely costs of £350 per vehicle, including not just the catalytic converter but also other necessary developments, such as fuel injection. Finally, the catalyst manufacturer, Johnson Matthey, is known to have sold converters to the motor industry at a price of only £30 to £50 per unit, though we stress that this does not include costs of installation and other developments required alongside the catalyst.

2.5.3. A similar picture emerges in the US, where the Low Emission Vehicle regulation was adopted in California in 1990 and implemented from 1994. A review by Clackette (1998) compared the ARB's (Air Resources Board, part of the California Environmental Protection Agency) estimates of LEV costs for three models and the fleet average from 1994 with actual data collected in 1998. The results show reasonable agreement between the two sets of data, though ARB's figures from 1994 are generally a little higher than the actual cost data from 1998. In contrast, comparison of component costs (ex ante) by industry were found to be far higher ($877/vehicle) than those made by the ARB ($174/vehicle). The high ex ante costs were due to an overestimation of technical requirements and hardware costs, assumptions on a non-optimal phase-in of the regulation, excessive dealer costs, and unrealistic warranty costs.

2.5.4. There is also some evidence from the US on later standards. Data on ULEVs (Ultra Low Emission Vehicles) shows a split in the opinion of industry. In 1996 Honda's Vice President estimated that the ULEV regulations would cost under $300/vehicle, a figure in agreement with ARB's 1998 estimate of $251/vehicle. In contrast, the cost could be up to $1,000/vehicle according to a statement from General Motors in 1998. Anderson and Sherwood (2002) assessed ex-ante and ex-post cost data for changes in vehicle emission standards and for improved fuel quality, though they took a US-national perspective rather than limiting their analysis to the state of California. They found USEPA estimates tended to be closest to actual data, though they were generally higher. Industry estimates, however, in many cases gave substantially higher costs. Oil industry (see also below) estimates were in the range 2 to 4 times higher than actual costs whilst the cumulative effect of overestimates made by motor manufacturers in the period 1994 to 2001 equates to about $500/vehicle.

2.5.5. The UK regulatory impact assessments (appraisals) for the later Euro legislation (Euro II, III and IV) have estimated the total ex ante costs of compliance to the UK, as the likely cost to consumers. The separate regulatory impact appraisal of each standard predicted increased costs of £250 - £500 for Euro II cars (a 2.5% - 5% increase), £210 - £295 per vehicle for Euro III cars, and £210 – £590 for Euro IV cars. This is additional to the estimated £400 - £600 for Euro I technology (ex ante) above. If the ex ante estimates for all four Euro standards are combined, this would lead to an increase in the unit costs per vehicle of £1070 to £1730 (petrol cars) and £1240 to £1985 (diesel cars). When multiplied by the annual number of new car registrations in the UK (typically 2 to 2.5 million), this produces extremely high ex ante costs, e.g. of the order of £2 billion to £3.6 billion per year in the UK. This calculation method was used to estimate the total cost to consumers from the new legislation in the RIAs.

2.5.6. With the exception of Euro I technology, we have not been able to find reliable estimates of the ex post costs of the Euro standards. We highlight this as a major area for future research, though it would require a significant resource and need buy-in from industry. Because of this lack of data, we have investigated other approaches to try to explore ex post out-turns. Based on the RIAs above, the combined ex ante estimates would have led to a total additive cost increase of 10% – 20% for new vehicle prices, because of the legislation introduced from Euro I to Euro IV (i.e. assuming additional costs were passed through to consumers – the assumption made explicit in the RIA). We would expect price changes of this magnitude to show up in new car prices. However, this is not borne out by analysis of car prices in the UK, undertaken as part of this study. The graph below shows actual car prices in the UK over the period of the Euro standard introduction. This shows that, in real terms, the costs of purchasing a new car in the UK has remained broadly constant over the entire period from pre-Euro vehicles (1990) through to Euro III/Euro IV (2003), despite the four rounds of tighter emission controls and abatement equipment. Prices increased by about 8% in the period 1994 to 1997 (the year when Euro II became mandatory), though a large part of this can be accounted for by changes in the way that new car prices were calculated in the UK. Since 1999, even with the introduction of Euro III, and with early introduction of Euro IV vehicles, there has been a substantial fall in prices. Over the period as a whole the real terms price of the vehicles considered fell by 7%, despite the changes to the way prices were reported in 1997 (stripping this out would give an even greater fall in price). These price rises also have to be seen against a background of other improvements with associated costs (e.g. safety equipment including air bags, etc).

2.5.7. Some care must be taken in interpreting this data. The figure could imply that the impact of air quality legislation via emission standards has not led to a noticeable increase in the costs to consumers, though of course any potential cost rises could have been offset by other factors. Indeed, it is most likely that the data shows that the large drop in UK cars prices are dominated by other factors than development or production costs – and it could be that the drop in prices would have been greater without new regulation. It is more difficult to assess how much impact (ex post), the legislation has had on car manufacturers and production costs. It would clearly be wrong to conclude that equipping cars with sophisticated equipment for emission control reduces prices. Indeed, we know there have been additional components to meet Euro standards, with associated costs. The last decade has seen increased competition in the car market (though note – the additional component costs, or costs of meeting new standards applies equally to European and non-European car manufacturers). What is clear is that the price effects of new emission limits are secondary to other determinants of price (note in a competitive market, the way that costs are recovered is complex, and so technology costs may not reflect costs at retail).

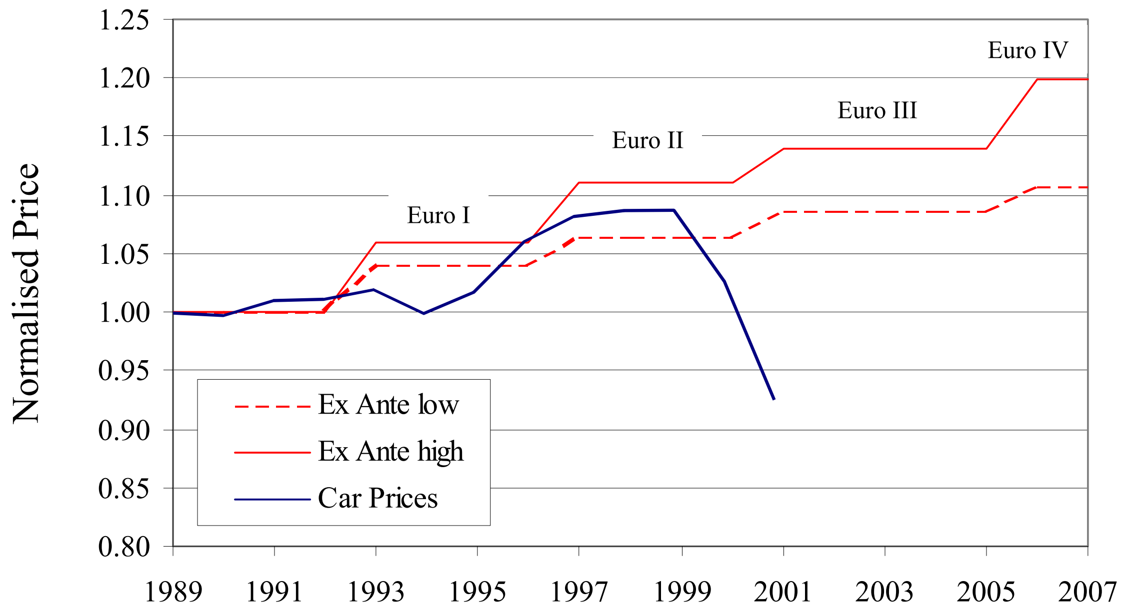

Figure 2-16. Normalised Car Prices vs. Projected Increases from Euro Standards.

Actual price of cars (best selling models) tracked over the time (expressed in 2002£) and averaged. Ex ante costs based on increase on car production costs, due to technical component cost, relative to average car price, as quoted in UK RIAs.

2.5.8. One reason for lower cost out-turns may be that the costs of meeting successive Euro policies do not seem to be additive. To explain, the costs of meeting Euro IV standards has not necessarily been the additive component costs of Euro I + Euro II + Euro III + Euro IV.

2.5.9. The ex ante costs of Euro standards on light goods vehicles and heavy goods vehicles also appear high, though it has been difficult to obtain reliable ex post data. The RIAs that have been undertaken predict high costs to consumers (operators) in the UK and it is difficult to find evidence that such increases have occurred.

2.5.10. Finally, in many cases the ex ante costs are based on specific technical components, that in practice, the manufacturers did not need to fit. To illustrate, it was anticipated that Euro IV standards for heavy vehicles would require the installation of particulate traps to hit PM_{10} standards. Recent discussion with manufacturers has found that this is not the case, and these standards can be achieved through lower cost options associated with engine management. Note however, that there is a possibility that high abatement costs may still be incurred for Euro IV or subsequent Euro standards for heavy vehicles in order to meet the NO_X emissions limits.

Costs of Fuel Quality Standards

2.5.11. A similar trend of high ex ante costs has been found for *fuel quality improvements*, though there is more variation in the pattern of ex ante and ex post costs by specific policy. It is also very difficult to undertake an ex post analysis of petrol and diesel prices (as above for cars), because price variations are masked by the very substantial fluctuations that occur in oil prices and exchange rates.

2.5.12. We have not found any ex ante studies on the costs of unleaded petrol[31]. There is some ex post data on the price changes seen immediately after introduction, with the Competition Commission (1990) finding that the cost of producing unleaded fuel (ex post) was initially about 1p/per litre more than for leaded fuel (after duty and tax was accounted for), an additional cost of around 8%. However, this higher cost of production fell rapidly and significantly. By September 1989 it had fallen to 0.42 pence per litre. The initial higher costs of unleaded petrol are a reflection not just of production costs, but also of costs linked to storage, marketing, distribution and promotion[32].

2.5.13. US studies exist on the costs of lead free petrol. The earlier studies in the US (Cannon, 1990), relate to the 1985 US EPA RIA for costs and benefit of reducing lead in gasoline (adjusting the lead limit from 1.1 grams per gallon to 0.1 grams per gallon by 1988). The study looked at the costs of producing fuels with reduced lead concentrations and used a refinery cost model that estimated the differential as less than $0.01/gallon between leaded and low lead gasoline. The total incremental cost of supplying low-lead gasoline was ultimately calculated by the US EPA to be $525 million per year (1988 prices), though costs varied by $114 million to a total of $723 million as the oil refining industry adjusted to the production requirements.

2.5.14. The estimated costs of regulations in California with respect to reformulated gasoline (RFG) fell substantially between 1991, when the regulation for its introduction was adopted in 1997, a year after state-wide introduction of RFG (note this is not the same as the European standards). The Air Resources Board (ARB) first estimated costs to be between 12 and 17 US cents/gallon, compared to industry estimates of 23 cents/gallon. Improvements in ARB modelling and reduced estimates of capital costs led to a reduced estimate of 10 cents/gallon in 1996 (in a range of 5 to 15 cents/gallon). Final data, from 1997, were based on a comparison of fuel prices within California and in other states that had not adopted the regulation. The final estimate of 5.4 cents/gallon is less than 25% of the original estimate provided by the refiners.

2.5.15. There is a UK cost of compliance assessment relating to the motor fuel regulations (1994) for the relevant British Standard Specifications (BSS), which includes the analysis of low sulphur diesel[33]. This estimated the costs of the regulations from volatility requirements of BS EN 228:1993 for leaded petrol in summertime at £7 million in 1995, and £23 million for all summer periods 1995 to 2000. It also estimated the cost of meeting the future sulphur content requirements of diesel to be negligible in respect of the 0.2 limit from 1.10.91, and £250 million in investment and total costs (including capital charges) of 0.4 – 0.5 pence per litre in respect of the 0.05 limit from 1.10.96. No ex post data has been found to examine the accuracy of this estimate.

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[31] DfT have confirmed there were no RIAs as the time of introduction of unleaded petrol.

[32] The move to unleaded petrol was stimulated by a reduction, in March 1989, in the duty charged on unleaded petrol, which provided a differential of 2.2 pence per litre (ppl) (10 p/gallon) below the 4-star leaded price. The January 1989 average price for lead fuel of 37.14 ppl includes 20.44 pence excise duty and 4.84 pence VAT. During 1989 sales of unleaded petrol rose from under 5 per cent of sales to over 25 per cent of the total. Analysis of the price of unleaded petrol, excluding duty and VAT, was above the price of 4-star leaded. Companies made substantial investments in order to supply unleaded and start-up costs and the relatively low volumes meant that unit costs were higher than on leaded petrol (though these fell as volumes increased).

[33] The regulations, which introduced into UK (from 1/9/94) requirements for super unleaded petrol (BS7800:1992, except for volatility which is set as BS EN 228:1993), regular or premium grade unleaded petrol (BS EN 228:1993, which replaced BS7070:1988), leaded petrol (BS EN 228:1993), and diesel (BS EN 590:1993 subject to provisions on sulphur content, set out in Directive 93/12/EEC).

2.5.16. There is better data on the ex ante and ex post costs of the 2000 and 2005 fuel quality limits. The ex ante studies include a UK Regulatory Impact Assessment and CONCAWE analysis (Oil Companies European Organization for Environment, Health and Safety). There is also an ex post analysis for these policies in the UK (Ecotec, 2002).

2.5.17. The two ex ante costs for the 2000 fuel quality limits (UK RIA and CONCAWE) reveal dramatically different results. Interestingly, the industry association estimate (CONCAWE) is dramatically lower than the RIA value (though both are based on industry cost estimates). The costs per refinery were estimated at £13 million by CONCAWE, compared to £60 - £70 million in the UK RIA. The total UK capital costs were estimated at £119 million by CONCAWE, whereas total costs are estimated at £1255– £1345 million in the UK RIA. The ex post analysis of the 2000 fuel quality data provides data broadly between the two ex ante costs (per refinery), i.e. they appear to be higher than the CONCAWE estimates, but lower or similar to the estimates in the UK RIA.

2.5.18. The ex ante analysis for introducing the 2005 quality fuel early in the UK forecast very high costs, with a value of £653 million from CONCAWE and £908 – £1089 million in the UK RIA. Both ex ante assessments seem to be overestimates when compared to the actual out-turn (ex post) costs of going straight to 2005 quality fuel. The Ecotec study indicates, however, that these lower ex post costs may have arisen because UK refineries have postponed rather than avoided the costs of the legislation. The Ecotec study also made a general conclusion that all companies reported initial cost estimates (for technical changes to produce higher quality fuels) that were conservative (high), due to the risk of under-costing a project. Initial estimates were reported as being within a +/-30% to 40% accuracy.

2.5.19. The costs (ex ante) outlined in the UK regulatory impact assessments for fuel quality improvements, predict that the 1996 low sulphur diesel standard, together with the 2000 and 2005 fuel quality standards, would have led to an increase of 2.5 pence/litre for the price of diesel (only 0.4 – 0.5 p/litre of which was from the 1996 fuel quality standard). Similarly, the 2000 and 2005 fuel quality standards predicted would have led to an increase of 0.8 – 1.0 pence per litre for petrol.

Summary of Costs of Policies

2.5.20. The ex ante data for the four Euro standards, in the evaluation period (1990 –2001) leads to extremely high estimated costs, totalling £12 to £19 billion. The ex post data that does exist indicates that the actual cost premium in terms of vehicle prices for consumers is low – though we highlight that the costs to consumers could actually have fallen in the absence of the legislation (though we have no data to support this). A simplistic analysis of the underlying technical component cost to manufacturers indicates possible costs for Euro 1 of £0.5 to £0.9 billion in the evaluation period. It is difficult to estimate the ex post costs for all vehicles, from Euro I to IV technology (especially given the uncertainty over Euro IV technology), though we believe it could be below £4 billion, perhaps significantly so.

2.5.21. For fuel quality polices, it is clear that there is an additional cost to the refinery sector for upgrading facilities, a premium on the production of cleaner fuel (greater processing or more expensive feedstock), and the additional costs of storage, marketing, and distribution. All of these costs were predicted to lead to large increases in fuel prices ex ante. The ex ante costs indicate that the introduction of the three main fuel quality improvements (low sulphur diesel in 1996, and 2000 and 2005 fuel quality standards for diesel and petrol) would require very large investment, with estimated total costs of £250 million for 1996 diesel, £1255 - £1345 million for 2000 fuel quality, and £908 – 1089 million for 2005 fuel quality levels. There is also the additional cost of unleaded fuel. The predicted price rises from the four fuel quality policies, if passed through to petrol and diesel prices (at 2.5 pence/litre for diesel and 1.8 – 2.0 pence per litre for petrol) would have led to ex ante costs in the evaluation period of £4.2 billion. The ex post costs for unleaded petrol indicates much lower values than predicted ex ante. The ex post cost estimates of the investment costs for the sulphur policies indicate that these are also a significant over-estimate.

2.5.22. However, it would be wrong to assume that ex ante appraisal always underestimates costs. There are a number of high profile examples where the costs have turned out to be much higher than anticipated.

- One such example is the appraisal undertaken for the first air quality daughter directive on behalf of the European Commission (IVM, 1997). Their analysis suggested that the standards being proposed from a health protection perspective could be met without the need to adopt additional measures in most places. Where action was necessary it was proposed that standards could be met through the application of a limited number of measures, largely provision of cleaner buses and lorries. This led to total compliance costs for the whole EU 15 of around Euro 15 billion. However, subsequent preliminary analysis in the Netherlands found that the costs of meeting the NO_2 standard throughout the country would be €16 billion alone, or selectively at all locations where people live, in a range of €1 billion to €3 billion. The reason for this error was not in the cost estimates, but in the air quality modelling analysis. Specifically, the methods used to determine the future concentrations of pollutants did not quantify levels appropriate to the legislation that was under consideration. The models that were used factored in an urban enhancement, but in doing so merely indicated what future urban *background* concentrations would be. In contrast, the framework directive requires that account is taken of concentrations in any area outdoors and outside the workplace where people may be exposed to levels in excess of the air quality standards. In this way the directive is not limited to consideration of urban background locations, but also to 'hot-spots'. These were not explicitly modelled, and so the scale of urban pollution problems in the context of the Directive was underestimated, particularly with respect to NO_2. This emphasises the need for adequate spatial (local) air quality modelling in such appraisal.
- There are also examples of ex ante costs being lower than ex post costs for specific transport schemes. This is examined in more detail in the separate local transport report.

2.5.23. The study has assessed the reasons for some of the differences between ex ante and ex post costs. It is concluded that there are sometimes errors from the baseline predictions. There are also often omissions of measures that allow cost-effective reductions (options other than end of pipe, consideration of technological innovation, etc.). It is stressed that we have found no evidence of industry providing deliberately exaggerated cost estimates, but it is also clear that the costs that have been put forward by industry are usually based on pessimistic/'worst case' assumptions, or with a limited field of reference (i.e. without potential advances (learning), new measures, the fall of costs with large scale production, etc.). Note this also leads us to the conclusion that *legislation itself acts as a spur to research and innovation.*

2.5.24. The study has also investigated the wider economic impacts of air quality policy. The lack of ex post studies makes it difficult to draw robust conclusions on the extent of the wider economic effects that may have resulted from the imposition of the transport-related air quality policies. This difficulty is compounded by the fact that the ex ante studies that do exist, do not take a consistent approach in their treatment of wider effects (these studies do not generally separate out the wider economic effects of the Auto-oil and price differential legislation in the UK from legislation pertaining to stationary sources). The ex ante studies that do exist indicate two broad conclusions for wider economic costs:

- The impacts on competitiveness are minor in macro-economic terms, and;
- That employment effects in sectors that are responsible for supplying technologies that meet the requirements of the legislation might be significant.

2.5.25. For the first of these, EU legislation, in harmonising its impacts across EU countries and on imports to the EU, is assumed to have negated any major potential impacts on competitiveness to affected UK sectors (though note, the encouragement of the 2005 S limit in 2000/1 through duty differentials is a potential exception to this).

2.5.26. With respect to employment, the ex ante studies indicated that the refinery sector was likely to bear the largest sectoral impact of the legislation considered. Employment effects relating to this sector (refinery) were studied on an ex ante basis and estimated to provide positive employment effects of between 11,500 and 51,500 jobs in the UK (Bartonova et al, 2000), as a result of the operating and capital expenditure required in the refining sector under the legislation. No specific ex post analysis has been undertaken, but it is likely this is an overestimate, not least because the ex post costs of the main legislation is lower than predicted (i.e. capital expenditure was lower), but also because the benefits of extra employment in a climate of full employment are not considered relevant for current appraisal.

2.5.27. It is stressed that the ex ante studies have not generally undertaken detailed modelling when generating results of wider economic costs (the expense involved in undertaking comprehensive analysis of these effects through general equilibrium modelling is not justified by the potential findings of such studies). In particular, it is likely that the positive employment effects are partial and may give an optimistic impression when compared to an analysis that includes price, net margin and tax revenue effects.

2.5.28. A summary of the costs for each policy is included in the table in the next section. Further research on the ex post costs of the Euro and fuel quality standards are highlighted as a research priority.

2.6 The Comparison of Costs and Benefits

Summary of individual policies

2.6.1. The overall costs and benefits of policies are brought together in the table below. We stress that because policies have different implementation dates, the absolute costs and benefits will appear very different for different policies in the evaluation period. To illustrate, unleaded petrol has been in force for the entire evaluation period, while Euro IV technology has only entered a small proportion of the car fleet (from early compliance – the official date for compliance is not until 2006). We highlight the need for a more robust analysis of ex post cost data as a future priority.

Table 2-9. Costs and Benefits of Road Transport Sector Policies in the UK. Columns in Grey show Key Evaluation Data.

	Ex Ante Costs				Ex Post Costs			Air Quality Benefits	
Policy	**Unit cost (£)**	**Annual Cost (£ Mill.)**	**Total Cost 1990-2001 £M <u>Evaluation</u>**	**Total Cost 2002-2010 £M Projected**	**Unit cost (£)**	**Total Cost (£ Mill.) <u>Evaluation</u> 1990-2001**	**Total Cost (£ Mill.) Projected 2002-2010**	**(£ Mill) <u>Evaluation Period</u> 1990 – 2001**	**(£ Mill) Projected period 2002 - 2010**
Lead free petrol	No RIA	No RIA Based on annual fuel sales in 2001 and 1989 cost of 1ppl = £285 M	No RIA, but assuming a value of 1 pence per litre (initial 1989 price), with actual unleaded fuel volumes, total cost 1990 – 2001 = **£2590 M.** This may be an underestimate of likely ex ante estimate.	Not calculated. Policy fully in place in evaluation period.	In January 1989 price of premium unleaded was 1.05 pence per litre above leaded price (almost 10%). By June 1989 the difference was 0.98 ppl and by Sept 1989 it had fallen to 0.42 ppl.	Using value of 0.42 pence per litre (later 1989 price), with unleaded fuel volumes, total cost 1990 –2001 = **£1036 M.** This may be an over-estimate of later ex post cost.	Not calculated. Policy fully in place in evaluation period.	Total benefits (1990 – 2001) = **£357 M (L)** to **£3662 M (H)** Note, values are subject to high uncertainty.	Not calculated. Policy fully in place in evaluation period.
Euro I petrol cars	Industry catalytic converter technology £400 to £600 per vehicle. UK government cost survey prior £350 per vehicle (include CC + fuel injection)	No RIA. Based on annual new registrations = £648 M to £972 M.	No RIA. Based on estimate of unit costs (£400 - £600), plus new car registrations 1993 – 2001 = **£ 5834 M to £ 8751 M**	Based on estimate of unit costs (£400 - £600), plus new car registrations 2002 – 2010 = **£ 7190 M to £10785 M**	SEI reported at £30-£50 per unit.	Based on SEI estimate, plus new registrations 1993 –2001 = **£ 437 M to £ 729 M**	Based on SEI estimate, plus new registrations 2002–2010 = **£ 539M to £ 898M**	Total benefits (1990 – 2001) = **£ 1126 M (CL) to £ 4922 M (CH)**	Total benefits (2002 – 2010) = £ 2239 (CL) to £ 9748 (CH)

All costs and benefits in 2002 – 2010 are presented in 2002 constant prices with no discounting to allow direct comparison. The table includes the benefits categorised under high, medium and low confidence bands, but excludes those included in the sensitivity analysis and exclude CO_2 benefits. The values only include UK benefits, and do not account for the benefits from the reduction in trans-boundary pollution. RIA costs for vehicles (Euro standard) are based on annual registrations and capital costs only of the technology – and does not include the potential benefits or dis-benefits from fuel consumption, maintenance (as predicted by European economic studies). Environmental benefits do not include all benefits, with a number of areas excluded including impacts on natural and semi-natural ecosystems (terrestrial and aquatic), impacts on forests, visibility, and others (see main text). The analysis does not include the effects of NO_X emissions on ozone formation. Note total benefits are from emissions in the time period 1990 – 2010 only. They do not include benefits from lower emissions in future years (post 2001 for the evaluation or post 2010 for the projected analysis) from a move to sustained new pollution levels.

Table 2-9. Costs and Benefits of Road Transport Sector Policies in the UK (continued). Columns in Grey show Key Evaluation Data.

	Ex Ante Costs				**Ex Post Costs**			**Air Quality Benefits**	
Policy	**Unit cost (£)**	**Annual Cost (£ Mill.)**	**Total Cost 1990-2001 £M Evaluation**	**Total Cost 2002-2010 £M Projected**	**Unit cost (£)**	**Total Cost (£ Mill.) Evaluation 1990-2001**	**Total Cost (£ Mill.) Projected 2002-2010**	**(£ Mill) Evaluation Period 1990 – 2001**	**(£ Mill) Projected period 2002 - 2010**
Euro I light and heavy vehicles (and diesel cars)	No RIA Data from European cost data indicates similar costs for LGVs as for diesel cars. We have assumed higher costs per vehicle for HGVs.	No RIA.	Based on unit costs / new registrations 1993 – 2001 = Diesel cars **£ 1392 M to £ 2089 M** Vans **£ 696 M** HGV **£ 185 M**	Based on unit costs / new registrations 2002 – 2010 = Diesel cars £ 2677 M to £ 4015 M Vans £979 M HGV £205M	Not known	Not known	Not known	Total benefits (1990 – 2001) = **£ 702 M (CL) to £ 4256 M (CH)**	Total benefits (2002 – 2010) = £ 1594 (CL) to £ 9635 (CH)
1996 low Sulphur	1) EU level. Costs (inc.luding capital recovery) 0.1 – 0.7 pence per litre, average 0.3 – 0.4 pence per litre. 2) UK Cost of compliance. Diesel (incl. capital charges) for 0.05 limit from Oct 96 = 0.4 – 0.5 pence/ litre	Based on 2001 fuel sales in UK, and ex ante cost of 0.45 ppl = £100 M	1) EU invest-ment £500 - £2500 M (central £1500 M). 2) UKRIA Diesel 0.2 limit Oct 1994 negligible, capital cost for diesel 0.05 limit Oct 96 = £250M 3) Based on 0.45 ppl and 1996 – 2001 fuel sales = **£561 M**	Based on 0.45 ppl and 1996 – 2002 – 2010 fuel sales = £1049 M	Not known	Not known	Not known	Total benefits (1990 – 2001) = **£ 263 M (CL) to £ 2409 M (CH)**	Total benefits (2002 – 2010) = £ 400 (CL) to £ 3660 (CH)

See caveats above.

Table 2-9. Costs and Benefits of Road Transport Sector Policies in the UK (continued). Columns in Grey show Key Evaluation Data.

	Ex Ante Costs				Ex Post Costs			Air Quality Benefits	
Policy	**Unit cost (£)**	**Annual Cost (£ Mill.)**	**Total Cost 1990-2001 £M <u>Evaluation</u>**	**Total Cost 2002-2010 £M Projected**	**Unit cost (£)**	**Total Cost (£ Mill.) <u>Evaluation</u> 1990-2001**	**Total Cost (£ Mill.) Projected 2002-2010**	**(£ Mill) <u>Evaluation Period</u> 1990 – 2001**	**(£ Mill) Projected period 2002 - 2010**
Euro II	UKRIA (industry sources). Passenger cars increase production costs by 2.5 to 5% (£250 - £500). Car derived vans by 7 to 8% =£350/veh.. Large vans by 2% =£125/veh.		Based on estimate of unit costs, plus new car registrations 1997 – 2001 = **Cars £ 2712 M to £5423M** **Vans £ 156 to £437M** **HGV £ 329 M**	Based on unit costs / new registrations 2002 – 2010 = Cars £ 6167M to £12335M Vans £ 350 M to £975 M HGV £ 616 M	Not known	Not known	Not known	Total benefits (1990 – 2001) = **£ 329 M (CL) to £ 1972 M (CH)**	Total benefits (2002 – 2010) = £ 1125 (CL) to £ 6662 (CH)
2000 fuel standards	1) UK RIA Total cost <u>per refinery</u> petrol=£62-£71M and diesel=64 M & <u>pence/litre</u> pet =0.4–0.5 & diesel=1.1 2) Concawe cost <u>per refinery</u> (UK) = £13 Mill.	1) UK RIA annualised. Petrol=£121–139M and diesel = £190M. Total=£311–329 M (12%IRR 15yr lif.tim.) Based on 0.45 ppl petr and 1.1 ppl dies, with 2001 fuel sales = £ 372 M	1) UK RIA pet = £615–705M and dies =£640M. Total = £1255–£1345 Mill. 2) Concawe = Total capital cost £119 M 3) Based on 0.45 ppl pet and 1.1 ppl dies, with 2000-2001 fuel sales = **£ 737 M**	Based on 0.45 ppl pet and 1.1 ppl dies, with 2002-2010 fuel sales = £ 3739 M	Estimates for ex post costs of action for refineries (Ecotec, 2002)	Ex post analysis indicates UK RAI generally <u>over</u>-estimate, but Concawe <u>under</u>-estimate		Total benefits (1990 – 2001) = **£ 36 M (CL) to £ 329 M (CH)**	Total benefits (2002 – 2010) = £ 99 (CL) to £ 903 (CH)

See caveats above.

Table 2-9. Costs and Benefits of Road Transport Sector Policies in the UK (continued). Columns in Grey show Key Evaluation Data.

	Ex Ante Costs				Ex Post Costs			Air Quality Benefits	
Policy	**Unit cost (£)**	**Annual Cost (£ Mill.)**	**Total Cost 1990-2001 £M Evaluation**	**Total Cost 2002-2010 £M Projected**	**Unit cost (£)**	**Total Cost (£ Mill.) Evaluation 1990-2001**	**Total Cost (£ Mill.) Projected 2002-2010**	**(£ Mill) Evaluation Period 1990 – 2001**	**(£ Mill) Projected period 2002 - 2010**
Euro III	1) Vans £100-£200 per vehicle (Euro 145-290, 95 prices) Heavy £350 to £1,073 (Euro 530 to 1620) = of ~ 1.5% increase in costs to the consumer 2) UKRIA (95 prices). Pass. cars increase production costs by £210 (petrol) and £295 (diesel). 0.5 - 2% to purchase price of new car. Vans extra £200 (petrol) and £350 (diesel) vehicle. Heavy extra £600 to £1500 per veh.. UK manufact. consultatation. Incremental cost to the consumer 7.5% to 0.8% for smallest to largest vehicles respect. Later ex ante (UK RIA) indicated £150 to £2,500.	1) Auto-oil. Vans £257M per annum (ECU 373M, 1995 values) across the Community. Heavy £450M per annum (ECU 675M, 1995 values) across the Community 2)UK RIA (95 prices) Passenger cars = petrol (£340M) and diesel (£150M) = total £454 - 520M annual cost Vans 203,000 reg/yr = £20-40m per annum to consumers (based on EC c.p.v.) and £40 –71M (based on UK c.p.v.) Heavy 48,200 reg/year = £29M to £72M based on UK c.p.v.). Total = £527 M - £682 Million/year	Based on unit costs, plus new car registrations 2001 = = Cars £ 558 M Vans £ 56 M to £97M HGV £ 33 M to £83M	Based on unit costs / new registrations 2002 – 2010 = = Cars £5749 M Vans £ 560 M to £979 M HGV £ 308M to £770 £M	Not known	Not known	Not known	Total benefits (1990 – 2001) = **£ 42 M (CL) to £ 213 M (CH)**	Total benefits (2002 – 2010) = £ 924 (CL) to £ 5518 (CH)

See caveats above.

Table 2-9. Costs and Benefits of Road Transport Sector Policies in the UK (continued). Columns in Grey show Key Evaluation Data.

	Ex Ante Costs				Ex Post Costs			Air Quality Benefits	
Policy	**Unit cost (£)**	**Annual Cost (£ Mill.)**	**Total Cost 1990-2001 £M Evaluation**	**Total Cost 2002-2010 £M Projected**	**Unit cost (£)**	**Total Cost (£ Mill.) Evaluation 1990-2001**	**Total Cost (£ Mill.) Projected 2002-2010**	**(£ Mill) Evaluation Period 1990 – 2001**	**(£ Mill) Projected period 2002 - 2010**
2005 fuel standards early – in 2000/1	1) UK RIA cost per refinery Pet. = £31-£42M and diesel = £60M. Pence/litre pet =0.2 –0.3 & diesel=0.9 Total cost per ref. from pre-2000 to 2004 = £124M 2) Concawe UK refineries (straight to petrol and diesel to 50 ppm S) cost per refinery = £73 M	1) UK RIA annualised cost petrol= £60–86 M and diesel = £179M. Total = £239–265 M (12%IRR 15yr lifetime)	1) UK RIA petrol = £306–427 M and diesel = £602 M. Total = £908 – £1089M 2)Concawe = £653 M total capital cost (plus some operating cost) **3)** Based on 0.25 ppl pet and 0.91 ppl dies, with 2001 fuel sales = **£ 270M**	**3)** Based on 0.25 ppl pet and 0.91 ppl dies, with 2002 - 2010 fuel sales = £ 2750 M	Estimates for ex post costs of action for refineries (Ecotec, 2002)	Ex post indicates both UKRIA and Concawe over-estimate costs of going straight to 2005, though may be artefact (costs may be postponed not avoided). Ex post analysis show low additional cost short-term in the UK. May change post 2005.		Total benefits (1990 – 2001) = **£ 68 M (CL) to £ 500 M (CH)**	Total benefits (2002 – 2010) = £ 242 (CL) to £ 1799 (CH)

See caveats above.
Note ultra-low sulphur fuel was due to be introduced in 2005. The UK implemented this policy early, in 2000 to 2001, through the introduction of duty differentials. The costs estimates are for introducing this legislation. The benefits are broken down into those benefits realised earlier within the evaluation period (to 2001) and those that are projected to occur through to 2010.

Table 2-9. Costs and Benefits of Road Transport Sector Policies in the UK (continued). Columns in Grey show Key Evaluation Data.

	Ex Ante Costs				Ex Post Costs			Air Quality Benefits	
Policy	**Unit cost (£)**	**Annual Cost (£ Mill.)**	**Total Cost 1990-2001 £M Evaluation**	**Total Cost 2002-2010 £M Projected**	**Unit cost (£)**	**Total Cost (£ Mill.) Evaluation 1990-2001**	**Total Cost (£ Mill.) Projected 2002-2010**	**(£ Mill) Evaluation Period 1990 – 2001**	**(£ Mill) Projected period 2002 - 2010**
Euro IV	1) Auto-oil Heavy £500 (ECU760) and £1500 (ECU2270) assuming particulate traps (EC). This increase of between 2.0% and 2.5% of total new vehicle cost. 2) UKRIA (95 prices) Pass. Cars = £210 –£420 (petrol) £295 - £590 (diesel) Vans. DTI estimated 2005 limits would be one and two times costs of meeting Euro III Heavy. Heavy. £2,000 to £2,500 (manufacturer consultation) UK (in UK RIA)	2) UKRIA (95 prices) Pass cars (petrol = £340 - £680M) (diesel = £150M - £300M) total = £490M – 980M	For most vehicles, no compliance until 2006 (required data). RIA predicts no costs at this point However, some early Euro IV petrol vehicles into fleet in evaluation period.	Based on estimate of unit costs, plus new registrations 2006 - 2010 = Cars = £ 3342 M to £6686 M Vans = £ 646M to £1131 M Heavy = £ 593M to £ 741M	Not available for all vehicles yet, so not known	Not available for all vehicles yet, so not known	Not available for all vehicles yet, so not known	Total benefits (1990 – 2001) = **£ 19 M (CL) to £ 109 M (CH)**	Total benefits (2002 – 2010) = £ 310 (CL) to £ 1850 (CH) note benefits extend well beyond 2010 as introduction not until 2006

See caveats above.

Table 2-9. Costs and Benefits of Road Transport Sector Policies in the UK (continued). Columns in Grey show Key Evaluation Data.

	Ex Ante Costs				Ex Post Costs			Air Quality Benefits	
Policy			**Total Cost 1990-2001 £M Evaluation**	**Total Cost 2002-2010 £M Projected**	**Unit cost (£)**	**Total Cost (£ Mill.) Evaluation 1990-2001**	**Total Cost (£ Mill.) Projected 2002-2010**	**(£ Mill) Evaluation Period 1990 – 2001**	**(£ Mill) Projected period 2002 - 2010**
All policies			Unleaded 1990-2001 = £ 2590 M. Euro I 1993 – 2001 = £ 8108 M to £ 11721 M Euro II 1997- 2001= £ 3197M to £ 6189 M Euro III 2001 = £ 648M to £ 739 M Euro IV Not in compliance period 1996 fuel quality 1996-2001 = £ 560 M 2000 fuel quality in 200-2001= £ 737 M 2005 fuel in 2001 = £ 270 M All in evaluation period £ 16109 M £ 22807 M	Euro I 2002- 2010 = £ 11 051M to £ 15 985 M Euro II 2002- 2010 = £ 7132 M to £ 13929 M Euro III 2002- 2010 = £ 6616 M to £ 7498M Euro IV 2006- 2010 = £ 4582 M to £ 8558M 1996 fuel quality 2002- 2010 = £ 1049M 2000 fuel quality 2002- 2010 = £ 3739M 2005 fuel in 2002- 2010 = £ 2750 M All in projected period £ 36921M £ 53508M				Total benefits (1990 – 2001) = **£ 2,941 M (CL) to £ 18,370 M (CH)**	Total benefits (2002 – 2010) = £6,935 M (CL) to £39,787 (CH)

See caveats above. All costs and benefits in 2002 – 2010 are presented in 2002 constant prices with no discounting to allow direct comparison.

Summary of all policies

2.6.2. The costs and benefits of policies are summarised in the tables below. Note it is not possible to estimate ex post costs for the projected period (2002- 2010).

Table 2-7. Summary of Present Values for Ex Ante Costs, Ex Post Costs and Ex Post Benefits of Road Transport Sector Policies in the Evaluation Period (1990 – 2001)

	Evaluation Period (1990 – 2001) £ Million		
Policy	**Ex Ante Cost low to high**	**Ex Post Cost low to high**	**Ex Post AQ Benefit – Central low to Central high**
Unleaded petrol	£2590 M	£1036 M (though probably lower)	£357 M (L) £3662 M (H)
Euro I petrol cars*	£5834 M £8751 M	£437 M £729 M	£1126 M (CL) £4922 M (CH)
Euro I diesel	£2273 M £2970 M	Not known	£702 M (CL) £4256 M (CH)
1996 low Sulphur	£561 M	Not known	£263 M (CL) £2409 M (CH)
Euro II all vehicles	£3197 M £6189 M	Not known	£329 M (CL) £1972 M (CH)
2000 fuel standards	£737 M	£ 368 M*	£36 M (CL) £329 M (CH)
Euro III all vehicles	£648 M £739 M	Not known	£42 M (CL) £213 M (CH)
2005 fuel in 2000/1	£270 M	£135M*	£68 M (CL) £500 M (CH)
Euro IV all vehicles	Not in evaluation period	Not available yet	£19 M (CL) £109 M (CH)
All Policies	**£16109 M £22807 M**	**Estimated £2000 M £4000 M**	**£2941 M (CL £18370 M (CH)**

The table includes the benefits categorised under high, medium and low confidence bands, but excludes those included in the sensitivity analysis and exclude CO_2 benefits. The values only include UK benefits, and do not account for the benefits from the reduction in trans-boundary pollution. Environmental benefits do not include all benefits, with a number of areas excluded including impacts on natural and semi-natural ecosystems (terrestrial and aquatic), impacts on forests, visibility, and others (see main text). The analysis does not include the effects of NO_X emissions on ozone formation.

Note total benefits are from emissions in the time period 1990 – 2010 only. They do not include benefits from lower emissions in future years (post 2001 for the evaluation or post 2010 for the projected analysis) from a move to sustained new pollution levels.

Note because policies have different implementation dates, the absolute costs and benefits will appear very different for different policies in the evaluation period – unleaded petrol has been in force for the entire evaluation period, while Euro IV technology has only entered a small proportion of the car fleet (from early compliance – the official date for compliance is not until 2006).

* This is based on components costs only. It does not include development costs.

* There is no comprehensive analysis of specific costs of ex post out-turn, but data for 2000 fuel indicates ex post costs were around half the ex ante costs. Range of values for 2005 fuel quality from zero to around half ex ante costs.

Table 2-7. Summary of Present Values for Ex Ante Costs and Ex Post Benefits of Road Transport Sector Policies in the Projected Period (2002 – 2010)*, and total Period (1990 – 2010)*.

	Projected (2002 – 2010) £ Million		Total (1990 – 2010) £ Million	
Policy	**Ex Ante Cost low to high**	**Ex Post Benefit – Central low to Central high**	**Ex Ante Cost low to high**	**Ex Post AQ Benefit – Central low to Central high**
Unleaded petrol			£2590 M	£357 M (L) £3662 M (H)
Euro I petrol cars	£6069 M to £9104 M	£1885 M (CL) £8207 M (CH)	£11,903 M £17,855 M	£3,011 M (CL) £13,129 M (CH)
Euro I diesel	£3230 M £4347 M	£1335 M (CL) £8071 M (CH)	£5,503 M £7,317 M	£2,037 M (CL) £12,327 M (CH)
1996 low Sulphur	£883M	£ 337 M (CL) £3083 M (CH)	£1,444 M	£600 M (CL) £5,492 M (CH)
Euro II all vehicles	£6002 M £11721 M	£939 M (CL) £5561 M (CH)	£9,199 M £17,910 M	£1,268 M (CL) £7,533 M (CH)
2000 fuel standards	£3146M	£83 M (CL) £763 M (CH)	£3,883 M	£119 M (CL) £1,092 M (CH)
Euro III all vehicles	£5564 M £6304 M	£750 M (CL) £4477 M (CH)	£6,212 M £7,043 M	£792 M (CL) £4,690 M (CH)
2005 fuel in 2000/1	£2315 M	£207 M (CL) £1535 M (CH)	£2,585 M	£275 M (CL) £2,035 M (CH)
Euro IV all vehicles	£3600 M £6724 M	£242 M (CL) £1444 M (CH)	£3,600 M £6,724 M	£261 M (CL) £1,553 M (CH)
All Policies	**£30808 M** **£44544 M**	**£5780 M (CL)** **£33140 M (CH)**	**£46,917 M** **£67,351 M**	**£8,721 M (CL)** **£51,510 M (CH)**

*Note for 2002 – 2010, a 3.5% discount rate has been applied to all costs and benefits. Therefore, the summary results in this table differ from main tables above. Values in 2002-2010 in 2002 constant prices.

The table includes the benefits categorised under high, medium and low confidence bands, but excludes those included in the sensitivity analysis and exclude CO_2 benefits. The values only include UK benefits, and do not account for the benefits from the reduction in trans-boundary pollution. RIA for refineries expressed as annual cost (12% discount rate, discounted over 15 year lifetime). Environmental benefits do not include all benefits, with a number of areas excluded including impacts on natural and semi-natural ecosystems (terrestrial and aquatic), impacts on forests, visibility, and others (see main text). The analysis does not include the effects of NO_X emissions on ozone formation.

Note total benefits are from emissions in the time period 1990 – 2010 only. They do not include benefits from lower emissions in future years (post 2001 for the evaluation or post 2010 for the projected analysis) from a move to sustained new pollution levels.

** Note that benefits will continue in later years – i.e. there will be health benefits from unleaded petrol in years after 2000 (after the additional costs of the policies such as to refineries are fully paid off). This applies to all policies.

2.6.3. Extending the benefits analysis to the period 2020 would further increase the above values, because of the benefits of Euro III and especially IV technology (the latter is only partially realised by 2010).

2.6.4. The data for Euro standards and fuel quality standards are plotted below. Note the scale is different for the two graphs.

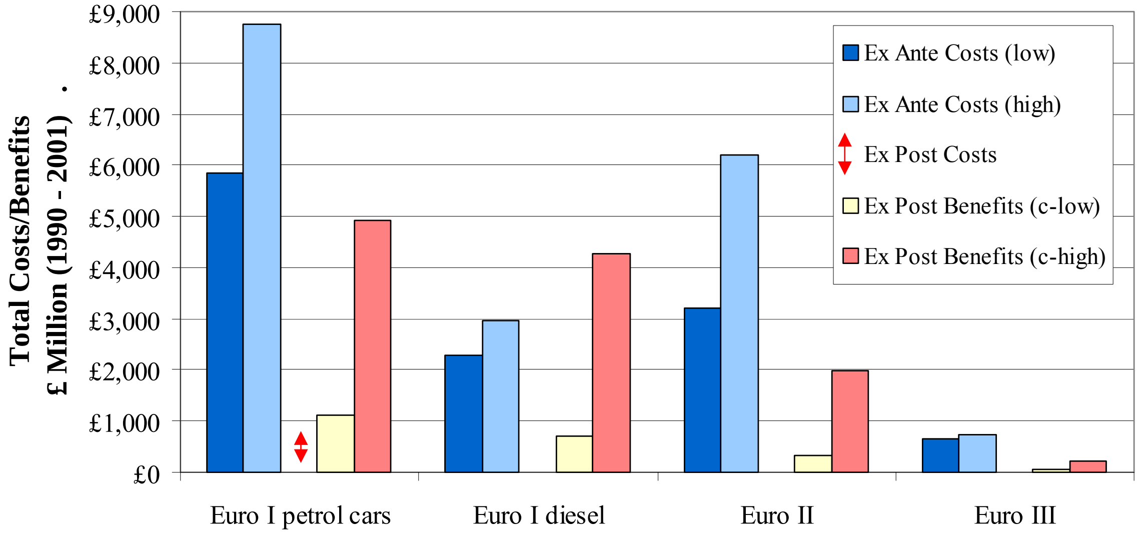

Figure 2-17. Present Value Ex Ante and Ex Post Cost, and Ex Post Benefits, in the Evaluation Period (1990 –2001) from Euro Standards.

See earlier text for caveats. Note because policies have different implementation dates, the absolute costs and benefits will appear very different for different policies in the evaluation period.

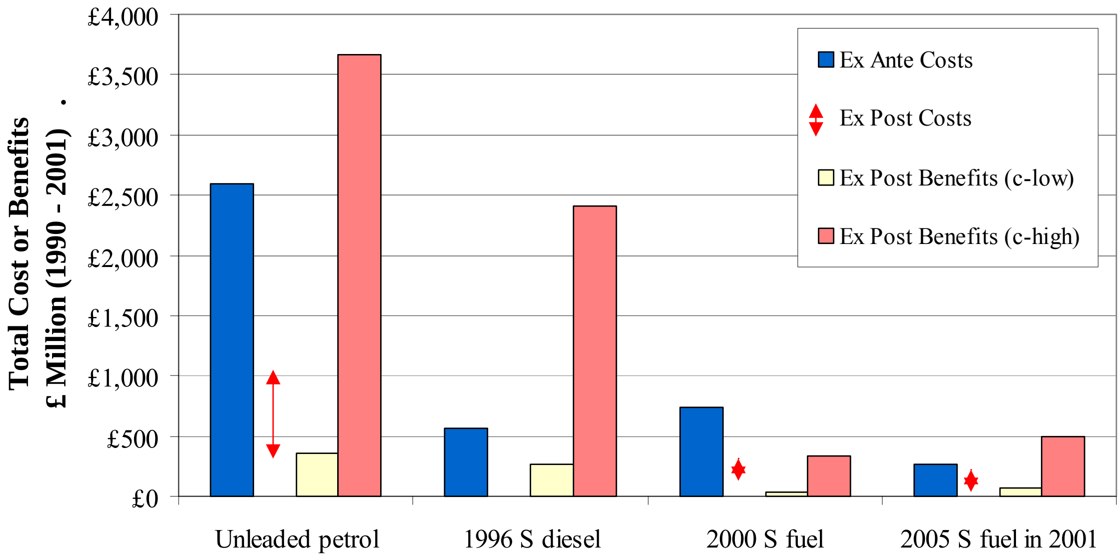

Figure 2-18. Present Value Ex Ante and Ex Post Cost, and Ex Post Benefits, in the Evaluation Period (1990 –2001) from Fuel Quality Standards.

See earlier text for caveats. Note because policies have different implementation dates, the absolute costs and benefits will appear very different for different policies in the evaluation period.

2.6.5. It is also interesting to look at the ratio of benefits to costs, for all policies. The comparison of benefits against ex ante costs is shown below.

Table 2-8. Benefit to <u>Ex Ante Cost</u> Ratio for Road Transport Sector Policies

	Ratio of Benefit : low ex ante cost		Ratio of Benefit : high ex ante cost	
	Where benefits = central low	Where benefits = central high	Where benefits = central low	Where benefits = central high
Unleaded petrol	0.1	1.4	0.1	1.4
Euro I petrol cars	0.3	1.1	0.2	0.7
Euro I diesel	0.4	2.2	0.3	1.7
1996 low Sulphur	0.4	3.8	0.4	3.8
Euro II all vehicles	0.1	0.8	0.1	0.4
2000 fuel standards	0.03	0.3	0.03	0.3
Euro III all vehicles	0.1	0.8	0.1	0.7
2005 fuel in 2000/1	0.1	0.8	0.1	0.8
Euro IV all vehicles	0.1	0.4	0.04	0.2
All	**0.2**	**1.1**	**0.1**	**0.8**

2.6.6. It is much harder to do this with confidence for the ex post costs. Where ex post data has been found (e.g. unleaded petrol, Euro I vehicles, 2000 and 2005 standards), the ex post benefit: cost ratio increases dramatically, shown below.

Table 2-8. Benefit to <u>Ex Post Cost</u> Ratio for Road Transport Sector Policies

	Ratio of Benefit : low ex Post cost		Ratio of Benefit : high ex Post cost	
	Where benefits = central low	Where benefits = central high	Where benefits = central low	Where benefits = central high
Unleaded petrol	0.3	3.5	0.3	3.5
Euro I petrol cars	3.4	14.7	2.0	8.8
Euro I diesel				
1996 low Sulphur				
Euro II all vehicles				
2000 fuel standards	0.3	3.0	0.3	3.0
Euro III all vehicles				
2005 fuel in 2000/1	2.0	15.1	2.0	15.1

2.6.7. An analysis of all the above information leads to the following conclusions:

- The <u>ex ante costs</u> (both low and high estimates) exceed the <u>low ex post benefits</u> for all policies.
- The <u>high ex post benefits</u> exceed the <u>low ex ante costs</u> for most early policies (unleaded, Euro I, 1996 low sulphur diesel). Most of these policies also exceed the high ex ante costs. The benefits of later policies (Euro II – IV and 2000 and 2005 fuel quality) do not exceed the ex ante costs, though we stress that not all benefits (e.g. ecosystems) are captured in the values. Overall, the high estimate of benefits of 'all policies' are similar to the ex ante costs. The low estimate of benefits of 'all policies' is much lower than the ex ante costs.
- The ex post analysis (that is available) indicates that the cost out-turns of early Euro standards were very much lower than anticipated ex ante. The same pattern emerges for fuel quality standards. The benefit to ex post cost ratio is much more favourable, such that

in nearly all cases, the ex post benefits exceed the ex post costs, by a very significant factor.

- The largest economic benefits have arisen from the introduction of Euro I policies. This policy was also predicted, ex ante, to have the highest costs. This has not been borne out by the ex post analysis, so the policy has had an extremely high ratio of benefits to costs.
- The introduction of Euro II and Euro III policies (individually) have lower ex post benefits than Euro I. In the projected period (to 2010), the benefits of Euro II and Euro III are broadly similar, but this is because Euro III benefits do not fully accrue until after 2010. The benefits of Euro IV are much lower than earlier Euro standards (though the benefits of Euro IV will be mostly post 2010).
- The benefits of unleaded petrol and low S diesel have high benefit:cost ratios, of a similar level to Euro I.
- Later fuel quality policies (2000 and 2005) have lower benefits than the Euro standards. However, it is also important to consider the role of these policies in enabling the introduction of tighter emission standards (improved fuel quality is needed to enable the introduction of certain abatement equipment).

Sensitivity Analysis

2.6.8. The study has also assessed the implications of different confidence levels in the benefits (the high, medium, low and sensitivity banding), and compared these against the costs of policies. The conclusions of this analysis are:

- The use of the COMEAP ‘acute’ functions for deaths brought forward and respiratory hospital admissions, together with the study team’s view on the appropriate current valuations of these endpoints, do not provide sufficient benefits to justify polices (ex post). However, estimates in the past (ex ante) used much higher valuation values for deaths brought forward, which would have led to much higher benefits (of a similar order to that shown for chronic effects); a credible quantification now would not ignore the life expectancy benefits from chronic mortality and particles.
- Including PM_{10} related chronic mortality (as per the IGCB analysis) significantly increases the benefits from policies, such that the ex post benefits are broadly equal to or exceed the ex post costs of policies. However, it is only with a higher quantification and valuation estimate for chronic mortality from PM_{10} (our ‘central high’) that the ex post benefits rise to a level similar to the low estimate of ex ante costs.
- To justify the higher ex ante cost values, it is necessary to include the secondary pollutants associated with VOC and NO_X emissions (ex post), i.e. secondary particulates (nitrates) and ozone, and for later policies, additional sensitivity analysis. These benefits are rarely quantified in most UK appraisals – for example, secondary particulates and ozone were not included in the first IGCB analysis of the AQS (but secondary particulates were included in the second particle objective review). The role of nitrates in particular is unclear but the above analysis shows they are potentially very important for transport. The inclusion of nitrates is important because we attach a low confidence rating to these[34].

[34] Though if nitrates are not a casual part of the PM fraction, then the rest of PM fraction must be more important, and would lead to similar levels of overall benefits (indeed – for transport – it might actually lead to higher benefits because of the high levels of primary $PM_{2.5}$).

- The inclusion of additional PM_{10} sensitivity functions (e.g. with additional European and US functions) has a significant impact increasing benefits. Quantification studies by most of the leading groups worldwide do include at least some of these additional endpoints.
- Including the more uncertain sensitivity estimates (cancer) for benzene, butadiene or benzo[a]pyrene, or including CO effects, does increase the benefits, but the effects are much lower than from including the sensitivity analysis above (e.g. nitrates, other PM_{10} functions).
- It is highlighted that even for the analysis presented, certain categories of benefits (e.g. ecosystems) are excluded. These would alter the cost-benefit ratios seen.

2.7 Conclusions and lessons for future policy

2.7.1. The air quality policies implemented over the last decade in the transport policy have had a major impact in improving air quality. The policies have led to an almost complete removal of lead, a very high reduction (>90%) in SO_2 emissions, and a 35-55% of the other main pollutants (NO_X, PM_{10}, CO, VOC). These emissions reductionss are projected to increase in future years, so that by 2010 between 75% to 100% of all pollutants are reduced, relative to the expected out-turn that would have occurred in the absence of policies. National level technical policies (emission standards and fuel quality) have proved extremely successful in improving air quality, and improving health, and there is a very strong justification when their 'value for money' is measured by the costs and benefits, when looking at the actual costs of introducing these policies (ex post) [35]. We also summarise some wider conclusions on costs and benefits of air quality strategy in the overall study conclusions (chapter 4). A number of specific points for the transport sector are summarised below.

2.7.2. When considering the policies here, and the wider policy of the Air Quality Strategy, a number of important points emerge in relation to the transport sector:

- The UK may now be at the stage where targeted local action is more cost-effective than national level policies, at least for the pollutant **NO_2**. This is because the remaining exceedences of the NO_2 objective are mostly in the centres of large urban areas. The evaluation has undertaken a separate piece of work to investigate this. The initial results show that local measures which target air pollution may be a cost-effective approach compared to future national measures (such measures also have good benefit to cost ratios). For broader urban transport measures, primarily targeted at improving congestion or traffic flow, the situation is more complex. When considered only in terms of air quality, these broader local measures have a low ratio of benefits to costs. However, when other factors are taken into account (e.g. travel time) the ratio of benefits to costs improves dramatically. This raises the issue of whether future policy should concentrate on local measures targeted primarily towards improving local air quality, or towards local measures that give the greatest overall benefits across the urban environment (i.e. towards wider urban sustainability objectives including congestion, accidents, air quality, noise, quality of environment, etc). This warrants further investigation.

[35] Note we highlight that the study has focused on the major policy initiatives in this sector and we have not considered all measures introduced such as some Government programmes (such as wider marketing or information programmes). No inferences should be drawn from the study about the relative effectiveness of instruments or policies beyond those explicitly covered in the study, or the potential application of similar policies to those considered here for other sectors.

- The study has revealed some interesting points in relation to the NO_2 objective and future policies for NO_2/NO_X. These are summarised in the following points:
    - The NO_2 objective is currently being met in the great majority of the United Kingdom and cost-benefit assessment alone does not support further action beyond the existing objective for NO_2. This is because NO_2 is probably a threshold pollutant, unlike, for example, PM_{10}. Once the standard has been achieved, there are no additional health benefits from reducing concentrations further. Indeed the there is little justification for the current NO_2 objective when considered in terms of cost-benefit analysis alone. There are however additional benefits from reducing NO_X emissions, the precursor to NO_2 (see below). In other words it is not an economically optimal target, set on the basis of cost-benefit analysis, but one that seeks to ensure environmental protection and environmental justice.
    - The NO_2 objective, and further action to reduce NO_X, may be justified in cost-benefit terms when these additional secondary pollutants (nitrates and ozone) and additional impact categories (ecosystems) are included[36]. However, as these are regional pollutants, locally based objective levels are not as relevant. Therefore, future policy might achieve greater overall health and environmental benefits by considering different policy approaches, e.g. by trying to reduce overall population weighted exposure to these pollutants rather than focusing on hot-spots. This is highlighted as a research priority.
- In contrast, there is a very strong justification (benefits vs. costs) for future PM_{10} reductions. There is no evidence to justify any specific threshold of effect (i.e. a specific objective level), and it is important to stress that there are thought to be benefits in reducing PM_{10} below this level (note the benefit numbers above assume this is the case).

2.7.3. Finally, while it is clear that further primary PM_{10} reductions will have continued health benefits, there is an important issue of which emission sources to target. The graph below shows the marginal cost of a tonne of primary PM_{10} emissions from transport in different UK locations (based on detailed dispersion modelling of marginal pollution increases). This indicates that the highest impacts from primary PM_{10} emissions occur in London and larger urban areas – and so the greatest benefits of emissions reductions (measured by the reduction in population weighted exposure) will also be in these areas. This is because of the extremely high population density in these areas. Targeting emissions reductions in these areas will therefore be much more cost-effective in improving health (as they have an order of magnitude greater benefits than say rural areas). This may also mean that future policy will be more cost-effective if it is targeted towards specific components of the fleet, based on detailed analysis of activity data. To illustrate, we know that HGVs undertake most of their vehicle kilometres on motorways. A more cost-effective approach to reduce primary PM_{10} emissions from transport in urban areas might therefore be to target the diesel light goods vehicle fleet at a national level. Further investigation of these issues is highlighted as a research priority from the study.

[36] We highlight that an uncertainty analysis undertaken in the current study has established that there is a lower confidence attached to the health effects of nitrates (secondary PM_{10}), which might further weaken the case for future action for this pollutant.

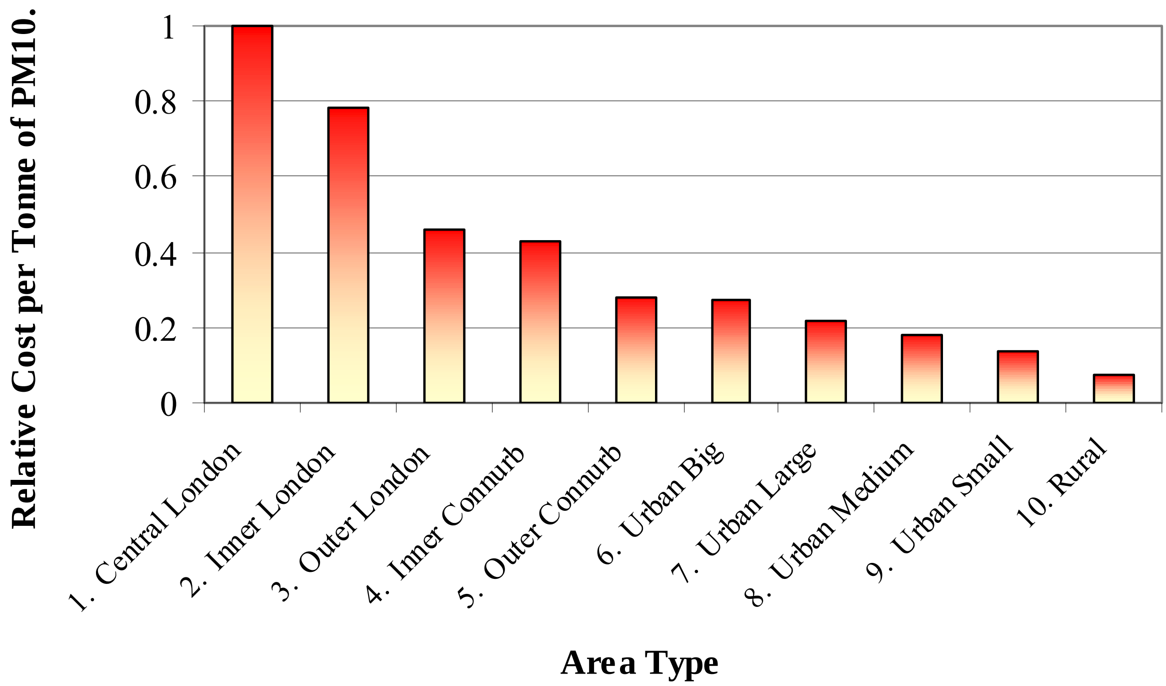

Figure 2-19. Cost per Tonne of Road Transport PM_{10} Emissions for different UK Locations.