

## CHAPTER 2: Transport Vehicles/Aviation

### INTRODUCTION

Transport activities in total are the most significant contributor to ambient air pollution. Road vehicles, because of their numbers and their use throughout the main population centres, are the dominant source of transport pollutants. Cars and light commercial vehicles (LCVs) account for 82% of all passenger kilometres (BTCE, 1991) with buses accounting for a further 7%.

Other transport modes cannot be overlooked. Rail and air provide approximately 4 and 6% of total passenger kilometres respectively. In particular, air transport has potential to impact on air quality in areas close to large airports.

Rail and maritime operations have only a marginal *direct* impact on air quality, and as a source of pollution are minor. However, trains and ferries play a major role as an alternative form of transport to get people out of their cars and can make very a significant *indirect* contribution to reducing pollution.

Concerted action to deal with air pollution has been hampered to some extent by an overly complex presentation of the issues, inadequate consideration of indoor and outdoor exposure aspects and lack of coherence and objectivity in the debate. While industry has generally participated willingly in discussions on possible responses, it has in some cases had a marked reluctance to move away from the status quo on the grounds that the benefit and effectiveness of proposed initiatives are not fully understood.

This chapter and SR 2 aim to distil the scientific and technical complexities into straightforward policy options involving practical measures that will deliver real results at a minimum cost to the community.

### MOTOR VEHICLES

#### Road Vehicle Fleet Characteristics

The number of registered vehicles continues to increase steadily. Total registrations increased from 8,832,800 in 1984 to 10,947,530 in 1995. During that period, passenger vehicle registrations increased by 30% (1.99 million), while light commercial, truck (both rigid and articulated) and bus registrations combined have increased 13.4% (232,026). Motor cycle registration decreased by 25.6% (101,772) over the same period.

**Table 9: Australian vehicle fleet composition**

Type of Vehicle	1984	1995	% change
Passenger vehicles	6,636,200	8,628,806	30.0
Light commercial vehicles <sup>a</sup>	1,121,000	1,527,212	36.2
Rigid trucks <sup>a</sup>	520,600	337,421	-35.2
Articulated trucks	49,100	58,322	18.8
Non-freight trucks	47,200	46,971	-0.5
Buses <sup>a</sup>	60,500	52,170	-13.8
Motor cycles	398,400	296,628	-25.6
<b>Total<sup>b</sup></b>	<b>8,852,800</b>	<b>10,947,530</b>	<b>23.9</b>

Source: ABS catalogue nos. 9303.0 and 9304.0

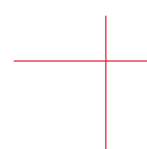
Note: (a) A change in the classification since 1991 has caused an apparent decrease in the registrations of rigid trucks and buses and a corresponding increase for light commercial vehicles. If the two vehicle types are grouped together, total registrations have increased steadily.

(b) Total excludes plant and equipment, caravans and trailers.

### Vehicle Age Profile

From 1993/94 to 1994/95, new passenger vehicle registrations increased by less than 1% to 531,758 units. Light commercial vehicle registrations decreased by 2.5% to 86,667 units, while new registrations of trucks and buses decreased by 16.1% to 18,990. New registrations are indicative of new vehicle sales.

Table 10 below illustrates the dominance of older vehicles in the Australian road transport population. Of the total 10.6 million vehicles registered nationally, around 5 million are 10 years or older. The Australian vehicle fleet is quite old in comparison with other countries that have similar levels of automobile ownership and use.



**Table 10: Age profile of the Australian vehicle fleet**

<b>Year</b>	<b>Age in Years</b>	<b>Passenger</b>	<b>Light Commercial</b>	<b>Others</b>	<b>Total</b>
1995	Under 1	173,773	28,340	5,738	207,852
	Under 2	501,174	87,698	20,402	609,274
	Under 3	453,870	73,897	17,374	545,141
	Under 4	433,543	73,665	17,109	524,317
	Under 5	414,222	63,695	15,427	493,344
	Under 6	494,652	79,619	22,290	596,561
	Under 7-9	1,280,150	193,518	64,251	1,537,919
	Over 10	4,857,835	920,906	328,864	6,107,605
	Unknown	19,587	5,873	3,429	28,889
	<b>Total</b>	<b>8,628,806</b>	<b>1,527,212</b>	<b>494,884</b>	<b>10,650,902</b>

Source: (ABS 1997)

A consequence is that emissions and safety benefits of new vehicle technologies have yet to be fully realised. For example, it was only in 1994 that sales by volume of unleaded petrol exceeded those for leaded fuel.

The most rapidly growing segment of the vehicle fleet, in VKT terms, is LCVs. For these, emissions standards have, in the past, been less regulated than for passenger cars. Only in 1997 have catalytic converters been required on petrol driven LCVs.

### **Basic Policy Options**

At the heart of all the technical arguments and analyses, there are just two basic policy directions for dealing with pollution from transport vehicles. These are to:

- reduce vehicle use; and
- clean up the vehicles.

Opportunities for the former are primarily allied to urban design, transport logistics and a range of economic measures. As such, they are being dealt with by other Task Groups attached to this Inquiry.

### **Cleaning Up Vehicles**

Measures directed towards the optimisation of the vehicle fleet may be divided into three priority areas:

- ensuring that transport vehicles are intrinsically low polluters when they are first brought into service;
- ensuring that transport vehicles maintain compliance with realistic standards, based on those they had to meet when new; and
- providing the cleanest, economically viable fuels to operate the vehicles.

Among the many options that can be identified to reduce pollution from transport, a relatively small number of key actions will deliver the greatest impact. It is these measures that should form the basis of future action. This is not to say that other measures should be put aside. If they have value, their use should be encouraged and they should be taken up where it is cost-effective to do so. However, by focusing efforts on a relatively small number of high return measures, it should be possible to achieve significant improvements in urban air quality.

### **Implications of “Business as Usual”**

Air quality in our major cities has, with respect to ozone levels, essentially been maintained over the last decade or more. Lead levels have fallen dramatically. This has been largely due to the effects of measures taken in the mid-70s and 80s, most recently in 1986 with the introduction of catalyst based emission control systems on petrol vehicles that reduce emissions of photochemical smog-forming NO<sub>x</sub> and VOCs.

The accompanying charts (Figures 31, 32 and 33) show that, for the private vehicle fleet, the Australian Design Rule (ADR) standards now coming into effect will reduce CO and VOCs by up to 50% by 2015 and the less tractable NO<sub>x</sub> by up to 25%.

Two recently introduced standards (ADR37/01 for gasoline vehicles and ADR70/00 for diesel vehicles) will in due course deliver further substantial

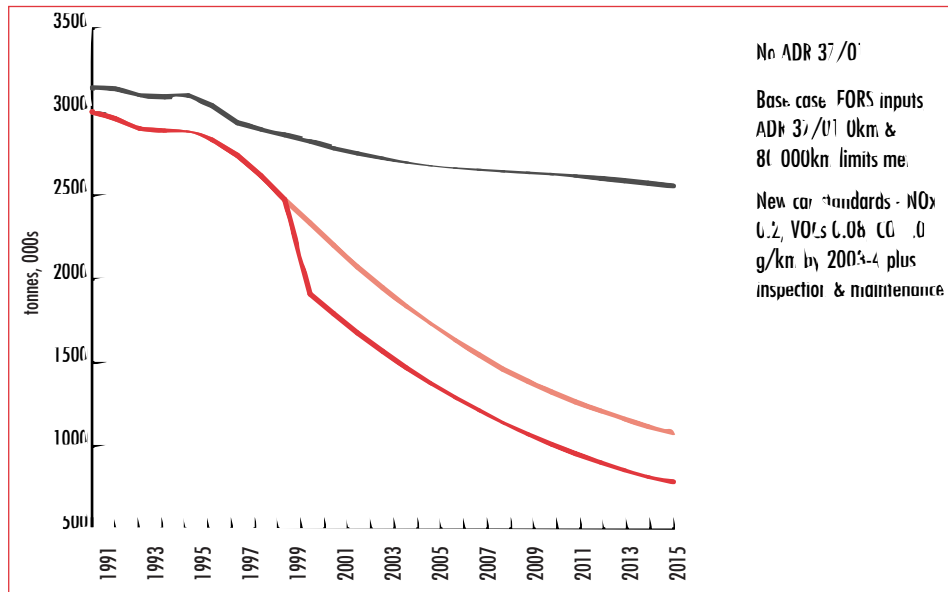


Figure 31: BTCE/FORS projections for CO emissions from the national car fleet for existing ADR 37 (base case); with ADR 37/01 at 0 and 80,000 km; scenario with lower emissions plus I and M

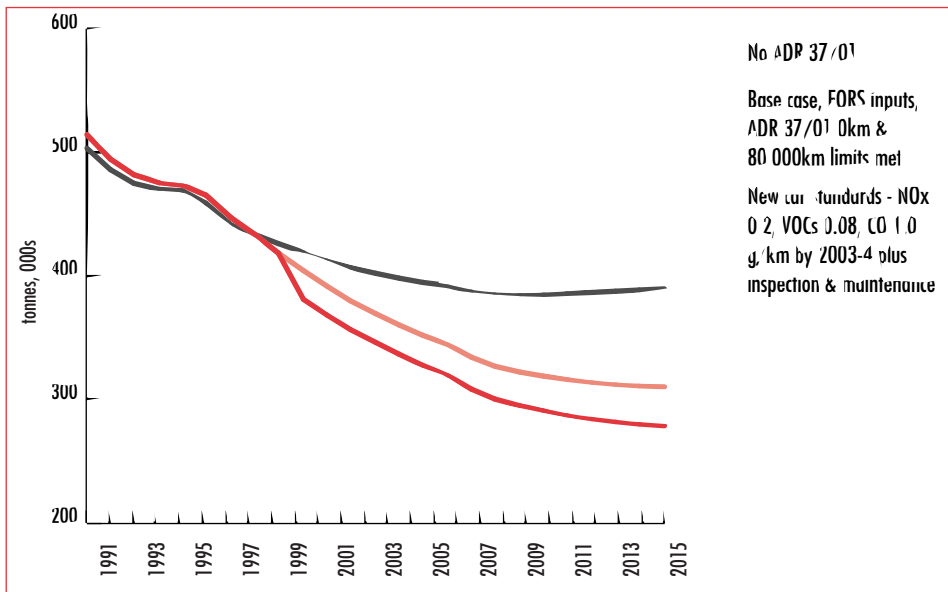
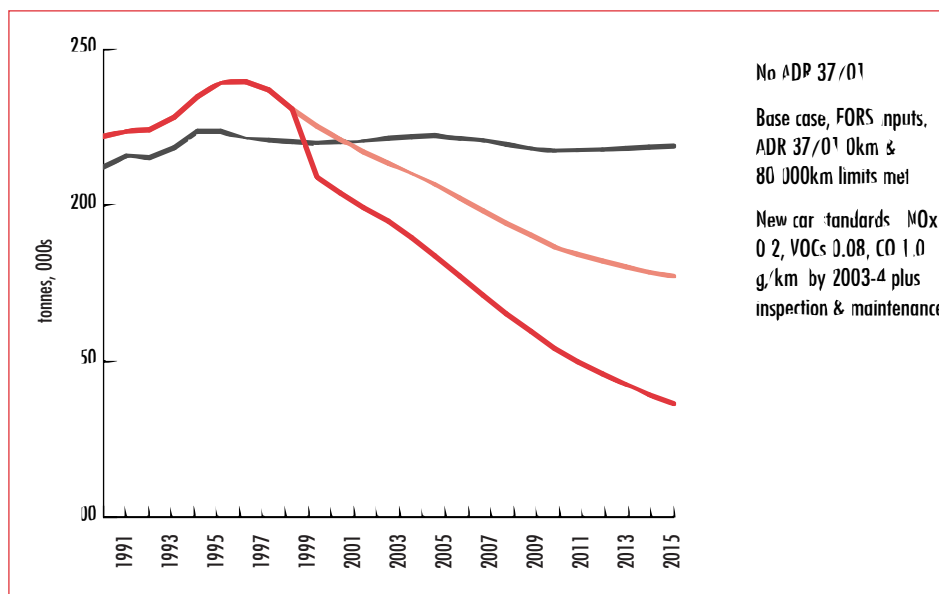


Figure 32: BTCE/FORS projections for VOCs emissions from the national car fleet for existing ADR 37 (base case); with ADR 37/01 at 0 and 80,000 km; scenario with lower emissions plus I and M



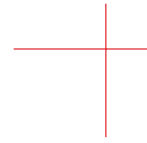
**Figure 33: BTCE/FORS projections for NOx emissions from the national car fleet for existing ADR37 (base case); with ADR37/01 at 0 and 80,000 km; scenario with lower emissions plus I and M**

reductions in emissions from new vehicles entering the fleet. Improvements in these areas provide no reason to be complacent, as photochemical smog episodes, while relatively infrequent compared with some badly polluted cities overseas, can be severe when they do occur.

Several well designed studies have raised serious concerns that fine particulate matter from both petrol and (mainly) diesel vehicles constitute a public health issue. As the BTCE projects the number of light commercial vehicles to rise substantially over the next decade, measures should be introduced to prevent the potential degradation of air quality.

BTCE fleet models predict (SR3) a continuing substantial rise in NOx, VOCs and CO from the national road freight fleet. In cities the effects will be dominated by LCVs, but larger freight vehicles will also contribute.

As can be seen from Figures 14-16, the impact of LCVs on emissions of NOx, VOCs and CO will, if not controlled, escalate dramatically. Even with the promulgation of the new standards, entry rates for new vehicles will mean that emission levels from LCVs will not start to fall for many years.



Overall increase in vehicle use may mean that the air quality gains already made, mainly through improved vehicles and unleaded fuel, will not be sustained. A steadily growing urban population will result in larger vehicle volumes and increased vehicle population densities unless there is appropriate intervention by all levels of government and a synergistic response by the vehicle operating community, urban planners, vehicle producers and fuel providers.

In summary, environmental models and forecasts suggest that, under a “business as usual” scenario:

- there will be an upward swing in some gaseous pollutant levels in the next decade or so; and
- fine particulate emissions may rise from current levels, and could accelerate if diesel vehicles become more prevalent.

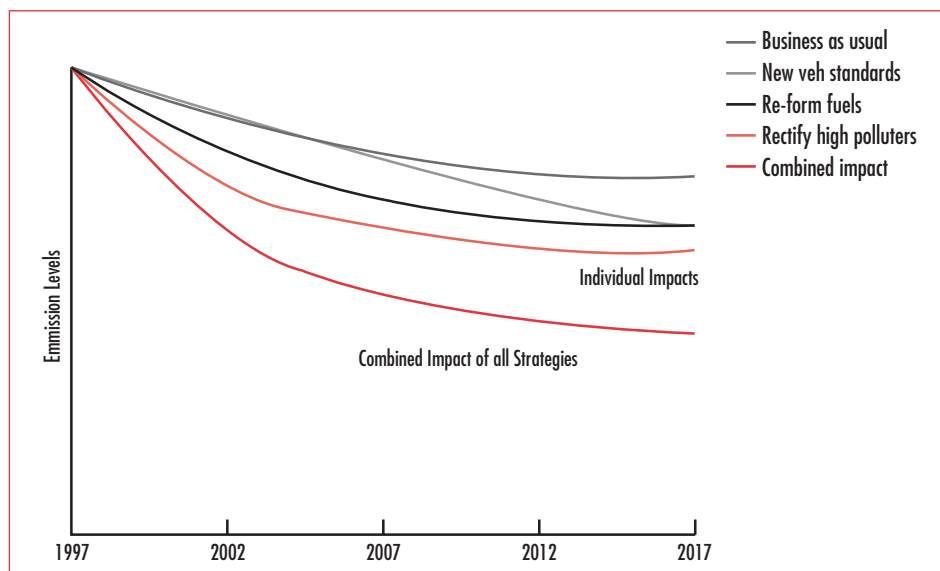
### Timeframes

Not all measures have impacts in the same timeframe. For instance, the introduction of tighter emission standards for new vehicles will not have a significant effect on total emissions until seven or more years have passed from the date of promulgation of the standard. This can be attributed to the very slow turnover of the Australian vehicle fleet, added to the lead times necessary for industry to develop and introduce new models complying with any new standards.

On the other hand, changes to the formulation of fuels or programs to improve the levels of compliance of in-service vehicles, can have major impacts over a relatively short period of time because they act on *all vehicles*, not just the new vehicles progressively entering the fleet (annual new vehicle sales represent around 5% of the total vehicle population).

By recognising the timeframes in which the various measures operate, planners can ensure that the effects of measures delivering results in the short term are sustained and reinforced in the longer term.

Figure 34 illustrates how short and longer term strategies can work together. Reliance on new vehicle standards alone means waiting for upwards of seven years to achieve sustained incremental gains relative to “business as usual”. On the other hand, gasoline fuel reformulation together with an effective program



**Figure 34: Individual and combined impacts of key emission reduction strategies — schematic**

to identify and rectify high polluters (gasoline and diesel) can deliver substantial short term reductions that, alone, would tend to be overtaken in the future because of fleet growth.

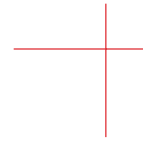
Combining the two groups of strategies delivers a substantial shorter term reduction, which is then sustained over the longer term when the effects of new vehicle standards start to bite.

The range of options summarised below provide opportunities to make significant improvements in air quality relatively quickly, then build on these improvements over the following years.

### Summary of Options (Road Vehicles)

Of all the potential options considered by the Inquiry, several emerged as practical, effective and able to deliver meaningful impacts over the next decade and beyond.

The following measures fulfil these criteria and are considered to have the most potential to improve urban air quality in Australia:



- adoption of UN ECE emission standards for new diesel and spark-ignition (petrol and gas) powered vehicles;
- a program that sets emission limits for in-service vehicles and ensures that compliance with these standards is maintained over the life of the vehicle;
- introduction of vehicle on-board diagnostic systems that monitor the performance of the emissions' control devices and cause the owner to implement repairs when a failure occurs. In the longer term (15 years or more) this measure could overtake the need for in-service compliance programs;
- lowering the vapour pressure of gasoline to reduce evaporative emissions of VOCs; and
- encouraging the use of vehicles using cleaner fuels (CNG, LPG, and "City Diesel") in urban areas.

Ethanol blended fuels, provided they are contained to normal vapour pressure levels, may also have potential for emissions reductions.

Other measures of potentially significant value could also be included in the above lists, but a lack of properly researched information on their effectiveness, or the potentially high investment needed for implementation, indicate a need for further research in these areas. They include:

- the use of additives in diesel fuel to combat carbon build-up on injectors, one of the major factors in diesel engine emission performance deterioration; and
- incentives to use intrinsically low polluting powertrains, such as electric or hybrid/electric power units in commercial vehicles that are driven almost exclusively in urban areas (urban delivery and courier vehicles, light buses/taxis, council vehicles, etc).

### **Discussion of Options (Road Vehicles)**

#### *Delivery of clean vehicles to the market*

Since 1974, the Australian Design Rules have been the primary means of controlling the *emissions performance of new gasoline powered vehicles*. Traditionally the emission ADRs have been based on US Federal standards and

this still is the case with the latest standard, ADR37/01.

The situation has now changed somewhat. Australia has made a strong commitment to the Asia Pacific Economic Co-operation (APEC) forum and is leading efforts within this forum to achieve a high degree of international harmonisation in vehicle safety and emission standards.

Because the United Nations Economic Commission for Europe (ECE) regulations are the only truly international standards applying to motor vehicles, it is almost certain that Australia will provide leadership to other APEC members by adopting the ECE regulations as the certification standards for new vehicles.

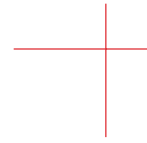
As well as being a strategically astute move, it also has technical merit as the UN ECE has, in recent years, significantly upgraded their emission standards so that they are now on a par with those of the USA.

The Federal Chamber of Automotive Industries (FCAI) has opposed the introduction of tighter emission standards for new vehicles, arguing that the costs of compliance are not presently warranted. From a narrow, short term perspective, there may be some substance for these arguments, but they do not stand up to examination from a broader perspective. However, the industry has acknowledged that tighter new standards should be introduced where warranted.

Firstly, any standards applying to new vehicles take a very long time to have any substantial effect. This is due in part to the two or three years lead time necessary for the industry to develop and manufacture upgraded models meeting the new standards. A further seven years then passes before vehicles meeting the new standard account for more than half of the total kilometres travelled.

Their value, nevertheless, should not be underestimated. *New vehicle standards are the long term foundation for maintaining and improving air quality, and the impacts of decisions taken now will still be measurable in 20 or even 30 years time.*

Secondly, it is clear that Australia's vehicle manufacturing sector must become increasingly export oriented if it is to survive. Given that most regional economies and all of continental Europe now mandate compliance with the UN ECE regulations (or their equivalent EU Directives), the failure of local product to comply with these standards would automatically mean that export markets



would need specially developed vehicles which would be higher cost per unit than for increased production runs of vehicles also produced for the local market.

Emissions of fine particulates and other air toxics from *diesel engines* are an emerging health concern and it is essential that vehicles entering the fleet have the most effective controls for reducing public exposure to these hazards. Diesel vehicles are also a major source of emissions of NO<sub>x</sub>, a key ingredient in the formation of photochemical smog.

A slightly different regulatory situation prevails for diesel powered vehicles, because the current ADR70/00 already requires compliance with the 1992 UN ECE regulation (although other Japanese, US or EU standards may alternatively be used for certification). The current ADR was, however, introduced as an interim measure, allowing manufacturers to certify against one of a number of overseas standards in order to facilitate its unusually rapid introduction (with a lead time of only 15 months).

It was always intended, as the preface to the ADR specifically states, to be a “first step”. It would be reviewed as soon as possible to decide on a single international standard that would form the basis of a revised diesel emission ADR to take effect towards the end of the 1990s. This review is now underway under the auspices of the Advisory Committee on Vehicle Emissions and Noise (ACVEN).

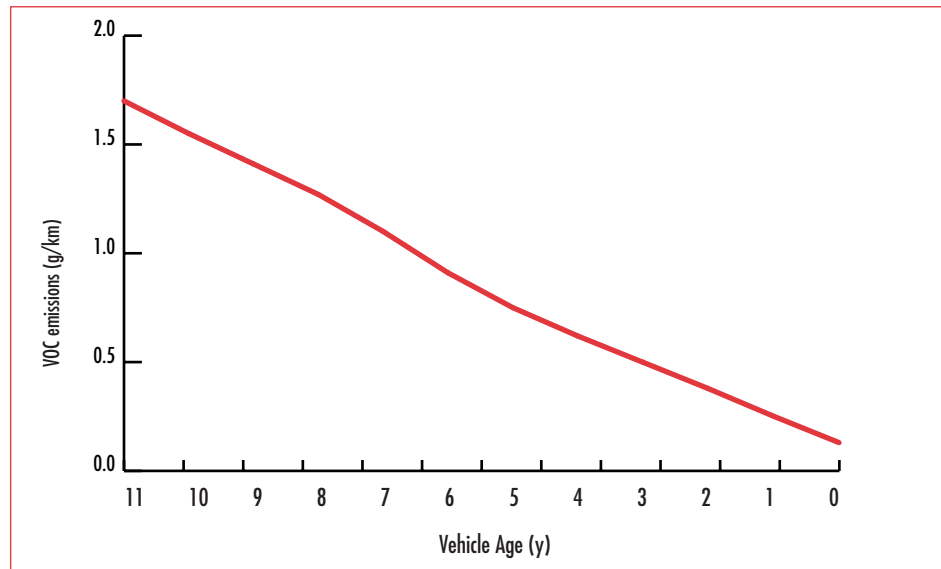
For the same reasons that apply to gasoline powered vehicles, the new diesel ADR should also adopt the current UN ECE regulation.

### **Recommendation 1**

*Australia should, without delay, move to adopt the current United Nations Economic Commission for Europe (UN ECE) vehicle emission regulations for spark ignition and diesel engines, as the basis for certifying all new vehicles sold in Australia.*

### *Maintaining compliance*

While new vehicle standards have been very effective in containing emissions from motor vehicles, reliance on this measure alone would result in outcomes falling a long way short of what can be realistically achieved through a more integrated “whole of life” approach (see Figure 34 above). To fully realise the



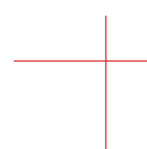
**Figure 35: Worsening of individual vehicle emission levels over time (FORS 1996)**

benefits of tighter new vehicle standards, there must be some way of ensuring that emissions control systems remain effective throughout each vehicle's operating life.

Research in Australia by the Federal Office of Road Safety (FORS 1996) has shown that deterioration, abuse and tampering over the life of a vehicle can result in emissions from individual vehicles being up to 100 times higher than typical new vehicles. Figure 35 shows the effect of deterioration in emission control systems over time for VOCs emissions. By the time the vehicle has reached the median age of the fleet (10-11 yrs), emissions have jumped tenfold.

Fortunately, recent developments in vehicle emission testing technology have dramatically reduced the cost of routinely and effectively testing in-service vehicles to "weed out" the high polluters that are responsible for a disproportionate amount of pollution.

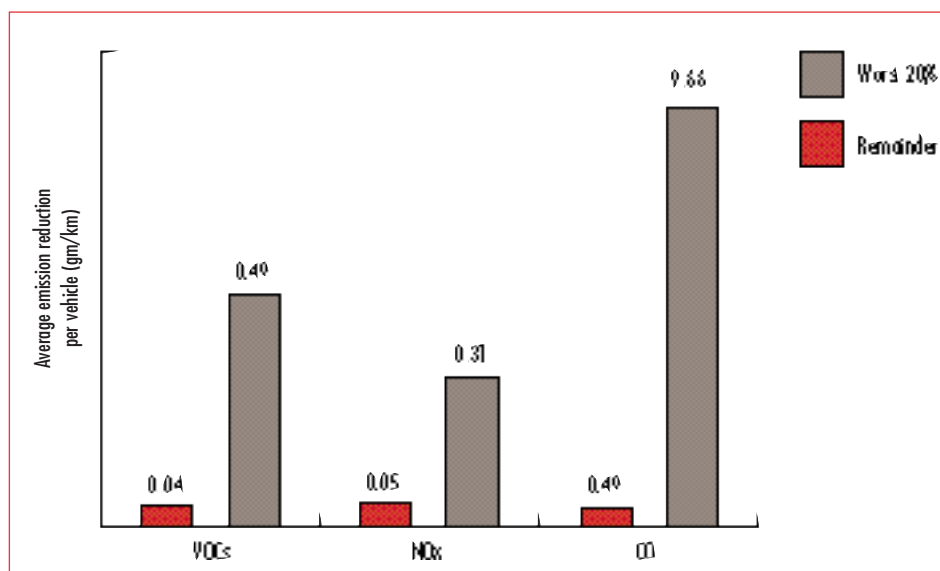
For the reasons outlined above, *in-service emission reduction programs* (frequently referred to as *Inspection and Maintenance* programs) can play a vital role in reducing overall pollution from motor vehicles. For petrol engine



vehicles, the cost of these programs is now quite modest. In the US, even the most comprehensive tests can now be provided on a commercial basis for US\$30.

It is also very important that these programs are designed and operated in a way that delivers the best outcome. The two fundamental decision points are; (a) whether to run a centralised or decentralised system and (b) whether to use a simple tailpipe check with the engine idling, or test the vehicle under load on a “rolling road” dynamometer which simulates actual driving conditions.

*Centralised* systems, where the vehicle is taken to an independent, test only facility, serving a local area, tend to use dynamometers (cost \$30~\$40 per test). *Decentralised* systems, where the vehicle is tested at a local service



(Note different scale for CO)

**Figure 36: Reductions in emissions produced by tuning those vehicles with highest emission levels**

station that will usually also carry out any necessary repairs, have tended to use less expensive (and much less effective) equipment. The cost of an idle test is up to \$25 per vehicle. These costs do not include the cost of the driver’s time and the lost operation time of the vehicle. Experience in the USA has shown that centralised programs are much more effective than decentralised programs in detecting and rectifying high polluting vehicles.

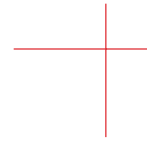
The Federal Office of Road Safety (FORS 1996) showed that most of the potential gains from an Inspection and Maintenance (I/M) program can be achieved through simple maintenance and tuning. Indeed, 80% of all the potential gains from an I/M program flow from rectifying the highest 20% polluters.

By arbitrarily deeming vehicles to “fail” an I/M test if any one of the pollutants was 50% or more above the ADR level, around 20% of the post-1986 (ie catalyst equipped) cars would fail. As will be seen in the following chart, the average (per vehicle) emission reductions from tuning and repairing the failures was between 6 and 20 times greater than for the group of vehicles that were deemed to have “passed” the test (Figure 36). This highlights the value of a simple, low cost test to focus rectification action on that proportion of the car population most in need of repairs or maintenance.

In terms of repair costs, it is quite rare for even gross polluting vehicles to require major repairs to bring their pollution levels down to acceptable levels. Simple maintenance tasks, such as the replacement of plugs, points and filters, often have a dramatic effect on a badly polluting vehicle, yet cost very little to perform. The FORS research noted an average cost of \$220, including parts and labour, to repair vehicles that exceeded the ADR limit by more than 50%. In Denver, the reported average cost of repairing I/M test failures is \$240.

In the longer term, similar results can be achieved through *on-board diagnostic (OBD) systems* such as those which will shortly be mandatory throughout the US. On-board diagnostic systems monitor all the emission controls on a vehicle and warn the driver, through instrument panel displays, of any faults that may occur. A further development, that uses a transponder to allow roadside units to monitor the condition of vehicles as they drive by, provides even greater opportunities to detect malfunctioning vehicles. It would, however, be 15 to 20 years before these systems could be installed in sufficient numbers of vehicles to render inspection and maintenance programs unnecessary.

The situation for *diesel vehicle in-service programs* is less clear. Although it is now recognised that diesel exhaust emissions pose health threats, programs to identify and rectify high polluting diesel powered vehicles are still constrained by the lack of a simple, low cost test to identify these vehicles. As a result, there is now intense interest in Australia, the USA and in parts of Asia in developing a suitable test and in co-operation between these countries.



Much of this work, particularly in the rapidly growing light to medium classes, draws on what has been done for gasoline vehicles and it is now likely that there can be a high degree of commonality in the equipment used to test both types of vehicles. There is some further development work to be done in this area to determine the methodology to be used. Progress to date has been hampered by the lack of clear direction and, to some extent, the availability of funds to do the task.

To be successful, any Inspection and Maintenance program must be reasonably priced, reliable and be recognised by motorists and transport operators as contributing to improvements in air quality.

### **Recommendation 2**

- (a) That emission limits based on ADR standards are set for in-service vehicles, backed by effective Inspection and Maintenance programs in the major urban airsheds, to ensure that compliance with these standards is maintained over the life of the vehicle.*
- (b) Consideration is given to the adoption of an on-board diagnostic systems in the formulation of new emission ADRs.*
- (c) State and Federal governments cooperate in developing and implementing, as quickly as possible, an effective, low cost test to identify high polluting diesel powered vehicles.*

### *Cleaner diesel fuel*

It is very difficult to discuss diesel pollution without some reference to *diesel fuel quality*. Although there is some dispute as to the extent of the relationship, emissions of potentially carcinogenic fine particulates are linked to levels of sulfur in diesel fuel.

There has been some reluctance on the part of local refiners to provide low sulfur fuels before there is some evidence that these would have positive cost benefits in Australian airsheds. Overseas regulators have already established this by extensive studies on management options and modelling of likely future airshed pollution levels and are acting quickly to reduce sulfur levels in a bid to reduce fine particulate emissions.

For instance, the European Commission has now put forward an EU Directive for common diesel fuel standards throughout the European Union. The Directive will be applied in two stages:

- the first applies from 2000 and cuts sulfur levels to 350ppm (.035%); and
- the second applies from 2005 and lowers sulfur to 50ppm (.005%).

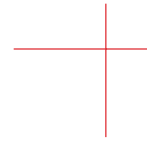
It is already mooted that there may be pressure from some quarters within the EU to mandate even more stringent levels, possibly 50ppm in 2000 and 30ppm by 2005, but the final result is likely to be a compromise somewhere between the two positions. This compares with the diesel fuel standard in Australia which allows sulfur content of up to 5000ppm with an average content, in 1996, of around 1500ppm. The FCAI has indicated that it will not support a revised diesel emission ADR until lower sulfur fuel (<500ppm) is commercially available in Australia.

The extremely low sulfur levels proposed for Europe are being driven by two factors:

- testing in Europe has shown that the use of “city diesel”, which has less than 50ppm sulfur, in existing vehicles can achieve substantial reductions in fine particulate emissions; and
- new technology engines and exhaust treatment technologies with lean burn de-NO<sub>x</sub> systems can only operate effectively with sulfur levels less than 50ppm, preferably less than 30ppm.

Another related issue is the use of *additives in diesel fuel* to help reduce the build-up of gums, varnishes and carbon deposits on engine components, particularly the fuel injectors. Such deposits can seriously affect injector spray patterns and fuel atomisation resulting in degradation of the combustion process and increased emissions.

Most unleaded petrol since the late 80s has contained similar additives, which have proved to be very effective. Although Australian oil companies have acknowledged their value in diesel fuel and have in the past marketed fuels blended with these additives, transport operators have been unwilling to pay the extra cost, so they are no longer commercially available.



### **Recommendation 3**

*Governments and industry should jointly explore the potential emissions benefits that could flow from:*

- *reducing the sulfur content of diesel fuel to levels comparable with those planned for Europe; and*
- *assessing the likely benefits of mandating the use of detergent additives in diesel fuel to combat the build-up of detrimental deposits on fuel injectors.*

*If necessary, this research should include a limited test program to gather data relevant to Australian operating conditions.*

#### **Evaporative emissions**

Although most discussion of vehicle emissions focuses on what comes out of the tailpipe, a substantial proportion of VOC emissions are released directly to the atmosphere. This occurs during the delivery of petrol to terminals and service stations, during vehicle refuelling, during the diurnal breathing of vehicle fuel tanks (as they heat up and cool down with normal daily temperature variations) and the fugitive losses which occur from carburettors and other equipment during normal vehicle operation.

A major determinant in the level of these emissions is the vapour pressure of petrol (gasoline). A reduction in vapour pressure is considered to be one of the more cost effective of the fuel related approaches available. Most benefit is gained from the first vapour pressure reduction step, with successive reduction steps becoming both less effective and more costly.

A 9 kPa reduction in petrol vapour pressure is considered achievable, in the short term, without any major detrimental impact on the local refining industry. It would result in an estimated 44% reduction in evaporative VOC emissions, with a further 5% reduction in tailpipe VOC emissions. The impact of further reductions in fuel volatility on the driveability of vehicles needs to be taken into consideration.

### **Recommendation 4**

*A voluntary reduction of 9 kPa in gasoline vapour pressure, which is currently being discussed between the oil industry and the NSW EPA for the Sydney airshed, should be strongly supported in view of its significant impact on evaporative VOC emissions. The feasibility of extending similar reductions to other regional centres should be explored.*

### *Alternative fuels*

A number of *alternative fuels*, including Compressed Natural Gas (CNG), Liquefied Petroleum Gas (LPG) and hydrogen, plus naphtha and ethanol based fuels are all claimed to offer a variety of emission benefits. These fuels (with the possible exception of naphtha), are all exempt from fuel excise. An objective assessment of the real costs and benefits of these fuels should take into account the economic impact of this exemption.

A recent Australian study on *LPG* vehicles by the NSW EPA found that there were only small differences in CO, VOCs and NO<sub>x</sub> emissions performance between current LPG and equivalent petrol powered cars. LPG vehicles also responded to tuning and maintenance in much the same way as petrol vehicles. It is therefore not possible to identify any clear benefits by way of reductions in regulated gases, flowing from the conversion of existing gasoline vehicles to LPG.

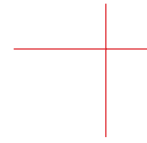
Data from the Society of Automotive Engineering (SAE, 1994) does, however, indicate substantially lower emissions of air toxics (ie Formaldehyde, Acetaldehyde, Benzene and 1,3-Butadiene) from the use of both LPG and CNG.

The use of LPG as a replacement for diesel offers the virtual elimination of particulate emissions, substantial NO<sub>x</sub>, VOCs and CO emission benefits and a small greenhouse emission benefit. While the excise exemption remains there are economic benefits for operators of high usage vehicles using LPG.

*CNG* also has potential to play a more prominent role in urban transport, as dedicated natural gas engines offer substantial reductions in emissions of both noxious emissions and carbon dioxide, compared to their conventional diesel or petrol counterparts. Particulate emissions are virtually eliminated and NO<sub>x</sub> reduced significantly by the use of CNG in lieu of diesel. The energy consumption of dedicated CNG engines is also lower than equivalent petrol engines.

Pending the development of a retail fuelling infrastructure, CNG remains practicable only for depot based vehicles, operating within a limited radius around major population centres. In particular, the use of CNG in urban bus fleets is rapidly increasing.

The draft Sustainable Energy paper (CoA, 1996) recognises that Australia has very large reserves of natural gas and LPG that offer potential energy security benefits.



*Ethanol* can be used as a fuel in its own right in engines specifically designed for its use, or in conventional engines blended with petrol, or as a diesel/ethanol emulsion. It has a mixture of positive and negative attributes, but the over-riding consideration is that it is, at present, relatively costly to produce.

There is no naturally occurring source of ethanol and currently there is only a very small infrastructure base for manufacture. Without a major breakthrough in ethanol feedstock, such as a process to economically derive the fuel from forest thinnings, it is difficult, at this stage, to demonstrate that the benefits to society of ethanol's use can match or exceed the costs. Unlike any of the fossil fuels, however, ethanol is a renewable fuel option but it is unlikely to provide any substantial contribution to transport fuel supplies until cheaper technology becomes available.

While the use of *hydrogen* in internal combustion engines has made substantial technical progress in recent years, the high cost of its on-board storage and control prevents it from offering a realistic alternative to petrol or diesel in the near term. Although the cost of extracting hydrogen from natural gas now approaches the production cost of petrol, a heavy premium is incurred in storing the hydrogen on the vehicles. It is not generally considered feasible to store hydrogen in a (cryogenic) liquid form, but on the other hand, it has a low energy density at realistic storage cylinder pressures.

Current technology envisages either storing it on-board the vehicle as a metal hydride, or producing it on-board the vehicle from another feedstock, eg a hydrocarbon. Nevertheless, it is inherently clean burning, with only steam, and possible small amounts of NO<sub>x</sub> being produced in the combustion process. This makes it a potentially attractive and totally renewable fuel source for the future.

*Oil/water emulsions, including naptha*, have recently emerged as potential emission reducing transport fuels, but little is known about their long term performance, stability or emissions characteristics. The proponents of these fuels claim NO<sub>x</sub> and particulate reductions of 30~40%, but these claims have yet to be verified by independent test data using accredited test methods.

## Recommendation 5

*The use of CNG and LPG in all classes of vehicles should be encouraged through clear policies in the use of gaseous fuels and by private and public sector investment in both vehicles and refuelling infrastructure.*

### *Improved passenger car technologies*

There is also potential to reduce transport emissions through improved passenger car technologies.

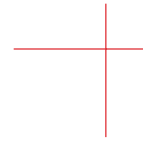
One strategy often proposed is a *vehicle downsizing* program where, through various policy initiatives or economic instruments, governments seek to alter the composition of the market mix of car sales. Although superficially attractive, this option has little impact on emissions and is likely to have a major down-side by way of increased road trauma costs and diminished consumer surplus.

In a report of the Vic EPA, (EPAV Vic, 1994), the benefits from realistic downsizing scenarios ranged from carbon dioxide emission reductions of 0.67%, to 1.77%. There would be no change in the emissions of VOCs, CO or NO<sub>x</sub> because all vehicles are required to meet the same standard irrespective of size. There would be benefits in reduced fuel costs, estimated to be of the order of \$65m pa for the first scenario, and \$156m p.a. for the second scenario.

Against these benefits, there would be considerable costs. Already, motor vehicle accidents cost in the order of \$6 billion per annum in Australia. Work overseas and from the Monash University Accident Research Centre (Cameron *et al*, 1994) indicates that small vehicles lead to their occupants having a two to four times more likely specified level of detrimental accident consequence than those travelling in larger cars. When carefully examined, this strategy looks most unattractive to both the individual in terms of the increased accident risks and the loss of consumer surplus, and society as a whole in the loss of manufacturers' revenue and therefore employment.

A more radical approach to *downsizing* is through a complete break with traditional vehicle engineering. An example of this approach, often dubbed the *hypercar*, can be summarised as:

- reduction of mass through the use of lighter materials or advanced materials, including fibre reinforced composites;



- improved aerodynamics through sophisticated body design and reduced frontal area of the car;
- new, low energy and low pollution drivetrains; and
- improved rolling resistance through attention to tyre composition and tyre contact area.

Examples of powertrain improvements possible include the use of much smaller engines coupled to continuously variable transmission and possible hybrid drives. The advantages of these concepts have been modelled and indicate the possibility of 150 mpg or around 2litres/100 km fuel consumption if fully implemented. However, until there is progress in reducing the cost and complexity of construction techniques and powertrain design, the costs of advanced car technologies are likely to remain high.

Although some features of the hypercar concept may be incorporated in future vehicle programs, without a clear policy and funding commitment by the Government, they are unlikely to be implemented in Australia until significant success has been achieved overseas.

It is more likely that there will be continued *improvements in conventional passenger car technology*. The mix of sizes (as measured by interior volumes) of passenger cars will probably remain the same through to 2010. Small and large cars will remain. There is evidence that the fuel consumption gap between large cars and small cars is closing, largely because the fuel consumption of large cars is showing greater improvement than that of small cars.

Factors such as improved aerodynamic drag, weight reduction and the use of low friction material all contribute to improvements. Larger capacity engines also have inherent thermodynamic advantages.

With advances in car materials progressively penetrating the car market, there could be further improvements in passenger car fuel efficiency through:

- reducing mass from 1600 kg to 1250 kg by 2010 (or even 950kg if light alloys and composites are widely adopted);
- improvements in aerodynamic drag and tyres;
- engine efficiency increases of 30% ; and
- refined automatic transmissions giving 10-15% reduction in fuel consumption in urban driving.

Potential improvement in fuel consumption expected for the vehicle fleet 15 years from now is likely to be of the order of 30-40%, with a possibility of achieving 5.7 litres/100 km compared with the present fleet average of just under 9 litres/100 km. However, this may not be achieved unless there is a strong worldwide push for improving vehicle fuel efficiency.

These improvements are likely to add around \$1,000 to the cost of a typical passenger car.

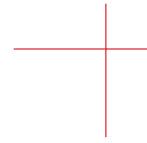
Unlike the passenger car assessment, there is real potential for improvement in *diesel emission technologies*. Unfortunately, as with spark ignition engines, the diesel engine suffers a trade-off between emissions improvements and fuel efficiency. Therefore, if greenhouse gas abatement becomes a more prominent issue, decisions may need to be made as to whether some relaxation in noxious emissions should be allowed to maximise fuel efficiency. In this case, it is likely that NO<sub>x</sub> emissions would be most affected.

The overall efficiency improvement likely in diesel engine technology in the period through to 2015 is of the order of 2-5% absolute. This means a relative improvement of the order of 5-12% in efficiency relative to today's engines. The timeframe of these developments will be progressive and will be very dependent upon the developments that take place overseas.

*Improvements in truck design*, which reduce the energy intensity required to move goods, offer several avenues for emission reductions.

Aerodynamic drag, with efficient and better matched transmissions, lighter structures and better power/load ratios through increased use of B-double combinations will all have incremental effects. The increased use of back loading and better fleet management, including using computer based management systems that allow just-in-time arrival for loading and unloading, will minimise emissions and fuel wastage. The impact of the above technologies is difficult to forecast with accuracy, but the BTCE indicate potential improvements in fuel efficiency of the articulated truck sector of 30% and for all commercial vehicles, an improvement of 17% by 2015.

The motivation for the *electric vehicle* has been mainly led by the requirement in California for zero emission vehicles. It is noteworthy that the timeframe for the mandatory sale of electric vehicles (2% of the market) has been put back, leaving their future uncertain. The underlying problem of the electric vehicle is



the limitations of the battery. These lead to a generally unacceptable range of less than 150 km and limit the vehicle's suitability to urban operation only.

In Australia, the same pressures do not exist for zero emission vehicles as in California and it is unlikely that, in the timeframe to the year 2015, electric vehicles will be able to play a role. Therefore, it is unlikely that anything other than demonstration fleets of electric vehicles will be seen in Australia in the foreseeable future.

The *hybrid vehicle* generally seeks to combine some of the advantages of the internal combustion engine with those of other motive systems, such as fly-wheel or electric traction. Current petrol engines and drivetrains have an overall efficiency of only around 12%, but this can be lifted to 18 or perhaps 22% using a hybrid drive. Hybrid drives are most effective in stop-start urban driving, where the braking energy can be used to recharge the on-board energy storage instead of being wasted as heat through a conventional friction brake. To date, hybrid drives have been complex and have added mass to the vehicle, thus degrading the benefits in efficiency obtained. There is, however, work already underway in Australia to develop a low cost hybrid drive that can be readily adapted to a wide range of vehicles. Industry analysis suggests that hybrid drives will typically add \$1,000-\$2,000 to the cost of a typical car. Without some policy direction, however, it is not expected that hybrid drives will make a significant impact in the timeframe to 2015, except perhaps in some niche markets related to specialised urban vehicles such as people movers, courier and service operations and council vehicles.

Australia has real opportunities to capitalise on these niche markets, both domestically and overseas, by utilising a range of new powertrain and electric control technologies already under development.

## AVIATION

Aviation is Australia's fastest growing transport sector and is particularly important because of the country's geography. In the ten years from 1985/6, the number of international passenger aircraft take-offs and landings in Australia increased from 44 572 to 98 608, a growth of 121%, while domestic air movements increased by 19% in the same time to reach 257 039 in 1995-6 (ABS, 1997).

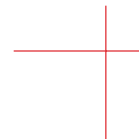
A fully laden Boeing 747-400 carries about 217 000 litres of fuel. During take-off it burns more than 10 litres of fuel per second, and its average, journey long fuel consumption rate is about 3.5 litres per second. However, compared with motor vehicles, the number of such aircraft and their hours of operation in an urban airshed is very small. As many inventories have shown, motor vehicles continually being operated in a large city greatly outweigh the fuel burn and emission production of all the large commercial aircraft using its airport.

Sydney is far and away the country's busiest airport, with 49% of all air passengers passing through it in 1995-6. The next busiest, Melbourne, accounted for 16.5%, closely followed by Brisbane. The percentage pollutant contribution to the Sydney airshed in 1992 from Sydney's Kingsford Smith Airport (KSA) was calculated to be as follows:

CO	0.6%
NO <sub>x</sub>	3.2%
HC	0.6%

The proportion of SO<sub>2</sub> was negligible and lead emissions were effectively zero. According to the Federal Minister for Transport and Regional Development, scheduled airline passenger traffic in the Sydney basin is predicted to double from 20.3 million in 1995/6 to 40.4 million by 2009/10.

For the purpose of this Inquiry, aviation emissions of relevance to urban air quality are those emitted from ground level to a height of about 900 m (3000 feet) above ground level. Emissions above 900 m will be dispersed and are unlikely to contribute to ground level air pollution. As a rough guide, aircraft are below the 900 metres cut off for a distance of about 20 km before landing, and for about 5 km from the airport after take-off.



## Fuels and emissions

The two fuels used by aircraft are aviation jet turbine fuel, a type of kerosene, and aviation gasoline (avgas). All jets and turboprop propeller aircraft (including large helicopters) have turbine engines and therefore use jet fuel. Avgas is similar to motor vehicle petrol and is used to fuel piston engines mainly for light propeller craft, small helicopters and recreational flying. From 1985/6 to 1995/6 jet fuel use in Australia increased by 84%, while avgas usage increased by 6% (ABS, 1997).

**Table 11: Emission factors and calorific values for jet fuel and avgas**

Fuel and energy content	Emission Factor (g/MJ)				
	CH <sub>4</sub>	N <sub>2</sub> O	NO <sub>x</sub>	CO	NMVOC*
Jet fuel (36.8 MJ/L)	0.0094	0.002	0.531	0.111	0.035
Avgas (31 MJ/L)	0.057	0.0009	0.076	22.8	0.513

\* non-methane hydrocarbons

Source: NGGIC, 1996

Table 11 above summarises the pollutant profiles of aviation fuels. Avgas has a higher volatility than jet fuel, and therefore refuelling and tank venting gives higher emissions of volatile hydrocarbons per kg of fuel.

With changes to jet engine designs since the 1970s, fuel efficiency has improved and emission factors have fallen for all pollutants except NO<sub>x</sub> and N<sub>2</sub>O for which they have increased. The relative proportion of pollutants, as well as the absolute quantities emitted, depends on the engine type and throttle setting. Nitrogenous pollutants are highest at full throttle, mainly in the form of NO; at this time CO and VOCs are very low as full oxidation is taking place. When idling, however, CO and VOCs emissions are much higher. Direct measurements of particulate emissions from aircraft engines are not readily available although evidence suggests an inverse connection to power rate.

## Non-Aircraft Emissions

Inventories worldwide show that the total of emissions from non-aircraft service operations at airports is less than that of the aircraft themselves. Airport induced surface transport journeys are, however, significant emission sources. The provision of better public transport links would help. In Sydney, a rail link to KSA is under construction.

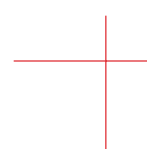
### EMISSION TOTALS

The emissions total depends on the amount of time an aircraft spends in the various modes of operation of the landing and take-off (LTO) cycle and the consequent throttle settings. This can vary with the load the aircraft is carrying and local factors such as temperature and wind. For modern aircraft, operating below maximum loading and on a long runway, take-off may not need full throttle. Alternatively, if noise abatement procedures demand that aircraft be above a certain height within a given range, then climb-out may occur on a higher than usual throttle setting, followed by throttling back while flying over the noise sensitive region.

An older Boeing 747-200 during its 33 minute typical LTO within the urban airshed would emit approximately 79 kg of CO, 49 kg of NO<sub>x</sub> and 18 kg of VOCs. However, modern 747-400s produce vastly less CO and VOCs during the LTO but marginally more NO<sub>x</sub>. The changes are the result of the introduction of lower emitting engines.

Auxiliary power unit (APU) usage will depend partly on how long an aircraft is parked at a gate. Again, times can vary widely.

The MAQS inventory demonstrates the importance of a busy general aviation aerodrome. Sydney's Bankstown airport, which serves no commercial jets, emitted only 25% less CO than KSA. This reflects the high emission index of avgas for CO. Figures for Hoxton Park and Camden (both within the Sydney airshed) underline the fact that CO is the major pollutant from general aviation, whereas this sector's contributions to VOCs, NO<sub>x</sub> and SO<sub>2</sub> are small.



**Table 12: Comparison of emissions from selected scheduled civil aviation, general aviation and military airports in the Sydney region**

Airport	Emission (kg/day)			
	VOC	NO <sub>x</sub>	CO	SO <sub>2</sub>
Sydney KSA	2,545	5,000	6,642	295
Williamtown	900	471	2,008	43
Richmond	488	252	655	45
Bankstown	192	35	4,992	4
Hoxton Park	36	4	1,054	neg

Notes: i) Sydney is mainly commercial, Williamtown and Richmond are RAAF bases, and Bankstown and Hoxton Park are busy GA aerodromes.

ii) The figures for Sydney are total airport emissions — ie they are slightly greater than aircraft-only emissions.

### Aviation Management Options

Australia is a technology taker in this sector and except by aircraft type and engine specification, unable to directly affect the emissions performance of aircraft. Aircraft usage and management of airport activities present the only realistic opportunities for emissions reductions from this sector. In terms of the whole airshed, the contribution from these measures is likely to be small although they may be more significant in airport localities.

#### *Reduce air travel or aircraft movements*

It seems likely that, as the real cost of air travel continues to fall and airlines continue to operate incentive schemes to reward greater travel, only pricing instruments will be effective in reducing the number of journeys or the number of aircraft movements.

Fast train travel, where feasible and available, can replace shorthaul trips by air. Such possibilities are unlikely in Australia in the next 15 years. According to the Dutch Ministry of Housing, Spatial Planning and the Environment (DMH 1995), high speed rail has been found to be cheaper, faster and less polluting

than air travel for distances less than 250 km. However, as the distance increases to 1000 km — more similar to most business journeys in Australia — aircraft start to have increasing advantages in time and cost.

#### *Improve aircraft fuel efficiency*

Fuel efficiency of recent aircraft models (eg the Boeing 767) are about 80 seat-miles per gallon — nearly four times that of the early 707 models in the 1960s. A putative 1200-seat aircraft for early next century could probably double the existing fuel efficiency (BTCE, 1992). Currently, the B747-400 models (the mainstay of the QANTAS international fleet) are one of the most fuel efficient passenger aircraft in regular use, partly because of their large passenger load and long range capabilities.

Aircraft engine design seeks chiefly to minimise noise and secondarily to minimise emissions per litre of fuel burnt. The trend is towards larger engines with a higher by-pass ratio. (This essentially means more air is shunted at slower speed, which reduces noise.) To achieve this, combustion takes places at a higher temperature, improving efficiency and reducing unoxidised carbons in the exhaust, but the result is an increase in NO<sub>x</sub> emissions.

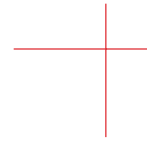
#### *Use engines that produce less pollution*

The bulk of the Australian fleet is already using higher efficiency “Chapter 3” engines and the rest use the more efficient of the Chapter 2 engines. There are, therefore, few changes that are possible in Australian registered commercial aircraft. Foreign registered aircraft are not required by Australian law to have Chapter 3 engines in order to use Australian airports.

#### *Reduce the use of auxiliary power units (APUs)*

APU usage can be minimised by providing centrally supplied 400 Hz electric power and pre-conditioned air (PCA) at parking gates. Overseas experience, at Zurich and Munich, demonstrates that a significant saving in localised emissions can result if all gates at an airport are supplied with power and air.

Studies for the proposed ten new gates that would be built as part of the Olympic upgrading to the international terminal at Sydney suggest that provision of power and PCA would cut APU emissions by about 85% for VOCs 76% for NO<sub>x</sub> and 90% for CO (FAC, 1997). The main impediment is undoubtedly the high upfront cost of converting existing gates. Given higher occupancy rates of gates, however, the change will eventually pay for itself.



### *Shutdown some engines while taxiing*

The LTO mode in which aircraft spend the greatest amount of time (19 minutes according to the ICAO average) is taxiing. From an emissions perspective it is preferable to have two engines operating at a slightly higher setting than to have four on the very low settings used for taxiing

Using fewer engines is not feasible before take-off, when pilots need to run engine checks and monitor performance, but it has been suggested after landing, as at Schipol Airport in the Netherlands.

### *Reduce air traffic congestion*

Congestion in the air and on the ground is a major pollution producing problem. At peak times, aircraft queue to land, take-off and berth. Such delays mean planes must carry more fuel and greater weight than they otherwise would.

Queuing stems from the desire by airlines to provide services at peak times, minimum safe separation distances and times between aircraft and traffic flow disruption if aircraft of vastly different weights and speeds are using the same airport. These causes all need to be addressed.

### *Minimise airport induced motor vehicle emissions*

Any large airport is a major destination point within a city and passengers accessing Australia's major airports do so mainly by private car and taxi. Near the airport itself, there are additionally deliveries of stock and equipment. This impacts disproportionately on people living in nearby areas.

Across the world, airports make an increasing proportion of their incomes from non-aviation activities, including at retail level. In Australia, retailing is the FAC's fastest growing area of commercial activity. It has overtaken aeronautical charges as an income generator and now accounts for 38.6% of total revenue. Of this retail income, 28% (about \$62.6 million) comes from car parking (FAC, 1996). There could be a reluctance to lose this income stream by promoting better public transport, unless airport owners are likely to benefit financially.

### **Future Planning Issues**

Some literature (NRDC, 1996) advocates use of the 'bubble concept' when assessing the contribution of an airport to the total pollution load of an urban airshed. The concept assumes that all the emissions associated with the airport, which includes all surface transport journeys to and from it, be lumped together under one 'bubble'. When cities are considered area by area, busy airports usually rank in the top ten single pollution sources.

This concept, akin to an ecological footprint, Chapter 5, could be a useful way of assessing the total effect of a large airport or for assessing a site for a major new one. It is especially important when considering areas of an airshed which may already be subject to a disproportionate pollutant loading due to their geographical position.