References

ABARE (1997a) *Australian Energy Consumption and Production*. Research Report No. 97.2, Canberra.

ABARE (1997b) *Outlook For Base Metals*. Haine I, Roarty M, In Outlook '97. Australian Bureau Of Agricultural and Resource Economics, Canberra.

ABS (1992) *Motor Vehicle Registrations, Australia*. Australian Bureau Of Statistics 9303.0, Canberra.

ABS (1993) *Motor Vehicle Registrations, Australia*. Australian Bureau Of Statistics 9304.0, Canberra.

ABS (1996) *Australians And The Environment*. Australian Bureau Of Statistics 4601.0 , Canberra.

ABS (1997) *Australian Transport and the Environment*. Australian Bureau of Statistics 4605.0, Canberra.

AGA (1997) *Cogeneration In Australia, Situation And Prospects*. Australian Gas Association, Canberra.

ANSTO, CSIRO (1997) *Aerosol Pilot Study*. CSIRO Information Bulletin, Division of Atmospheric Research, Aspendale.

Austroads (1995) *Travel Demand Management Guidelines*. Report No. AP-117/95, Sydney.

Austroads (1997) *Roads in the Community, Part I and Part II*. Report No. AP-49/97, Sydney.

Baldwin R and Yates A, (1996) *An Environmental Assessment Method For Buildings*. Paper Presented to CIB Conference, RMIT, Melbourne.

Biggs DC and Akçelik R, (1986) *Estimation of Car Fuel Consumption in Urban Traffic*. Proc Australian Road Research Board Conf, **13** (7), 124-132.

Bowman FM, Pilinis C and Seinfeld JH, (1995) *Ozone And Aerosol Productivity Of Reactive Organics*. Atmospheric Environment, **29**, 579-589.

BTCE (1992) *Fuel Efficiency Of Ships And Aircraft*. Working Paper 4, Bureau Of Transport And Communications Economics, Canberra.

BTCE (1994) *Cost Of Reducing Greenhouse Gas Emissions From Australian Road Freight Vehicles — An Application Of The BTCE Truckmod Model*. Working Paper 22, Bureau Of Transport and Communications Economics, Canberra.

BTCE (1996a) *Transport and Greenhouse — Costs and Options for Reducing Emissions, Report 94*. AGPS, Canberra.

BTCE (1996b) *Traffic Congestion and Road User Charges in Australian Capital Cities, Report 92*. AGPS, Canberra.

Cameron MH, Finch CF, Le T, (1994). *Vehicle Crash Worthiness Rating, Vic and NSW Crashes*. Monash University Accident Research Centre, Report No. 55.

CoA (1996) *Sustainable Energy Policy For Australia*. Commonwealth of Australia Green Paper, Canberra.

Colley P, (1997) *Reforming Energy*. *Sustainable Futures And Global Labour*. Pluto Press, London.

Cope M and Hess D, (1997) *The Application to an Integrated Meteorological Air Quality Modelling System for a Photochemical Smog Event In Perth Australia*. 22nd NATO/CCMS International Technical Meeting on Air Pollution Modelling and its Applications, 2-6 June, Clermont Ferrand.

Carnovale F, Alviano P, Carvalho C, Deitch G, Jiang S, Macaulay D, and Summers M, (1991) *Air Emissions Inventory Port Phillip Control Region: Planning for the Future*. SRS 91/001, Environment Protection Authority of Victoria, Melbourne.

Desvousges WH, Naughton MC and Parsons GR, (1992) *Benefit Transfer: Conceptual Problems In Estimating Water Quality Benefits Using Existing Studies*. Water Resources Research, **28**(3), 657-663.

DMH (1995) *Government Policy of the Netherlands on Air Pollution And Aviation*. Netherlands Ministry Of Housing, Spatial Planning And Environment, The Hague.

EPAV (1994) *Victorian Transport Externalities Study*. EPA Victoria Publication No. 415, Melbourne.

EPAV (1996) *National Pollutant Inventory*. Australian Government Publishing Service, Canberra.

FAC (1996) *Annual Report*. Federal Airports Corporation, Sydney.

FAC (1997) *Sydney (Kingsford Smith) Airport International Terminal — Olympic Upgrading Proposal. Notice of Intention*. Federal Airports Corporation, Sydney.

FORS (1996) *Motor Vehicle Pollution in Australia. Report on the National In-Service Vehicle Emissions Study*. Federal Office of Road Safety, Canberra.

Gibson (1977) *Designing The New City*. Wiley Interscience, NY.

Hamilton C, Hundloe T and Quiggin J, (1997) *Ecological Tax Reform In Australia*. Australia Institute Discussion Paper No 10, Canberra.

Harrison RM, (1992) *The Chemistry and Deposition of Particulate Nitrogen-Containing Species.* In: The Chemistry and Deposition of Nitrogen Species in the Troposphere. Ed. Cocks AT, Royal Society of Chemistry Symposium Proceedings.

IEAUST (1996) *Policy On Travel Demand Management In Urban Areas.* Institution of Engineers Australia, Canberra.

James D, (1997) *Environmental Incentives: Australian Experience With Economic Instruments for Environmental Management.* Environmental Economics Research Paper No 5 , Environment Australia, Canberrra.

Johnson GM, (1984) *A Simple Model for Predicting the Ozone Concentration of Ambient Air* . Proceedings of the Eighth International Clean Air Conference, **2**, 715 - 731. Clean Air Society of Australia and New Zealand.

Johnson GM, (1992a) *AIRTRAK and IER Model.* Third US/FRG/CEC Workshop: The Photochemical Ozone Problem and its Control. Lindau, FRG.

Johnson GM, (1992b) *Discussion Notes: Nitrogen Dioxide and Ozone Pollution Episodes — the Role of Reactive Organic Compounds and Sunlight.* United Nations Organisation Program on Chemical Safety, International Workshop on Human Health Effects of Motor Vehicle Fuels and their Exhaust Emissions, Sydney.

Johnston RJ, (1971) *Urban Residential Patterns*. G Bell and Sons, London.

Kenworthy J, Laube F, Newman P and Barter P, (1997) *Indicators of Transport Efficiency in 37 Global Cities*. Report for the World Bank, Institute for Science and Technology Policy, Murdoch University, Perth.

Luk JYK and Hepburn S, (1993) *New Review Of Australian Travel Demand Elasticities*. ARR 249, Australian Road Research Board, Melbourne.

Manins PC, (1995) *Regional Air Pollution Modelling for Planners*. Terrestrial, Atmospheric and Oceanic Sciences, **6**(3), 393-401.

MAQS (1996a) *Metropolitan Air Quality Study*. *Outcomes and Implication for Managing Air Quality*, NSW Environment Protection Authority, Sydney.

MAQS (1996b) *Metropolitan Air Quality Study*. Report to NSW Environment Protection Authority by Carnovale F, Tilly K, Stuart A, Carvalho C, Summers M, and Eriksen P, Sydney.

Meyrick Associates (1994) *Road User Charges: Discussion Papers Annex A*. In Refocussing Road Reform Ed. Cox, JB, Business Council Of Australia, Melbourne.

Minnery JR, (1992) *Urban Form And Development Strategies: Equity, Environmental And Economic Implications*. The National Housing Strategy Background Paper 7, AGPS, Canberra.

Murphy RE, (1974) *The American City*. Mcgraw Hill, NY.

NEPC (1997) *Draft National Environment Protection Measure for Ambient Air Quality*. National Environment Protection Council, Adelaide.

Newman P, Birrell B, Holmes D, Mathers C, Newton P, Oakley G, O'Connor, A, Walker B, Spessa A and Tait D, (1996) *Human Settlements*. Chapter 3, in State of the Environment, Canberra

NGGIC (1996) *Methodology For the Estimation of Greenhouse Gas Emissions and Sinks: Workbook for Transport (Mobile Sources)*, Revision 1. DEST, Canberra.

NRDC (1996) *Flying Off Course*. Natural Resources Defence Council, USA.

NSW (1996) *Developing an Air Quality Management Plan for Sydney, the Illawarra and the Lower Hunter*. NSW Government Green Paper, Sydney.

NSW EPA (1995) *ENVALUE, NSW EPA Environmental Database*. EPA 95/34, Sydney.

NSWT (1997) *Greater Western Sydney Public Transport Strategy. A Strategy for Improving Public Transport*. NSW Department of Transport, Sydney.

PPSS (1996) *The Perth Photochemical Smog Study*. Western Power and Department of Environment Protection, Perth.

Pressman N, (1985) *Forces For Spatial Change*. In JF Brotchie *et al* (Eds), The Future Of Urban Form, Croom Helm, London.

QDE (1995) *Air Emissions Inventory for SE Queensland*. Draft report to Queensland Department of Environment, Coffey Partners International, Brisbane.

QDE (1997) *Integrated Regional Transport Plan for South East Queensland*. Queensland Department of the Environment, Brisbane.

QT (1996) *Integrated Regional Transport Plan for South East Queensland*. Queensland Transport, Brisbane.

QUT (1997) Morawska L, Bofinger N and Ristovski Z, *Comprehensive Characterisation of Emissions Of Small Particles From Motor Vehicles*. Summary of a Report in Six Volumes to Environment Australia, Canberra.

Rees WE, (1992) *Ecological Footprints And Appropriate Carrying Capacity: What Urban Economics Leaves Out*. Environment And Urbanisation, 4, 121-130.

Roberts DB, Milne JW, Jones DJA, Cosstick RJ and Williams DJ, (1982) *The Chemical Composition of Sydney Brown Haze*. The Urban Atmosphere — Sydney, a Case Study, 141 - 151. (Eds) Carras JN and Johnson GM. CSIRO, Melbourne.

Rust-PPK (1996) *Incident Management and Driver Information Strategy*. Report to Road Transport Authority, Sydney.

SACTRA (1994) *Trunk Roads and the Generation of Traffic*. Report to The UK Secretary of State for Transport by the Standing Advisory Committee On Trunks Roads. UK Department of Transport, London.

SAE (1994) Whitney KA and Bailey BK, *Determination of Combustion Products from Alternative Fuels — Part 1: LPG and CNG Combustion Products*. SAE Technical Paper Series No. 9419803

Schwartz J and Dockery DW, (1992) *Increased Mortality in Philadelphia Associated with Daily Air Pollution Concentrations*. American Review Of Respiratory Disease, 145, 600-604.

Taylor MAP and Young TM, (1996) *Fuel Consumption and Emissions Models for Traffic Engineering and Transport Planning Applications: Some New Results*. Proc. Australian Road Research Board Conf. **18** (6), 189-204.

Williams DJ, Milne JW, Roberts DB and Jones DJA, (1982) *The Optical Properties of Sydney Brown Haze*. The Urban Atmosphere — Sydney, a Case Study, 127-140, (Eds) Carras JN and Johnson GM. CSIRO, Melbourne.

Appendix 1: Participants in the Inquiry

INQUIRY INTO URBAN AIR POLLUTION IN AUSTRALIA BY THE AUSTRALIAN ACADEMY OF TECHNOLOGICAL SCIENCES AND ENGINEERING

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Appendix 2: Summary of Existing and Proposed Ambient Air Quality Guidelines & Standards

Pollutant	Agency	Units	Averaging time	Maximum concentration (except as noted)	Allowed exceedences (days per year)
Carbon monoxide	WHO*		8 hours	9.0	0
	USA		8 hours	9.0	-
	NHMRC/ANZECC	ppm	8 hours	9.0	1
	Proposed NEPM		8 hours	9.0	1
Nitrogen dioxide	WHO		1 hour	0.11	-
			1 year	0.026	0
	USA		1 year	0.053	0
	NHMRC/ANZECC	ppm	1 hour	0.16	1 per month
	Proposed NEPM		1 hour	0.125	0
			1 year	0.03	0
Ozone**	WHO		8 hours	0.06	0
	USA		8 hours	0.08	-
	NHMRC/ANZECC	ppm	1 hour	0.10	1
	Proposed NEPM		1 hour	0.10	1
			4 hours	0.08	1
Sulfur dioxide	WHO		10 minutes	0.175	0
			24 hours	0.048	0
			1 year	0.02	0
	USA		24 hours	0.14	
			1 year	0.03	
	NHMRC/ANZECC	ppm	10 minutes	0.25	0
			1 hour	0.20	1
			1 year	0.02	0
	Proposed NEPM		1 hour	0.20	1
			24 hours	0.08	1
			1 year	0.02	0
Lead (as TSP)***	WHO		1 year	0.5-1.0	0
	USA		3 months	1.5	0
	NHMRC/ANZECC	$\mu g/m^3$	3 months	1.5	0
	Proposed NEPM		3 months	0.5	0
Particles (as TSP)	NHMRC/ANZECC	$\mu g/m^3$	1 year	90.0	0
Particles (as PM_{10})	USA	$\mu g/m^3$	24 hours	150	-
			1 year	50	0
	Proposed NEPM		24 hour	50	1
Particles as $PM_{2.5}$ US Revised Primary Standard 17.07.97	USA	$\mu g/m^3$	24 hours	65	-
			1 year	15	0
Visibility	Victoria	km	1 year	20km LVD+	0
	New South Wales		1 year	10 km	0

*** Total suspended particulate matter.
\+ Local visual distance
** Including photochemical oxidants
* World Health Organisation

Appendix 3: Smog and Urban Haze

In this Report we have used the term "smog" to mean photochemical smog. Urban haze, which is typically brown but which can appear white depending on the position of the sun, is mainly caused by fine particles, including aerosols, less than two microns in diameter which cause scattering or absorption of visible light. These very fine particles are part of a spectrum of sizes in the atmosphere extending up to tens of microns. Both forms of pollution can arise from common sources, particularly vehicles, but there are other sources as well. Under particular meteorological conditions either or both can form.

Photochemical Smog

Photochemical smog arises from the successive reactions of volatile organic compounds, sunlight and oxides of nitrogen. The reactions are complex, but a simplifying framework for understanding them has come from the work of Johnson *et a*l. in their now well established Integrated Empirical Rate (IER) Method (Johnson 1984, 1992a,b). Large scale smog chamber experiments in which controlled amounts of volatiles and of nitrogen oxides are exposed to sunlight underpin the theory. Although the reactivity of the average mixes of (non-methane) hydrocarbons in existing urban atmospheres are surprisingly constant, individual compounds show very different reactivities (Bowman 1995).

In brief, NOx, dominantly nitric oxide, NO, from vehicles and other fossil fuel combustion, reacts in the atmosphere to give nitrogen dioxide, NO_2 , which further reacts to give ozone, O_3. For these reactions to take place, volatile organic molecules present in the atmosphere must first absorb energy from sunlight to give reactive species. These in turn react with NO to give NO_2 , which with further sunlight energy input, reacts with oxygen in the atmosphere to give ozone. A by-product of this last step is the reformation of NO.

In parallel, a proportion of NO_2 reacts with water vapour and other species to give acid aerosol nitrates, a component of brown haze (Bowman 1995, Harrison 1992). After several cycles of NO conversion a "NOx limited" regime is reached beyond which no further smog species can form. This limit is reached in 4 to 8 hours under strongly conducive conditions. The maximum intensity of an episode in terms of smog level is almost entirely dependent on NOx availability. In most airsheds under most conditions there is a several fold excess of VOC molecules over NOx species. However, the rate of the reactions are directly proportional to the VOC concentration and to sunlight intensity, rising rapidly with ambient temperature. If the concentration of VOCs is lowered, the rate is lowered proportionately.

Fresh NO injected into an ozone containing air mass in the absence of strong sunlight can itself react with ozone to form NO_2 and oxygen. The amount of smog present, or smog produced, "SP", is therefore more properly measured as the sum of NO_2 and O_3 present.

In summary, it is important to minimise VOCs in order to slow the formation of smog formation as much as possible and to allow diffusion or dispersion of the affected air mass. This may avoid the peak concentrations that could build up during an adverse weather episode. At the same time NOx emissions and consequent concentrations in the atmosphere should be minimised. This would limit the final peak concentration of smog under strongly adverse conditions and minimise the formation of nitrate based aerosols, the ultimate sink for NO_2.

There is a strong case for preventing the evaporation of the more reactive organic compounds, typically olefins and aromatics, into the atmosphere as part of keeping the total burden of reactive organics in the atmosphere as low as possible.

Brown Haze

Brown haze (Williams *et al* 1982) results from the presence in the atmosphere of particulates, including aerosols, which scatter or, to a lesser extent, absorb light thus reducing long range visibility. Most of the visible effect arises from scattering by particles in the 0.1 to 2 micron range, but there may also be a contribution of up to 5% from the gaseous smog component nitric oxide, NO_2 which is brown in colour.

The particulate size range causing light scattering is only part of the particulate load in the atmosphere injurious to human health, the fabric of buildings and vegetation. A range of deleterious particles up to and above 10 microns are also present. Current monitoring has been mainly confined to the PM_{10} range, ie particle size 10 microns and smaller, but it is now believed in medical circles that perhaps the $PM_{2.5}$ fraction is the more harmful. A number of studies are now taking place over the full size range (ANSTO - CSIRO)

The atmospheric particulate load over Sydney in 1982 (Williams *et al,* Roberts et al) had a chemical composition comprising about 30% total carbon, much of it in the form of sooty or micrographitic particulates from motor vehicles and probably with a disproportionately high contribution from diesel engines (QUT 1997). The other major components were sulfates and nitrates deriving from SOx and NOx emissions, as well as sodium chloride, presumably ocean derived. Similar results, give or take sodium chloride, have been obtained in North American cities. High levels of sulfates, rarely experienced in Australia, can give rise to the "acid rain" observed in the northern hemisphere.

Health Impacts and Proposed Standards

Both ozone and NO_2 are noxious gases and proposed atmospheric exposure limits for both are similar (0.1ppm and 0.125 ppm respectively are the NEPM proposed limits for one hour exposure, NEPC 1997). In the atmosphere they are readily interchangeable under the influence either of sunlight or fresh NOx emissions. It is the sum of their concentrations which is more properly the measure of smog produced, "SP", and much of the analysis in this Report is based on this measure. While NO_2 may not have quite the severe effects of ozone on human health, its presence in the atmosphere allows ozone and nitrate aerosols to be readily formed. For most Australian monitoring stations and explicitly for "AIRTRAK", the CSIRO instrument invented to measure these species and their rates of formation, both can be measured and their sum determined.

Atmospheric particulates - carbons, sulfates, nitrates, inorganics and organics - are possibly an even higher health hazard than smog and low limits on their ambient concentrations are proposed. The Air NEPM discussion paper (NEPC 1997), details the nature and effects of the atmospheric pollutants discussed above and proposes concentration levels for various periods of exposure based on these effects. Similar standards have been proposed, or are in force, elsewhere in the world.

Appendix 4: List of Figures

Appendix 5: List of Tables