ATTACHMENT D

Work in progress

Preliminary Economic Analysis of Adopting New Vehicle Emission Standards

Economics and Environmental Reporting Branch

NSW Environment Protection Authority

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This paper has been provided to the Motor Vehicle Environment Committee (MVEC) and the Federal Office of Road Safety (FORS) to assist in considering the impacts of adopting European emission standards. The paper reports work in progress and presents preliminary results that have not been subject to comprehensive review.

Consequently, the results presented should be considered as indicative orders of magnitude rather than as precise estimates of impacts.

Executive Summary

Motor vehicle pollution in Australia is a pervasive problem within the highly urbanised cities of Australia and vehicles are estimated to contribute up to 70% of total air pollution. Australian emission standards for passenger vehicles lag more than a decade behind US standards.

This paper presents the results of work in progress of the costs and benefits of adopting more stringent emission standards for new motor vehicles in Australia. The report provides a framework upon which further work could be undertaken to confirm the conclusions. The results should be taken as providing a guide, not as definitive estimates. This preliminary analysis is therefore considered indicative and may be updated when further information becomes available.

The impact of adopting European emission standards (Euro 2 and Euro 3) are evaluated by assessing the marginal costs and benefits of moving to a higher standard. The analysis attempts to quantify, in dollar terms, the improved health and environmental benefits of tighter emission standards in comparison with industry costs. As there is no direct vehicle manufacturing within NSW the analysis is extrapolated to the national level to identify the total impact. Where quantification has not been possible, impacts are discussed in qualitative terms.

Modelling work by the NSW EPA in the NSW Metropolitan Air Quality Study area (MAQS) estimated the emission reductions in several major pollutants including particulates, carbon monoxide, nitrogen dioxide, hydrocarbons and benzene that are expected if more stringent standards are adopted.

The primary costs from adopting European standards include technology and hardware costs, fuel reformulation costs and compliance costs. The additional cost of upgrading vehicles with new equipment was estimated for both petrol and diesel vehicles and applied to the number of vehicles produced within Australia.

Positive health impacts were found to be the major feature of the identified benefits. The link between air pollutants and human health was examined using dose response relationships. The health cost avoided per tonne of pollutant was then calculated for four major pollutants. These were particulate matter, carbon monoxide, hydrocarbons and nitrogen dioxide. The results under-estimate the health benefits as the impacts of air toxics such as benzene and ozone and the personal and social costs of air pollution were not valued.

Emission reductions for light duty commercial vehicles could not be estimated for the analysis. This has the effect of underestimating the health benefits, as the reduction in pollutants from these vehicles was excluded. However the cost of technology and compliance to meet the new standards was included.

In addition to quantified health benefits, a range of other benefits were discussed but not quantified. These include enhanced investment opportunities, visual amenity and export potential. Reducing vehicle emissions may also provide benefits through infrastructure damage costs avoided and reduced greenhouse emissions.

The economic analysis demonstrates that adopting Euro 3 emission standards for all

vehicles in 2002 would generate net benefits in excess of $1 billion to the Australian community.

Adopting Euro 3 standards for heavy duty diesel (trucks) and Euro 2 for petrol vehicles (cars and light commercial) in 2002 progressing to Euro 3 later in 2005 was estimated to provide net benefits of around $800 million.

Phasing in the introduction of Euro 2 in 2002 and then Euro 3 in 2005 for all vehicle types was estimated to produce net benefits of around $600 million but would result in significant forgone benefits comparison to the earlier introduction of Euro 3 in 2002.

Adopting Euro 2 in 2002 would produce net benefits of only $100 million, some ten times smaller than the benefits of adopting Euro 3 from 2002.

Sensitivity testing of the major variables demonstrated that the absolute value of the net benefits of options was sensitive to estimates used. The most sensitive variables in the analysis are fuel reformulation costs and technology and hardware costs. However, costs of fuel reformulation associated with adopting Euro 3, would need to be increased 160% (above the conservative base assumptions) before adopting Euro 3 became less preferable than Euro 2.

The costs of adopting stronger emission standards would be initially borne by vehicle manufacturers and oil refinery producers in upgrading plant and equipment. The benefits from avoided health costs would flow to those with pre-existing health conditions, the public health system and families through lower levels of sickness and less restricted activity days.

This paper reports the results of a preliminary economic analysis of work in progress. Please forward comments to:

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Preliminary Economic Analysis of Adopting New Vehicle Emission Standards

1. Introduction

The purpose of this paper is to provide preliminary estimates of the costs and benefits of adopting more stringent emission standards for new motor vehicles in Australia. The analysis aims to quantify in dollar terms the improved health and environmental benefits of tighter emission standards in comparison with industry costs. Where quantification has not been possible, the issue is discussed in qualitative terms. The report provides a framework upon which further work could be undertaken to confirm the conclusions.

Motor vehicle pollution in Australia is an ongoing problem particularly in the densely urbanised cities of Sydney, Melbourne and Brisbane. Vehicles are estimated to contribute up to 70% of total air pollution. The Metropolitan Air Quality Study (EPA 1997a) estimates that vehicles contribute 80% of oxides of nitrogen (NOx) emissions, 50% of hydrocarbon (HC) emissions (precursors to photochemical smog, measured in terms of its principal constituent, ozone) and 90% of carbon monoxide (CO) emissions.

The impacts of emissions from vehicles has significant effects on air quality and hence our quality of life. High levels of primary and secondary air pollutants have been shown to result in a wide range of adverse health and visual impacts on our society. Increasing levels of pollution can have significant environmental and economic consequences. Health effects associated with air pollution include respiratory effects, ranging in severity from cough, chest congestion, asthma, to chronic illness and possibly death in susceptible people (ACVEN 1997 pii).

Emission standards for Australian vehicles lag more than a decade behind international standards for Europe and the US. The 1997 Industry Commission Inquiry into the Automotive Industry notes that Australia has significantly lower emission standards than other international standards (IC 1997, 276). The Federal Office of Road Safety (FORS) is currently coordinating a review of Australia's emission standards and recommends the introduction of Euro 2 levels for light duty and heavy vehicle standards.

While Euro 2 standards may lead to a possible decrease in emissions for new vehicles in comparison to earlier standards, the increasing number of new vehicles and increased use of existing vehicles will more than offset any new vehicle emissions savings. This issue has been widely recognised by FORS (1996), *"Increases both in car usage and in the total vehicle population will start to outweigh the benefits of tighter standards unless more is done to control emissions."*

The main findings of the NSW State of the Environment Report (NSW EPA 1997) support this conclusion and suggest that "improved vehicle emission controls may not compensate for continuing upward trends in motor vehicle use." The report also notes the continuing problems of photochemical smog and brown haze in metropolitan areas and the developing links between air toxics and human health.

Community surveys in 1995 revealed that air quality was the number one environmental concern for 28% of respondents while in 1997 it was the number two concern (24%) (EPA 1997b). Similar findings have been reported by the ABS (1996).

The NSW Air Quality Management Plan (AQMP) (NSW Gov 1998) includes a plan called *Action for Air* that focuses on regional pollution and outlines NSW's proposed approach to achieving the standards for the other NEPM pollutants, particularly ozone, nitrogen dioxide and fine particles. In *Action for Air*, NSW is proposing long term goals that are equivalent to, or more stringent than, the NEPM standards. Consequently, *Action for Air* identifies an extensive range of strategies that will be required to meet the NEPM. One of these actions is to reduce emissions from vehicles through improved emission standards.

2. Characteristics of the Australian Vehicle Fleet

To provide a context for the following analysis it is useful to outline some of the key characteristics of the Australian vehicle fleet.

- The total number of registered vehicles continues to increase steadily, from 8.3 million 1984 to 10.9 million in 1995 (a 24% increase). This represents an annual average increase of around 2.2% per annum (AATSE 1997).
- During the same period passenger vehicles increased by 2 million (30%).
- Australian vehicles are older relative to other countries with similar levels of car ownership and use. Of the total 10.9 million vehicles registered, over 6 million (57%) are 10 years old or more (AATSE 1997).
- Very low turnover and scrappage rates
- Cars 10 to 16 years old create the most pollution (HC and CO).
- New cars account for higher average annual travel but generally have lower average emissions because they are well maintained. However, deterioration of catalyst equipment is a significant problem in older vehicles.
- Emission standards currently specify durability requirements of 80,000 km. This means a vehicle must perform to the emission standard for the first 80,000 km of its life. There is no warranty, recall or testing procedures currently in place to test for durability. The US durability requirement is 100,000 km and is currently considering extending this to 160,000 km for new LEV (2) standards. Since 1994 the US has required on-board diagnostics and since 1992 a federal in-service testing. The Industry Commission notes that in revising emission standards greater attention could be paid to both durability requirements and on-board diagnostics (IC 1997, 277).
- Significantly more could be done to reduce motor vehicle pollution by tuning the existing car population. FORS (1996) estimate that emissions could be reduced by between 7% and 20% below existing levels by tuning the worst 20% of vehicles.

As a result of low turnover rates, the new emission standards may take some time before they take effect on reducing emission levels. However, the longer these standards are delayed, the longer the delay in achieving reduced emissions.

3. Emission Standards

Australian Design Rules for passenger cars (ADR37/01) now being introduced into the Australian market are based on the limits introduced federally in the US in 1981. These US standards were current until 1993. This places Australian standards more than a decade behind the US. The US is implementing an aggressive strategy to significantly reduce vehicle emissions. For passenger cars, Euro 3 is loosely equivalent to the US Low Emission Vehicle (LEV) standards, and Euro 4 is comparable to the Californian Ultra Low Emission Vehicle limits (ULEV).

Table 1 – Comparable standards – passenger cars

Aust	ADR37/01			
Europe		Euro 2 (1996)	Euro 3 (2000)	Euro 4 (2005)
US	1981-1993 Federal standar ds	Tier 1 (1994)	Tier 2 (2004, but may be brought forward to 2001) Low Emission Vehicle (LEV - California)	Ultra Low Emission Vehicle (ULEV - California)

The standards for LEV and ULEV are part of a package where manufacturers are required to meet an average for the total fleet sold per year. It is the manufacturer's choice as to what proportion is LEV/ULEV, although there are minimum requirements. These standards are being adopted federally in the US as part of the National LEV program.

For diesel engines, FORS is proposing the European limits as the primary standard and the equivalent US Federal standard as an alternate to allow for heavy duty vehicles which are almost exclusively imported from America. Euro 2 is equivalent to US 94 diesel standards, and these set significantly tighter limits than the existing standards for control of particulates. Euro 3 is equivalent to US 98, and both of these standards set tighter limits for particulates. Euro 4 diesel controls are still under discussion in the European Commission.

Table 2 – Comparable standards – diesel powered vehicles

Aust	ADR70 (1993)			
Europe	Euro 1 (1991)	Euro 2 (1996)	Euro 3 (2000)	Euro 4 (2005)
US	1991 Federal standards	US 94 Federal standards	US 98 federal standards	Not known
Japan	1993 standards			

4. Options to improve emission standards

This CBA only considers options related to improving emission standards in new vehicles. It does not evaluate alternative means of reducing pollution by other policy instruments such as taxes, subsidies or investment in public transport. In considering the range of alternatives for emission standards the following options are presented for analysis:

Do nothing (base case)

1) Adopt Euro 2 in 2002/3

2) Adopt Euro 2 in 2002/3 then Euro 3 in 2005/6

3) Adopt Euro 3 in 2002/3

4) Adopt Euro 3 in 2005/6

5) For petrol cars adopt Euro 2 in 2002/3, then Euro 3 in 2005/6 For heavy duty diesel vehicles adopt Euro 3 in 2002/3

Under the base case (do nothing) the existing Australian Design Rules (ADR 37/01) would continue to apply and air pollution would be likely to worsen. The base case sets the benchmark for comparing the performance of each option in the analysis. Each of the other alternatives is compared to the base case to assess the marginal costs and benefits of moving to a higher emission standard.

Euro 2 provides emission standards that are equivalent to or slightly stricter than current Australian standards. Euro 2 was adopted as the standard in Europe in 1996, with Euro 3 due to commence in the EU in 2000/1 and Euro 4 in 2005/6. Australia has historically lagged behind US and EU emission standards by a significant margin.

Euro 3 provides significantly stronger emission standards than current ADR's. As shown in the following section, Euro 3 is estimated to reduce pollutant emissions from between three and twelve times that of Euro 2 for various pollutants. Euro 3 is also expected to require the use of reformulated fuel with a lower sulphur content, so as to achieve the expected emission reductions.

Each of these options would result in different levels of costs and benefits to industry and the community depending upon the level of pollutants avoided, the timing of their introduction and the technology required to achieve such reductions.

5. Pollution reductions under new standards

Modelling work by the NSW EPA has assessed the reductions in some pollutants that come from adopting the various European standards. The assumptions used are based on annual emission reductions in tonnes per year from the assumed baseline averaged between the years 2002 and 2021 for the MAQS region of NSW. The results are summarised in table 3 below.

The modelling demonstrates that adopting Euro 3 produces the highest level of reductions in key pollutants. National estimates can be estimated at about 4.3 times the figures quoted. This national estimate comes from the ratio of national motor vehicles to those in NSW multiplied by ratio of the NSW population to the MAQS population (ie. 636,528/221,294 x (6/4) = 4.3).

Table 3. Reductions in Key Pollutants 1st and 15th year of each program

Pollutant (Tonne per year)		EURO2	EURO3
PM10	1st yr	46	128
	15th	299	821
CO	1st yr	1,171	3,778
	15th	10,354	115,300
NO_x as NO_2	1st yr	1,382	2,997
	15th	11,072	44,913
HC	1st yr	146	1,876
	15th	2,183	26,419
Benzene	1st yr	5	59
	15th	299	821

Source: NSW EPA

A number of assumptions have been made in the development of the EPA's emission projections (see Table 4). Appendix 3 includes graphs which represent the data used as the basis for the reductions shown in Table 3 above, as well as a comparison of the assumptions with other modelling.

Table 4. Key assumptions in NSW EPA emission projections

Factor	NSW EPA assumption
Vehicles[1]	Passenger vehicles and heavy duty diesels
Deterioration rates	Baseline – new cars emit 50% of allowable emissions at 0km; deterioration calculated from emissions at 80,000km based on laboratory tests of vehicles fitted with 3-way catalysts Euro 2 – same ratio to emission limits as baseline. For Euro 3 - all vehicles emit 50% of the allowable emissions at 0km, and 90% of allowable emissions at 80,000km.
% of cars requiring upgrading	24% of new cars require upgrading for both Euro 2 and Euro 3, other new vehicles being imported already meet the standards
Airshed	Sydney-Newcastle-Wollongong
VKT	NSW Dept of Transport travel forecast model
Fuel	Benefits of cleaner fuel not explicitly considered
Cycles	Ratio of US to Euro cycle based on literature survey (similar to Prof Watson)
Real world consideration	Five road categories including congestion
Cost of controls	Based on up-to-date information provided by Parsons engineering (1999)
Evaporative emissions	For Euro 3 a reduction in evaporative emissions by 60% over Euro 2 was included
HC/ NO_x split	50/50

Note 1. Vehicles

It is not possible at the moment to model the impact of regulation on light duty commercial vehicles with a reasonable degree of certainty, given that the impact of fuel and technology is largely unknown. The EPA believes that it has underestimated the emissions of PM_{10} for each scenario and has sought confirmation from the US EPA on its recent research.

6. Costs of adopting European standards

In cost benefit analysis, only the additional costs and benefits of moving to the new standard are identified and valued. This is known as the *marginal* approach in economics. To develop the estimates of costs and technologies required to meet the proposed standards a consultant {Parsons (1999)} was retained to review the existing literature from local and overseas sources. The key costs in revising current standards are identified below:

- **Technology and hardware costs** – Increased costs of production arising from requirement to invest in new technology to meet revised standards (eg. improved catalytic converters).
- **Fuel reformulation costs** – Cost to industry fuel refiners in making cleaner fuel.
- **Compliance costs** – Cost of auditing/ monitoring the new standards.

Most sources indicate that adopting Euro 3 or higher standards may require fuel reformulation, otherwise vehicles using new technology would not optimise emission performance. However, substantial reductions in emissions would still be realised from new vehicles using current fuel standards. The cost figures sourced from Parsons (1999) assume that fuel specifications and vehicle technology are upgraded simultaneously (note that the benefits from fuel reformulation are not explicitly considered in the modelling).

6.1 Technology and Hardware Costs

The technology and hardware required for adopting Euro 3 standards is evolutionary and generally well established. The type of technology used on individual models will depend on base engine technology and engine size. The broad costs of moving from Euro 2 to Euro 3 are given below.

Table 5 – Estimated retail costs of adopting Euro 3

Petrol vehicles	Additional Retail Cost	Diesel vehicles	Additional Retail Cost
Small	$456	N/A	N/A
Medium	$500	Medium	$739
Large	$614	Large	$982
Light commercial	$325-$579	Light commercial	$325-$579
		Diesel vans to heavy duty vehicles (EU mfrs)	$913 to $2793
		Diesel vans to heavy duty vehicles (UK mfrs)	$1670 to $4450

Source: Parsons 1999

Directly translating the cost estimates from Europe and UK studies may under or over-estimate the real cost to Australian manufacturers. However, these estimates serve to provide a reasonable benchmark from which to assess the additional industry costs. In relative terms the overall UK estimates suggest the cost increases per vehicle range between 7.5% for the smallest diesel vehicle to 0.8% for the largest vehicle. The European commission estimates the cost of compliance will increase costs by 1.5% on average.

Vehicles certified to European or US standards would not incur increased costs of compliance, as they would already meet the standard. It is assumed that Japanese and Korean vehicles exported to Australia meet the Euro standards. Based on 1997 sales figures and FORS data on certification, Parsons's estimates the annual number of vehicles sold annually in Australia affected by increased costs due to Euro 3 to be 173,052 or 24% of total sales.

Technological and hardware costs are likely to decrease over time as environmentally friendly products are gaining an increasing market share and demand. In fact, incremental costs are likely to approach zero as economies of scale reduce production costs and the costs of producing outdated and non-compliant emission engines increases. For this analysis it is assumed that technology and hardware costs would fall by 4% pa over the period of the analysis. The average unit costs of technology and hardware required were applied in each option to estimate total costs.

6.2 Fuel reformulation costs

Reducing the sulphur content of fuel is important for achieving the estimated reduction in particulate matter emissions. Improving the quality of fuel by reducing sulphur content improves the operation and efficiency of the catalytic equipment to reduce particulate and other emissions. Without fuel reformulation, the performance of new emission technology would be sub-optimal, but still generate significant reductions as compared with current emission standards.

The European Union estimates of fuel reformulation costs for meeting the Euro 3 standards are 0.35 c/L (cents per litre) for petrol and 0.35 c/L for diesel (Parsons 1999 – sourced from European Commission Auto-Oil Program 1998, Brussels). However, consideration must be given to the existing sulphur levels in fuel in Australia and Europe. For petrol, Australia is roughly equivalent to Europe with an average sulphur content of around 150 ppm. Australian diesel fuel has around 1500ppm sulphur with 500ppm proposed as a new standard. In Europe, diesel is already at 500ppm and will be reduced to 350ppm (Euro 3) and 50ppm (Euro 4). In addition, Australian refineries are generally small and relatively aged in comparison to world standards, therefore reformulation costs may be higher. Alternatively, reformulation costs would be lower if, over the period, new refining facilities were constructed for Australia, or the market share of imported fuels increased.

On balance, it is estimated in this analysis that the costs of fuel reformulation to quality equivalent to the fuel standards adopted for Euro 3 for petrol are the same as Europe (0.35 c/L) and for diesel production are double those estimated for European conditions (ie 0.7 c/L). These estimates are likely to be generous and include costs to address fuel components other than just sulfur. These are the best estimates available at the current time.

A recent announcement by BP Amoco indicates the company will be producing a new ultra-low sulphur diesel which is estimated to emit 90% less sulphur dioxide and 30% less particulates than standard diesel. The new fuel is part of a $100 million investment in greener fuels that the company plans to sell at no extra cost to consumers. The cost to BP of producing reformulated "greener fuels" is not known, so it is assumed in this analysis that the above costs from Parsons are indicative for

Australia.

The above figures were applied to projections of annual average fuel consumption for the Australian fleet (Australian Institute of Petroleum) for petrol and diesel to estimate total fuel reformulation costs. The timing of the introduction of these costs has a significant outcome on the final results. For option 2 and option 5, the cost of reformulation of diesel is assumed to be delayed until 2005. This is based on the assumption from engine manufacturers and importers that heavy-duty diesel engines are still able to perform to the European standards using existing diesel fuel quality.

Total fuel consumption figures were adjusted for imports of fuel, as the cost of reformulation would be borne outside Australia. Diesel imports averaged 6.3% and petrol imports 3.7% over the last three years (Australian Institute of Petroleum).

The introduction of a goods and services tax on fuel consumption may have a marked impact on the demand for fuel. If the excise duty on diesel fuel were removed the price of diesel would decline significantly leading to an increased demand. The Howard "Tax Package" states the cost of diesel would be cut 25 cents per litre (from 43 cents to 18 cents a litre). This needs to be considered in the context of future projections of fuel consumption of petrol and diesel.

6.3 Certification and compliance costs

Parsons (1999) estimate that the total cost to industry to upgrade emissions testing is approximately $4.5 million based on three key automotive emissions testing laboratories being upgraded (at a cost of $1 million each) plus the purchase of three new analysers (at $0.5 million each). Laboratory upgrade costs are assumed to be incurred for adopting Euro 3 standards but not for Euro 2.

Adopting Euro standards would involve additional certification costs particularly to Ford and Holden. Imported vehicles already with EU/ECE compliance are assumed to incur no additional cost. Industry estimates of certification costs to meet Euro 2 and Euro 3 are approximately $40 million per model. For these two key industry players the costs are therefore estimated at $80 million.

6.4 Total costs

The total costs to Australia in the first year of introduction of the new European standard are shown in the table below. The costs of adopting Euro 2 are significantly lower as it is assumed that there would be no additional fuel reformulation costs or laboratory testing upgrades. Fuel reformulation costs would apply in adopting Euro 3 hence the higher cost. The time lag between the adoption of new standards and implementation may have a significant effect on the real cost of the standard. Technology and hardware costs and fuel reformulation costs are assumed to be ongoing over the whole period of the analysis while laboratory upgrades and certification costs are one-off upfront costs.

Table 6. Total costs of Euro standards (A$/1999) for first year of operation

Standard	Euro 2	Euro 3
Technology and Hardware	$88 million	$107 million
Fuel reformulation	$0	$161 million*
Laboratory upgrade	$0	$4.5 million
Certification costs	$80 million	$80 million
Total costs (year 1)	**$168 million**	**$352 million**

*Includes cost for both petrol and diesel fuel reformulation (note in some options that cost of diesel reformulation is delayed)
Source: Parsons 1999

7. Benefits of European standards

7.1 Estimates of health effects from past studies

As noted in the introduction, vehicle emissions are linked to a wide range of adverse health effects such as respiratory disease (including asthma) and heart disease. The social and economic cost of these health impacts is considerable. Air pollution costs have been estimated at around 0.2% of GDP (BTCE 1994). With Australia's GDP at $444.6 billion in 1996-97 (ABS 1998) this equates to around $889 million pa. The Bureau of Transport and Communication Economics surveyed the international literature to broadly assess the total national costs of air pollution in other countries. Although each study used a wide range of techniques and assumptions, it is interesting to note that the estimates are in the same order of magnitude, ranging from 0.15% to 1.04% of GDP. In mainland China, the World Bank has estimated that the damage bill due to air and water pollution is a staggering 7.7% of GDP (AFR 1999).

The National Environment Protection Measure (NEPM) for ambient air quality, developed by the National Environment Protection Council (NEPC), sets national standards for six pollutants: carbon monoxide, nitrogen dioxide, photochemical oxidants (as ozone), sulfur dioxide, lead and particles (as PM_{10}). A cost-benefit analysis was undertaken on the NEPM indicated benefits significantly outweighed costs.

The Inter-State Commission made an attempt to estimate the costs of vehicle emissions in Australia in 1990 based on a similar study undertaken in the US. Using data on the rates of emissions and damage costs the Inter-State Commission estimated the annual cost of emission to be $786 m (NRTC 1995).

The National Road Transport Commission (1995) undertook a review of health costs associated with vehicle emissions. The report concludes that health costs to Australia are "likely to fall within the range of $20 to $100 million with $50 million suggested as reasonable midpoint". The analysis is based on a fairly arbitrary estimation of 0.1% of cancers and 0.1% of respiratory illnesses attributable to road vehicle emissions. The study produces a very low estimate of health costs because it only examines two health end-points, cancers and respiratory disease. The report concludes that more understanding is needed on the impact of vehicle emissions on health.

A study by Simpson and London (1995) of Griffith University Queensland estimated that the economic cost of current air pollution in the Brisbane city council area is in the range $254 million and $462 million per year. Of the total health impacts mortality effects from particulate pollution account for around 90% ($230 million to

$415 million) while morbidity effects account for the remainder. Ozone impacts were considerably less but estimated to account for $2.5 million in costs per year.

Morrison and Bernauer (1995) identified the external costs of petrol consumption in NSW. They estimated the health impacts due to air pollution from particulates, ozone and lead emissions were $232 million per year for particulates, $49 million per year for ozone and $294 million year for lead. The external cost associated with loss of visual amenity was estimated at $77 million per year. In addition, significant external costs associated with pollutants such as benzene and carbon monoxide were not quantified in the study.

7.2 Approach to estimating health impacts

Apart from directly quantifiable health and medical treatment costs, the *social* and *personal* costs of illness and disease are very high but cannot be readily quantified in monetary terms. Willingness to pay studies can estimate these costs but this has not been attempted in the analysis. There is often conjecture over the certainty of the relationship between emissions and health effects. However, there is growing evidence in Australian and international research that continuing exposure to air pollutants is having many detrimental health effects on urban populations. Dose response[1] relationships have been demonstrated to be significant for particulate matter, nitrogen dioxide and ozone.

The omission of health costs can seriously affect the results of decision-making processes. The Advisory Committee on Vehicle and Noise (ACVEN) in their review of ADR 37/01 emission controls for light vehicles notes that "*The absence of health costs represents a significant gap in the information required to justify a change to the current new emission standard"* (ACVEN 1997). The results of this paper will help fill this information gap.

The uncertainty of health effects does not necessarily mean the impacts should be ignored or remedial measures delayed. Ecologically sustainable development requires the effective integration of economic and environmental issues in decision- making processes. The precautionary principle is now a key tenant of ecologically sustainable development and embodied into a wide range of environmental law. This principle states that "if there are threats of serious or irreversible environmental damage, lack of full scientific certainty should not be used as a reason for postponing measures to prevent environmental degradation" (POEO Act 1998).

Determining the benefits of avoided health costs is a difficult exercise given a complex chain of factors that interact to cause air pollution. The BTCE (1994) study outlines a series of steps in the "causal chain". These can be summarised as follows:

Traffic volumes i:: primary emissions i:: secondary pollutants i::
air quality i:: human exposure i::dose response i::
health effects i:: health costs

[1] Dose response relationships are one of the criteria used to assess causality (cause-effect relationship). A strong relationship between the level of exposure to the factor being studied (the "dose") and the outcome being studied (the "response") suggests a true causal relationship exists.

Adopting the health costs estimated in overseas studies may be problematic as each country has different health standards and costs that may not be applicable to Australia. Another approach is to take the total cost of the health problem within Australia (such as hospital admissions, loss of work days etc.) and apply the dose response relationship that is attributable to motor vehicle emissions as estimated by medical studies. This approach accounts for Australian conditions and costs rather than relying on generalised international estimates. International studies play a critical role however, by providing dose response relationships and comparative estimates of costs.

7.3 Particulates

Particle pollution was one of the first types of air pollution to be associated with serious health effects. Of particular concern are fine particles, which are those less than 10 µm (PM_{10}). Fine particles can lodge in the lungs and cause irritation and disease. The main health effects of fine particles include:

- increased frequency of asthma attacks
- increased activity restrictions due to adverse lung reactions
- increased potential for severe respiratory distress and heart attacks
- increased mortality due to heart disease and respiratory illnesses.

The dose-response relationships between increases in particles and health impacts including mortality are well established. Overseas studies (Dockery & Pope 1994, Morgan et. al. 1998 and WHO 1994) have consistently shown that each 10 $\mu g/m^3$ increase in the 24 hour average for PM_{10} results in a 1% increase in daily mortality (all causes), a 3.4% increase in respiratory mortality and a 1.4% increase in cardiovascular mortality. There were similar results in the NSW Health and Air Research Programs (HARP) studies (see Morgan et al 1998a), which found an association between increased particle pollution and hospital admissions, and in daily mortality in Sydney. The National Environment Protection Council noted that these studies indicated that fine air particles account for almost 400 premature deaths in Sydney per year (1.8% of total deaths per year) (NEPC 1998, p138).

Notably, the observed health effects of PM_{10} appear to occur independently of the presence of other pollutants such as ozone, nitrogen dioxide and probably sulfur dioxide. WHO (1994) has not set a guideline for fine particles because of the absence of a threshold below which there are no effects, indicating the significant relationship between fine particles and health. This is supported by Morgan's (Morgan et al 1998) conclusion that the linear dose-response relationship between particulates and all-cause mortality showed no evidence of a threshold effect. This analysis assumes that there is no safe minimum level of exposure for the health effects of fine particulates.

The costs of particulate matter to human health are estimated in terms of mortality, morbidity and health treatment costs and described in Appendix 2. A brief discussion on estimating the value of a statistical life is given in Appendix 1.

The total estimated health costs avoided has been estimated to be mortality ($15,128) + morbidity ($2,217) + health treatment ($21,700) from a one-tonne reduction in fine particulate discharges. This represents in total $39,045 per tonne.

The above estimate was applied to the modelled PM_{10} reductions to estimate the health benefits from adopting Euro standards. PM_{10} reductions are projected to reduce by an average of 213 tonnes per year with Euro 2 and 580 tonnes per year with Euro 3 per annum.

Note that the total health costs avoided underestimate the full extent of benefits as chronic effects have not been taken into account. For example, asthma sufferers may require increased use of ventilin on high pollution days, those with other respiratory problems may experience discomfort and loss of energy. These effects have real economic and social effects on the exposed population but the monetary cost has not been valued in this analysis. As an indication of likely costs the US EPA value shortness of breath at $8.13 per day.

7.4 Nitrogen dioxide

NO_2 is an oxidising agent and can cause both short and medium term health impacts. It is one of the several oxides of Nitrogen (NO_x) which is largely produced by human activities such as combustion processes. Around 80% of ambient NO_2 comes from motor vehicles. Significant health effects from NO_2 can include:

- reduced lung function leading to increased potential for respiratory infection
- increased frequency of asthma attacks
- increased potential for heart disease and related complications
- a possible link between NO_2 and respiratory related deaths.

Nitrogen dioxide appears to exert its effect on the human organism both directly, leading to an inflammatory reactions in the human lung, and indirectly by the induction of relative impairment of immune defence mechanisms in the lung. Epidemiological studies suggest that young children are especially susceptible to these effects, resulting in the onset of respiratory infections following disturbances in immune defence mechanisms.

Nitrogen dioxide appears to contribute both to morbidity and to mortality, especially those susceptible subgroups such as young children, asthmatics, and in those individuals with chronic inflammatory airway disease (chronic bronchitis and related conditions). The NSW HARP studies found a strong correlation between increases in ambient NO_2 levels and hospital admissions for asthma and heart disease.

Acute exposure to nitrogen dioxide at 0.2 to 0.3 ppm can decrease lung function and increase airway responsiveness in mild asthmatics. Controlled exposure studies have shown varied results. Some epidemiological studies have shown associations between NO_2 concentrations and an increased risk of respiratory illness in children aged 5 to 12 years at annual average NO_2 levels of 0.04-0.08 ppm (75-151 $\mu g/m^3$), while others have not identified such links. Asthmatics and people with existing lung diseases are most susceptible to respiratory effects of NO_2.

The analysis of the health related data for short term exposures indicate that the lowest effect level is around 0.2-0.3 ppm and with the use of an uncertainty factor to ensure adequate protection of the most vulnerable sub groups of the population the guideline range of 0.1-0.15 should be used. Chronic exposure data from epidemiological studies for indoor exposures indicate health effects at levels of 0.04-

0.08 ppm., and some studies using ambient nitrogen dioxide concentrations found associations with incidence and duration of respiratory symptoms at in children at 60- 140 g/m^3 (approx. 0.03-0.07 ppm).

A wide range of studies undertaken in the US and Europe has estimated the damage effects of NO_2 on human health. The estimates from 16 separate studies that examined damage costs and avoidance costs range from a low of $3.50 per tonne to $6,000 per tonne. The median estimate of avoided health and damage costs is $1,385 per tonne of NO_2 (NSW EPA 1997c). This estimate has been applied to the modelled reductions in NO_2 that result from adopting the Euro standards.

7.5 Hydrocarbons – Air Toxics

Motor vehicles emit a wide range of hydrocarbons which are photochemicaly reactive organic compounds, sometimes referred to as reactive organic compounds (ROC) or non-methane hydrocarbons (NMHC). These compounds play an important role in the formation of ozone. Many of these compounds are also known or probable carcinogens. The impact of ozone is dealt with in the next section and the general impact of hydrocarbons from motor vehicles is addressed below.

Much attention is paid to benzene, which along with other aromatics, such as toluene, xylene and ethyl benzene, are important in the refining process as they increase the octane rating of petrol to that required by modern engines. In contrast to lead, benzene is not added to petrol rather, it is present in the crude oil and is produced via refinery processes (e.g. Reforming) and petrol combustion in engines.

About 80% of the benzene emitted from motor vehicles is in the exhaust gases. Benzene is also produced from the combustion of other aromatics in the fuel.
Vehicles produced since 1986 have used catalytic converters to clean up exhaust gases. This also reduces the emissions of benzene by up to 90% of that of a pre- catalyst vehicle.

Ambient benzene levels are the primary exposure for the general population and are directly related to motor vehicle usage (accounting for 76% to 85% of ambient benzene concentrations).

Hydrocarbons contain air toxics, such as 1-3 butadiene and benzene, are of concern because they are known to cause cancer. Benzene ambient air levels as a result of motor vehicle emissions have led to future predictions of cancer rates in large cities. Reductions in hydrocarbon exhaust emissions and evaporative emissions and durability required by Euro 3 should also reduce many air toxics such as benzene.

Motor vehicles are reported (Metropolitan Air Quality Study, NSW EPA 1997a) to emit some 10 tonnes per day of benzene in Sydney. San Francisco has a similar airshed to Sydney, and has previously experienced worse air quality. As a consequence of controls on engines and fuel, levels of benzene in San Francisco have fallen below levels measured in Sydney. Data for 1995 shows the annual average to be 0.95 parts per billion (ppb), compared to Sydney levels of 1.2 ppb annual average for outer Sydney and Central Sydney of 2.5 ppb (Bay Area Air Quality Management District, monitoring data for 1995). San Francisco's benzene levels for 1997 have continued to fall with levels about 0.6 ppb.

Studies from the US and Europe on human health effects of hydrocarbons has estimated the damage costs at between $90 and $10,130 per tonne (NSW EPA 1997c). The median estimate from these studies is $1,440 per tonne and this estimate has been assumed to provide a reasonable indication of the health costs avoided per tonne reduction in hydrocarbons. This estimate has been applied to the modelled reductions in hydrocarbons that result from adopting the Euro standards.

7.6 Ozone

Photochemical oxidant is a term used to describe a complex mixture of chemicals produced in the atmosphere by the action of sunlight. It is commonly known as photochemical smog. The principal component of photochemical oxidant is ozone: also present are formaldehyde, other aldehydes, and peroxyacetyl nitrate (PAN). Measurements of photochemical oxidant (and standards relating to it) are usually referenced to ozone.

Ozone is a secondary pollutant ie. it is not emitted directly but is formed in the atmosphere by the reaction of various precursor compounds. These include oxides of nitrogen (NOx) and photochemically reactive organic compounds, commonly referred to as reactive hydrocarbons, or reactive volatile organic compounds (ROCs), non methane hydrocarbons (NMHCs), or just hydrocarbons. Many chemical reactions and intermediate products are involved, and the reactions are driven by energy in the form of ultraviolet light.

There is strong supportive evidence from clinical, epidemiological and controlled exposure studies, of health effect associations at ambient ozone levels normally encountered in Australian cities. Health effects associated exposure to ozone include minor changes in lung function, increased symptoms consistent with airway irritation, leading to increased requirement for additional medication as well as medical and hospital services. There is also evidence of a slight but clearly present increase in mortality, chiefly from cardiovascular causes, especially in the elderly.
Exercise enhances the effects of ozone on lung function.

Most evidence of the effects of ozone come from studies and observations in North American and European cities. Recent studies in Sydney assessing various health outcomes including mortality and morbidity confirm the reproducibility of overseas health responses to ozone exposure in Australia. There is no reason why similar responses would not be observed in other Australian cities.

There is consistent evidence to suggest that there are specific subgroups in the population, in particular asthmatics, which are more susceptible to the adverse health effects from ozone exposure, and individual susceptibility is wide. There is also an increasing body of literature which details the interaction of ozone with other pollutants, in particular, the enhancement of the effects of ozone as a result of prior or concurrent exposure to particles, nitrogen dioxide, airborne allergens, and sulfur dioxide, and conversely, for people with asthma, sensitisation to other agents by exposure to ozone.
No threshold exposure level can be identified for ozone. There is a monotonic relationship between increasing ozone concentration and adverse health effects.

WHO has classified the overall effect of exposure to 1 hour ozone concentrations of between 0.05 and 0.10 ppm as 'mild'. In this range, of exposures, eye, nose and throat irritation would probably occur in a sensitive minority, an average FEV_1 (Forced Expiatory Volume - 1 second) decrement in the whole population, and a 10% decrement in FEV_1 in the most sensitive 10%. Other effects include some chest pains and cough, and slight reductions in peak athletic performance.

A 5% - 10% decrement in FEV_1 is considered significant in clinical terms and decrements of 10% and 20% are highly significant, particularly for susceptible subgroups. Under current exposure and regulatory regimes, the maximum probability that a 10 % decrement in FEV_1 is 1.3 %. The concentration at which this maximum probability occurs is 0.082 ppm and the affected population is approximately 6 million. This means the maximum expected cases per year with a 10% decrement in FEV_1 is approximately 78,000.

Current effects of air pollution for various health end points have been estimated by Simpson and London (1995) for the Brisbane City Council and could be extrapolated nationally. For various reasons, these are likely to be underestimates. Not all health points have costing data. For example the maximum expected occurrence of a 10% FEV decrement is close to 1 million cases, and the significance of this, and the effects cannot be estimated. Likewise, no deaths have been ascribed, although the health study indicates a small but clear relationship with ozone. There has been no estimates of the potential effects and long term costs of lung ageing, and none of the other distinct but subtle structural and biochemical changes. The assumed threshold of effects has been 0.08 ppm although the medical data suggests a zero threshold.

One of the key points to consider is the large number of minor symptoms estimated for ozone exposure. These include the combined incidence of one or more of sore throat, cough, headache, chest discomfort, and eye irritation is estimated at between 6 and 20 million incidents per annum. There are clearly very large impacts of irritating symptoms potentially affecting productivity, as well as general wellbeing.

The health impacts of ozone have not been calculated for this analysis since ozone is a secondary pollutant and including the effects may lead to double counting of the impacts.

7.7 Carbon Monoxide

Carbon Monoxide (CO) is a colourless, odourless, toxic gas produced by the incomplete combustion of organic compounds. The primary health effect of carbon monoxide is to reduce the oxygen carrying capacity of the blood. In ambient concentrations, CO can affect the functions of the brain, lungs, heart and ability to exercise, all of which are sensitive to blood oxygen content. Exposure to high CO levels is also associated with low birth weights in infants. Recent evidence from several countries suggests that fluctuations in CO levels increase the risk of hospital
admissions or death due to cardiovascular disease (UKDOH 1998). A rise of $10mg/m^3$ is associated with increases of about 10% in all-cause mortality and 20% in hospital admissions for cardiovascular diseases. These associations have been estimated in studies from the UK, Canada and US (UKDOH 1998).

Studies from the US and Europe on human health effects of carbon monoxide has estimated the damage costs at between $6 and $45 per tonne (NSW EPA 1997c). The median estimate from these studies is $12 per tonne and this estimate has been assumed to provide a reasonable indication of the health costs avoided per tonne reduction in CO. This estimate has been applied to the modelled reductions in CO that result from adopting the Euro standards.

8. Other benefits and costs not quantified

8.1 Investment Opportunities

Australia is in a strategic location to the Asia pacific region that is predicted to grow immensely over the next 2-3 decades. If Australia is to maintain its competitiveness as a centre for economic activity then keeping the air clean will provide attractive incentives for significant investments. There is global competition between cities not just for hosting the Olympic games but for attracting business investment that is environmentally friendly and brings the potential to create wealth. Many of the service industries such a telecommunications and information technology firms fit these criteria.

For example, when international companies are making a decision on where to locate their corporate headquarters, Sydney or Melbourne could be seen to have the edge over other Asia-Pacific cities on environmental grounds. Australian cities have many advantages over other cities, including political stability, public safety, favourable climates, natural attractions, low population density and public infrastructure.

The correlation between location decisions by corporations and air pollution however, would be second order considerations. The impact of the quality of the environment however, is a real effect and would have some influence on such decisions.
American Express located its regional head offices in Sydney in 1993-94 bringing with it a direct investment of $84 million (AATSE 1997). AATSE estimate that the loss of one medium size business would result in the loss of $0.75 million per annum. This estimate however, has not been included in the analysis. Improving air quality in Australian cities can therefore be considered an important element in attracting investment and maintaining a competitive edge.

8.2 Visual amenity

Tourism plays a highly significant role in generating economic activity for Australia's economy. At present tourism generates around $14 billion in export income that equates to about 10.5% of GDP in direct and indirect effects. A large proportion of inbound tourists spend their time in our cities. The relative cleanliness of the environment (including our air) is one of the major reasons Australia is highly regarded as a destination for international visitors (DSARD 1999).

The AATSE (1997) propose that 5% of international visitors might be deterred from visiting polluted cities. This would result in a loss of tourism income of $0.7 billion per annum. AATSE consider this scenario is conservative given that over 70% of inbound tourists choose to visit Australia because of its natural environment and unique flora and fauna.

Morrison and Bernauer (1995) estimate the value of visual disamenity currently associated with motor vehicle usage in Sydney is approximately $77 million per annum.

People's perceptions of air pollution play a critical role in determining visitation to an area. The Sydney 2000 Olympic Games will provide an opportunity to showcase

Sydney and Australia as a whole as environmentally responsible. Improving emission standards in new vehicles signals that Australia is committed to improving urban air quality and achieving sound environmental outcomes.

8.3 Enhanced export potential

The value of Australian automotive exports in 1997 was $2.6 billion. This figure represents a six-fold increase since 1984 (DISR 1997). Export growth has averaged 20% per year over the last three years with vehicles making up an increasing proportion of the total (vehicles 50%, components 50%). Exports to Japan and Europe have declined significantly since 1988 with the growth markets being South Korea, NAFTA and ASEAN countries. A range of export programs has seen the Toyota Camry exported to the Middle East, Ford Falcon to South Africa and Mitsubishi Diamante to the USA.

Adopting international standards means Australia is better able to compete on the world car market and export vehicles with similar emission standards. While export programs will depend heavily on price and quality considerations, emission standards will play a small but important role in meeting the regulatory requirements of the destination country and thereby opening up new opportunities.

"As global rationalisation of vehicle models increases a single global standard will effectively develop……If Australian manufacturers do not aspire to international standards in an increasingly global market, they will limit their ability to export to a range of open world markets" (IC 1997, 284*).*

Similarly, the NRMA in its submission to the Automotive Industry Inquiry notes that *"Australian manufacturers are not encouraged to design vehicles for export, where they would be able to sell their product into any world market."* (IC 1997, 284).

An increasing number of multi-national companies are now designing products with an "environmental" angle. New technologies have the potential to significantly reduce emissions. If it is assumed that adopting more stringent new emission standards will encourage car manufacturers to embrace new technologies sooner, this will increase the potential to increase export earnings from both component engine and vehicle sales.

Japan formally adopted the United Nations/ European Economic Community (UN/ECE) emissions standards system in 1998. Similarly Korea, has announced its intention to adopt UN/ECE standards from 1999. US standards exceed current and future European standards. Exports to countries with Euro 3 standards or higher is shown in the table below.

Table 7. Automotive exports to UN/ECE emission compliant countries

Country	Exports ($m)	Share (%)
NAFTA	708,577,12	26.7
South Korea	373,068,33	14.9
Japan	216,733,90	8.2
Germany	73,017,63	2.76
Unite Kingdom	52,576,56	2
France	20,683,55	0.78
Belgium/Luxembourg	11,765,13	0.44
Rest of Europe	6,714,55	0.25
Italy	2,504,24	0.09
Spain	2,208,02	0.08

Source: State of Automotive Industry, Dept Industry Science and Resources 1997

It should also be noted that Australia may potentially lose existing export markets if emission standards are not equivalent to our trading partners. This cost has not been quantified for the analysis.

8.4 Infrastructure damage costs avoided

A significant increase in emissions could eventually lead to acid rain thereby damaging buildings, crops and the environment. In Australia this is not a prevalent problem as in parts of the US with localised heavy industries combined with motor vehicle pollution. Improved standards may lead to reduced long-term motor vehicle emissions which means these costs are avoided in the future.

8.5 Reduced greenhouse gas emissions

Adopting more stringent emission standards for motor vehicles could assist Australia to meet its commitments under the Kyoto Protocol at lower cost to the economy.

Calculation of overall net benefits

This section summarises the key assumptions and calculates the net benefits for each option.

As noted in section 6, technology and hardware costs are assumed to decrease by 4% pa over the period of the analysis. This may still over-estimate the actual costs as the cost of new technology in almost all industries has been shown to significantly decrease over time due to economies of scale and innovation. Technology and hardware costs are assumed to be incurred from one year prior to the introduction of the standard in view of the fact manufacturers would be developing prototypes and gearing up for new production technology.

Fuel reformulation costs are based on the average consumption of petrol and diesel estimates from Australia Institute of Petroleum extrapolated to year 2020 and adjusted for imports of petrol (3.7%) and diesel (6.3%). Cost estimates for fuel reformulation derived from Europe are doubled for diesel production in Australia to promote a conservative allowance for the higher sulphur content in Australian diesel fuel. As with technology and hardware costs, fuel costs are assumed to be incurred from one year before the introduction of the new emission standard.

Fuel reformulation costs are assumed to be incurred over the full period of the analysis years from the introduction of the standard. Note also fuel costs are conservatively assumed to remain constant over the 20 year period whereas the additional costs are likely to decline significantly over time (as with hardware and technology costs) due to technological advances and economies of scale. Fuel reformulation is the largest cost component of adopting Euro 3 standards.

Laboratory upgrade and certification costs are one-off costs that are assumed to be incurred one year before the introduction of the standards in order to give industry time to install new testing equipment and commence certification protocols.

The modelled reduction in pollutants shows that the most significant benefits do not occur until a significant number of new vehicles have penetrated the total vehicle fleet. The early years demonstrate very marginal reductions while later years show very significant reductions (see table 3). Euro 3 generates significantly greater reductions than Euro 2 in all levels of pollutants which is reflected in the results.

Applying the broad industry costs associated with each option as outlined in section 6 and the benefits from avoided health costs (section 7) from those pollutants that can be valued gives the following results.

Table 8. Net Benefits of Euro Standards ($NPV million 1999)

OPTION	1 Euro 2 @ **2002**	2 Euro 2 @ **2002** then Euro 3 @ **2005**	3 Euro 3 @ **2002**	4 Euro 3 @ **2005**	5 Cars-E2 then E3; Trucks – E3@2002
Costs*					
Technology and hardware	662	831	803	623	807
Fuel reformulation	-	1,199	1,287	1,199	1,084
Laboratory upgrades	-	3	4	3	3
Certification	70	65	70	57	63
Total costs	732	2,098	2,164	1,882	1,957

Benefits* (Health costs avoided from):					
Hydrocarbons	80	701	892	611	630
Nitrogen dioxide	409	1,150	1,409	963	1,071
Carbon monoxide	38	262	341	227	217
Particulates	324	793	882	621	884
Unquantified benefits: includes personal and social costs avoided, investment opportunities, visual amenity, export potential, infrastructure damage avoided and reduced greenhouse emissions	Not quantified	Not quantified	Not quantified	Not quantified	Not quantified
Total benefits	**851**	**2,716**	**3,523**	**2,423**	**2,762**
Net Benefits	**119 m**	**618 m**	**1,359 m**	**541 m**	**804 m**

(* All figures in Present Values discounted at 7% over 20 years) Note: figures may not add due to rounding

This analysis demonstrates that adopting Euro 3 standards for all vehicles in 2002 would produce a net gain to the Australian community in excess of $1.3 billion over the next 20 years. This result is largely comprised of the avoided health costs that stem from motor vehicle pollution. The result can be considered conservative, as a wide range of other benefits was not quantified for the analysis. Option 5, adopting Euro 3 for heavy duty vehicles in 2002 and then a phased introduction of Euro 2 in 2002 and Euro 3 in 2005 for passenger and light duty vehicles, would result in a second best option producing net benefits $804 million.

Sensitivity Analysis

Sensitivity testing was conducted in relation to the major uncertainties in the assessment. Two tests were undertaken:

1) Worst case scenario: 10% increase in costs and 10% decrease in benefits
2) Best case scenario: 10% decrease in costs and 10% increase in benefits The key parameters tested include:

Variable	Worst case assumptions	Best case assumptions
Fuel reformulation cost estimates	10% increase	10% decrease
Technology and hardware cost estimates	10% increase	10% decrease
Future fuel consumption estimates	10% increase	10% decrease
Certification costs estimates	10% increase	10% decrease
Value of life estimates for mortality impacts from particulates	10% decrease	10% increase
Modelled reductions in pollutant emissions	10% decrease	10% increase

This sensitivity testing produced the following results:

($NPV million 1999)

OPTION	1 **Euro 2 @ 2002**	2 **Euro 2 @ 2002 then Euro 3 @**	3 **Euro 3 @ 2002**	4 **Euro 3 @ 2005**	5 **Cars-E2 then E3; Trucks –**
Worst case scenario	-51	-20	618	-43	263
Base assumptions (most likely result)	*119*	*618*	*1359*	*541*	*804*
Best case scenario	291	1239	2080	1106	1331

Overall, sensitivity testing shows that significant changes in cost and benefit estimates for the major variables does not affect the relative ranking of each option. In absolute terms, options 3 and 5 still demonstrate positive net benefits even under the 'worst case' scenario assumptions.

The key cost differential between Euro 2 and Euro 3 is fuel reformulation costs. However, it was also found that, holding other assumptions constant, fuel reformulation costs would need to be increased 160% before adopting Euro 2 yielded higher net benefits than Euro 3 in 2002.

Incidence Analysis

The costs associated with adopting stronger emission standards would be initially borne by the car manufacturing industry and oil refinery producers in upgrading plant and equipment to comply with the new standards. However, these costs are dynamic in the sense that a new standard may force manufacturers and producers to become more innovative as they seek to minimise costs and adopt best practice technology. Some costs would be passed on to consumers by way of higher fuel and vehicle prices. However, import competition would limit the extent such costs could be passed on particularly for car manufacturers.

The benefits from avoided health costs would flow primarily to those with pre-existing health conditions such as asthma or bronchitis. Reduced health costs would also ease the burden on public health system through reduced hospital admissions and attendances and treatment costs. In addition, families would benefit through lower levels of sickness and less restricted activity days.

Conclusion

This analysis has examined the costs and benefits of adopting improved emissions standards based on European standards for new motor vehicles. The costs examined include technology and hardware, laboratory upgrades, fuel reformulation and certification costs. These costs assume that the fuel specifications and vehicle technology are upgraded in parallel in order to deliver the estimated pollution reductions.

On the benefit side, health impacts were found to be the major feature of the analysis. The link between air pollutants and human health was examined using dose response relationships. The health cost avoided per tonne of pollutant was then calculated for four major pollutants. These were particulate matter, carbon monoxide, hydrocarbons and nitrogen dioxide. Modelling work undertaken to estimate reductions in the MAQS region (NSW) was extrapolated to provide nation-wide estimates of emission reductions. The results under-estimate the health benefits as the health effects of some pollutants were not valued.

Of the five options presented, it was found that adopting Euro 3 standards in 2002 produced the highest net benefit of almost $1.4 billion to the community over the next twenty years. Euro 3 was also shown to generate larger reductions in key pollutants of CO, NO_2, HC and Benzene. This result is conservative because the personal and social costs of air pollution have not been estimated, nor the health benefits from reductions in benzene and ozone.

Adopting Euro 3 standards for heavy duty diesel (trucks) and Euro 2 for petrol vehicles (cars and light commercial) in 2002 progressing to Euro 3 later in 2005 produces a second best option with estimated net benefits of around $800 million.

Phasing in the introduction of Euro 2 in 2002 and then Euro 3 in 2005 for all vehicle types was estimated to produce net benefits of around $600 million but would result in significant forgone benefits comparison to the earlier introduction of Euro 3 in 2002.

The fourth ranked option, adopting Euro 3 in 2005, was estimated to generate net benefits of $541 million.

Adopting Euro 2 in 2002, without any commitment to the future adoption of Euro 3 standards, was estimated to produce net benefits of $119 million to the Australian community. Therefore the adoption of Euro 3 in 2002 was estimated to generate over eleven times as many benefits as adopting Euro 2 in 2002.

These results were shown to be sensitive to assumptions in the timing and magnitude of fuel reformulation, technology and hardware costs. It was conservatively estimated that technology and hardware costs, associated with vehicle emissions controls decline slowly over the period of the analysis, whereas often, the costs of technology decline rapidly due to innovation and economies of scale. The results also assume that fuel reformulation occurs in parallel with the new standards. If fuel reformulation is delayed, the impact of the modelled reductions in pollutants on the health benefits is likely to be small. This is due to the low level of penetration of new vehicles into the total fleet in the early years.

By adopting a higher standard at the time of a review, manufacturers would be better prepared to face inevitable changes to emission standards. It would also involve less marginal cost than undergoing a review again in a few years time since producers can begin re-designing models and investing in new technology.

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Appendix 1

Estimating the value of a statistical life

Some forms of air pollution increase the risk that people will die prematurely. To estimate the benefits of pollution reductions on mortality, it is necessary to use an estimate of the value of life. The US EPA (1997) undertook a major review of mortality valuation estimates (see also Viscusi 1992). The US EPA examined 26 policy-relevant value of life studies, five of which were contingent valuation (CV) studies that directly obtain willingness to pay (WTP) information from people. The remainder of the studies were wage-risk studies which base WTP estimates on the additional compensation paid to workers in riskier jobs. The value of life estimates range from A$0.92 million to A$20.8 million (using exchange rate of AUD$/US$0.65). Using a Weibull (statistical) distribution, the best estimate was taken from each study and produced a mean of A$7.38 million and standard deviation of A$4.9 million. It is interesting to note that all the WTP studies produced an estimate lower than the mean estimate generated by the distribution exercise. The US EPA (1997) present an extensive discussion on the methods used to value health and welfare effects from pollution (see appendix I of US EPA 1997).

A UK study by National Economic Research Associates (1998) recommends the use of WTP approach taking into account life expectancy, income and contextual factors based on how WTP varies with age and health state. The criticisms of the approach – dependence on marginal utility of income and ranking problems - can be accommodated by circumspect use of the approach, using appropriately selected distributional weights. These, however, may be seen as arbitrary. Using the approach and distributional weights suggested in the paper, the value of a statistical life in Australia is estimated to be between $6 million and $9.5 million, depending on type of health impact and age.

This analysis adopts the estimate of $7.38 million as estimated by the US EPA. This is considered a reasonable approximation of the willingness to pay to avoid premature death from air pollution.

Appendix 2

Health effects of Particulates

Mortality

The 1992 Metropolitan Air Quality Study (NSW EPA 1992) estimated a total particulate load of 100 000 tonnes from all sources in the Sydney, Hunter and Illawarra area. Based on available data it is conservatively assumed for this analysis that approximately 40 000 tonnes of this comprised PM_{10}. The mean ambient PM_{10} loading for the greater Sydney region (incorporating the Sydney, Illawarra and Hunter regions) is approximately 23 ug/m^3 (NSW EPA 1997a). Assuming a linear relationship between changes in total pollutant load and ambient conditions at the margin, a one-tonne reduction in fine particulate loading represents a 0.000575 ug/m^3 reduction in mean ambient fine particulate loading in the Sydney region. It is assumed below that for locations outside the Sydney, Hunter and Illawarra regions, conditions are such that ambient loadings are negligible, and a one tonne reduction in fine particulate loadings has no effect on ambient levels of fine particles.

Based on studies by Schwartz and Dockery (1992 a,b) and Schwartz (1991), a Department of Energy and Minerals study adopts a mortality effect of 0.775 deaths per 100 000 for each 1 ug/m^3 increase in average annual PM_{10}. Ambient fine particulate conditions in the greater Sydney area are lower than United States EPA and Californian guidelines (NSW EPA 1997a). Given this, it would be expected that the majority of health impacts would occur among those most sensitive to air pollution – those with respiratory illnesses such as asthma or bronchitis. The National Health Survey conducted by the Australian Bureau of Statistics (ABS) in 1989-90 estimated that 34.4 out of every 1000 people have bronchitis and 81.5 out of every 1000 people have asthma. Allowing for some overlaps between the groups, approximately 10% of the population could be affected by fine particulate and other air pollution.

With a population of approximately 4.6 million residing in the Sydney, Hunter and Illawarra regions, approximately 460 000 people will be affected by fine particulate pollution. (This estimate is consistent with a Victorian EPA (1997) study which indicates the incidence of asthma in Melbourne at 120 000 per 1 million people). Given an affected population of this size, each 1 ug/m^3 increase in annual average PM_{10} would result in 3.6 statistical deaths annually in the Sydney, Hunter and Illawarra area. This estimate appears very conservative, given the findings of a recent NSW Health study (Morgan et al 1998) from which an estimate could derived of over 400 premature deaths in Sydney each year associated with fine particulate pollution.

Using the results of US EPA for the statistical value of life ($7.38 million in 1997) and the Schwartz and Dockery mortality rates, the mortality cost of fine particulate pollution is $26.3 million for each 1 ug/m^3 increase in annual average PM_{10}. To estimate the mortality cost per tonne for the existing level of particulate pollution we must multiply the total cost by 23 ug/m^3 (existing mean ambient measure of PM_{10}) and then divide by 40 000 t. This equates to a cost of mortality of $15,128 per tonne of fine particulate discharges. The estimated cost in regions outside of greater Sydney (ie. metropolitan areas including Newcastle and Wollongong) are assumed to be zero for fine particulate pollution from motor vehicles.

Morbidity

Morbidity effects of particulate pollution can be measured in terms of 'restricted activity days' (RADs). Based on US studies, the Department of Energy and Minerals (1993) estimates that fine particulate pollution causes an additional 5690 RADs per 100 000 people for each average annual change in ambient levels of PM_{10} of 1 ug/m^3. Assuming the average daily wage rate is a reasonable proxy for estimating the cost of a RAD, and given the average daily rate of $147.34 (ABS 1998), then this amounts to a cost of $838 364 per 100 000 people for each average annual change in ambient levels of PM_{10} per ug/m^3. Note that this value is believed to understate significantly the actual cost of morbidity because it ignores subjective individual losses and additional stresses placed on families with sickness. Given the effected population described above, this amounts to a morbidity benefit in the greater Sydney region of $2,217 per tonne of avoided fine particulate discharges.

Health Treatment Costs

As noted earlier, international research is demonstrating a growing consistency in the links between PM_{10} and adverse health. The UK Department of Health (1998) have estimated that for each 1 ug/m^3 daily increase there is a 0.326% increase in chronic obstructive airways disease (COAD), a 0.08% increase in respiratory admissions and a 0.07% increase in cardiovascular admissions.

Taking the total health costs of these key diseases and attributing the proportion of the total cost associated with PM_{10} can provide an indicative estimate of the health impacts of PM_{10}. The average treatment cost of these conditions and total number of admissions is given in the table below.

Table 9. Health costs and admissions in NSW

Condition	Average Cost (NSW average)	No. of Admissions (Sydney only)
(COAD)	$17,196	3,540
Bronchitis and Asthma	$5,517	8,942
Other Respiratory	$5,283	26,243
Heart disease	$2,368	17,228

Source: NSW Dept of Health

The estimate of total health costs avoided may under-estimate the total cost as areas outside Sydney are excluded and a higher average cost of treatment is more common in Sydney. Further, chronic (ie. ongoing long-term) cost effects of particulate pollution are also excluded from the analysis.

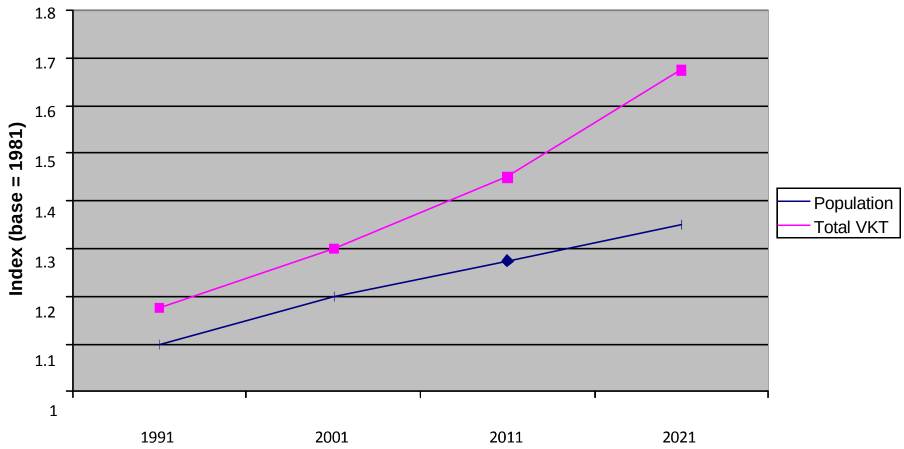
Applying the dose response relationships outlined above, the total health treatment costs of fine particulate pollution is $48.8 million for each 1 ug/m^3 increase in annual average PM_{10}. This translates into a health treatment cost of $21,700 per tonne of PM_{10} of discharged. Again this under-estimates the total health costs, as the analysis does not consider hospital attendance or cases not reported. The analysis also excludes the health costs to people that experience complications of existing health problems due to exposure to PM10. For example, the UK Department of Health (1998) estimate that every 1 ug/m3 increase in PM10 results in a 0.2% increase in bronchodilator use, meaning asthma suffers experience additional costs on high pollution days.

Appendix 3

Framework for assessment of impacts of options for new ADRs

1. This appendix outlines the key assumptions that underpin the emissions projections. Figure 1 shows projected growth for the Sydney-Newcastle-Wollongong region. This was developed by the NSW Department of Transport as part of its transport forecast model.

Figure 1 - Projected growth



(Source: NSW EPA 1998)

2. Figures 2-5 show the projected emissions for the whole vehicle fleet in the Sydney-Newcastle-Wollongong region covered by the Metropolitan Air Quality Study (MAQSR) prepared by the NSW EPA in 1999. These graphs show estimated emissions under four scenarios and represent the data used to calculate the benefits of each scenario:

- Business as usual – projected baseline, incorporating the impacts of ADR37/01
- Euro 2 for all vehicles in 2002/3
- MVEC proposal, labelled here as the 'hybrid' option
- Euro 3 for all vehicles in 2002/3

Figure 2 - HC emissions, Sydney region

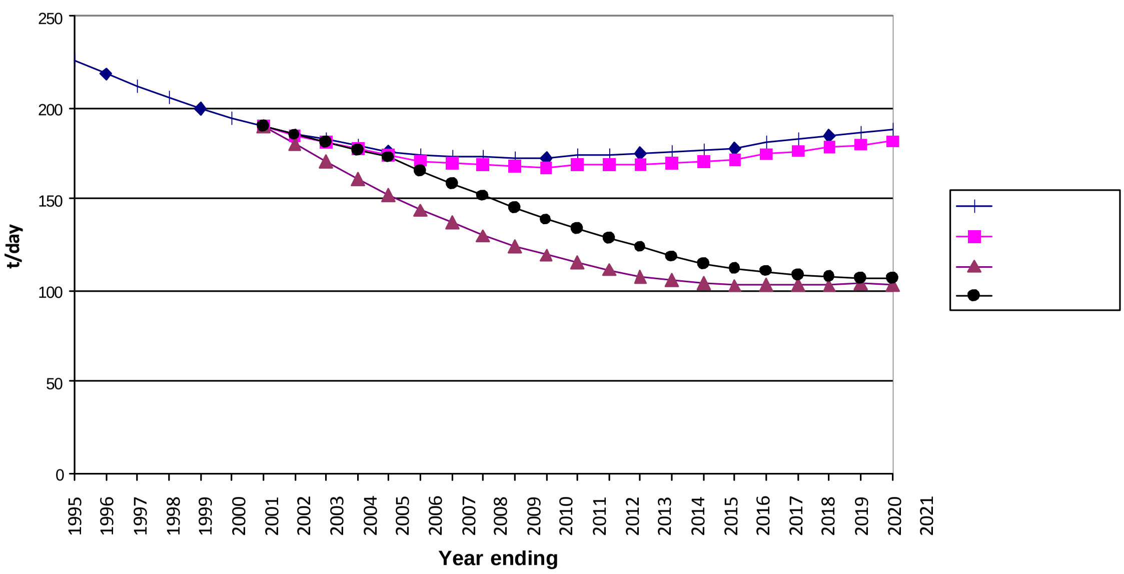


Figure 3 - NOx emissions, Sydney region

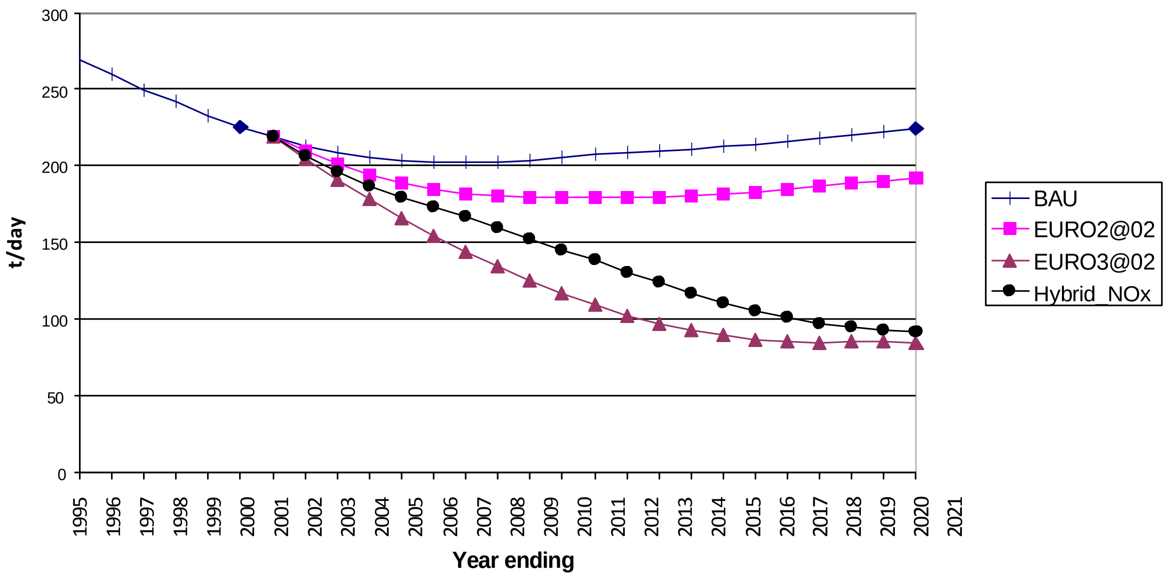


Figure 4 - CO emissions, Sydney region

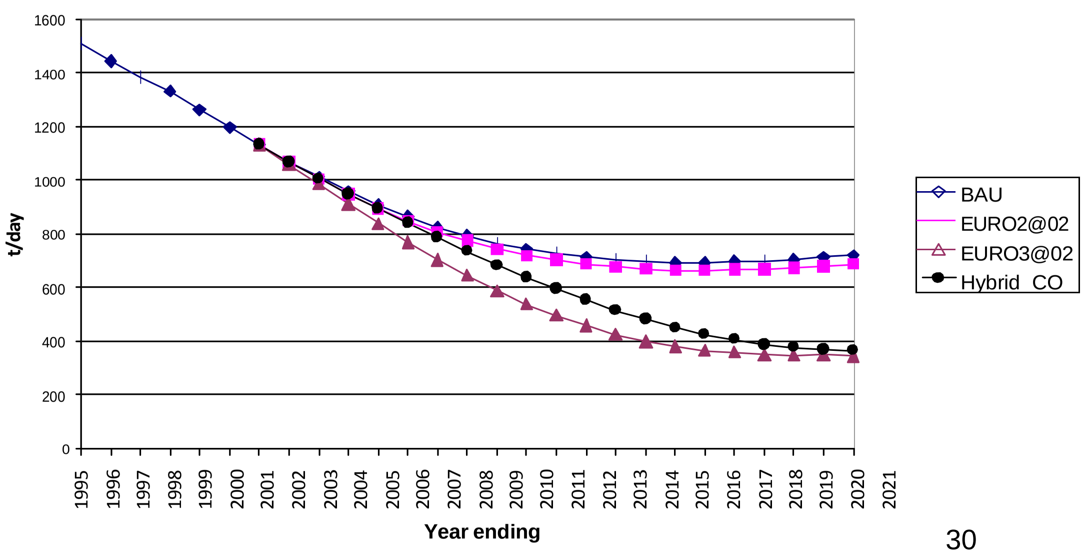


Figure 5 - PM10 emissions, Sydney region