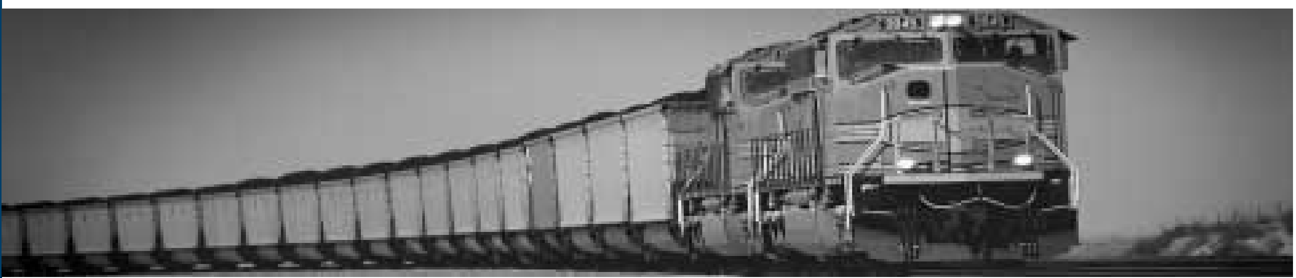
SUSTAINABLE TRANSPORT

RESPONDING TO THE CHALLENGES



SUSTAINABLE ENERGY TRANSPORT TASKFORCE REPORT NOVEMBER 1999

The
Institution
of Engineers,
Australia

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Foreword

16 November 1999

Dear President

It is with pleasure that I submit to you the Report of the Sustainable Energy Transport Task Force. The Report is the result of research and consultation with representatives of the community and the transport industry.

The Task Force has developed a series of recommendations for government which we encourage the Institution to consider and carry forward as appropriate.

The Task Force believes that sustainable transport issues are of increasing significance to engineering and the community. Accordingly, we trust that the recommendations to the Institution and the profession will also be carried forward.

From this perspective, this final Report is offered in the spirit of a working report and resource which we hope others will augment and build upon through their actions.

In forthcoming months, we suggest that the Report be widely circulated to members and the community to assist, identify and focus future sustainable transport initiatives of the Institution and the engineering community.

Members of the Task Force contributed considerable time and effort. I would like to thank them for their enthusiasm and particularly Anthea Fawcett and David Hood, for their support and patience.

Kind regards

Ted Butcher AM FCIT FIEAust CPEng

Task Force

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Introduction

The Institution of Engineers Australia convened the Transport Task Force to consider the role transport might play in contributing to a more sustainable energy culture in Australia. The objectives were to identify areas where the Institution might assist in the development of a National Sustainable Energy Strategy and to identify opportunities for engineers to contribute to the continuing process of developing a culture in which sustainable energy (both sources and use) is a primary consideration.

In reviewing Australia's transport systems and culture, the Task Force concentrated on more efficient use of energy and ways of reducing the adverse environmental effects of energy use. The Task Force's intention is to initiate informed debate, and it hopes that engineers will be encouraged to contribute their expertise to achieving more sustainable energy and transport outcomes.

This paper's main focus is land-based transport and energy: it does not attempt to cover the much broader concerns of ecologically sustainable development, such as biodiversity, emissions to water, road management, and vegetation. Considerable work is being done in many ESD areas that touch on transport, so the Task Force gave primary attention to the Institution's aim of contributing to the development of a National Sustainable Energy Strategy.

Sustainable transport is an enormously complex and dynamic subject, and this paper is offered to the profession and the community as a contribution to a debate that needs to advance on many fronts. If we are to achieve a sustainable transport sector and reduce national greenhouse gas emissions, government intervention will be necessary. The Institution and the engineering profession have an obligation to contribute to the debate and to help governments and the community work towards more sustainable transport systems and outcomes. Individually and collectively, we need to consider how we will contribute to meeting these ends.

Greenhouse gas emissions from Australia's international aviation and maritime activities are not at present included in our national greenhouse gas–reduction targets. Nor are they dealt with in detail in this paper, although the Task Force recognises that they are important areas that require further consideration as part of a national commitment to more sustainable transport.

This paper is presented in two parts. Part One provides an overview of the challenges we face in developing sustainable transport systems, commensurate with sustainable energy objectives, and puts forward recommendations for consideration by government and the engineering community. Part Two provides detailed background information and a review of some current transport emission–reduction initiatives. A number of case studies are presented in the attachments.

In doing its work, the Task Force drew on the work of the Institution's National Committee on Transport and Task Force on Sustainable Development, the Railway Technical Society of Australasia, and many other organisations and individuals whose assistance was greatly appreciated.

Part One The Task Force’s report

1 Where to begin?

1.1 Sustainable transport in a sustainable environment

Sustainability requires us to understand how our social, economic, cultural and biophysical systems interact with one another to the detriment or advantage of preserving all life on the planet, now and into the future.

So what does 'sustainable transport' mean? For some, it merely means the reduction of negative environmental impacts within the sector. For others—a much smaller group—it means a 'holistic' commitment to ecological sustainability and transport's role therein, which entails fundamental changes to our social, economic and industrial systems.

The majority, 'business as usual', interpretation of sustainability might be summarised as 'Growth is good; reforms may be needed in the future, but not in any way that might disrupt current patterns of growth and development.' The Task Force considers, however, that current patterns of transport growth and energy consumption already pose serious problems that need to be resolved in the immediate and longer term. Reform and innovation in our transport systems are vital but so, too, is the gradual reshaping of our social and economic expectations of what our transport systems should be, what we should demand of them, and how we should use them.

Transport is a derived demand

Much thought has been given to the various forms sustainable transport might take. Some experts claim that definitions of the term are already well developed, that the problems are clear, and that the real difficulty lies in determining where contributions can best be made. The OECD defines 'environmentally sustainable transport' thus:

> Transportation that does not endanger public health or ecosystems and meets the needs for access consistent with
>
> (a) sustainable use of renewable resources at below their rates of regeneration, and
>
> (b) use of non-renewable resources at below the rates of development of renewable substitutes. (OECD 1999)

This definition focuses on resource use within the sector, but to achieve the stated goals a paradigm change will be needed—not only in transport but more generally within our economies and by society. The OECD has a large, continuing program of research into environmentally sustainable transport. Its second research phase—which involved scenario modelling and analysis of action required to achieve EST by 2030—led to the conclusion that one-third of the effort necessary to meet the criteria expressed in the definition will come from technology and two-thirds from demand-side management (OECD 1999).

Such a finding emphasises that sustainable transport requires a relational approach, on many fronts. It cannot be treated as a closed system or as a series of isolated problems; nor can we rely on technological solutions alone. Sustainability of the transport system cannot be achieved independently of the socio-economic system as a whole. This is not to say that there is nothing we can do. Improvements *can* be achieved in the short term. Concerns about health, congestion costs, resource use (particularly fuel use) and, above all, atmospheric change and air pollution provide us with powerful reasons to act for greater sustainability.

We can focus on specific determinants of change and identify solutions to parts of the problem, but we need view these actions within a broader framework, taking into account the following.

- Sustainable transport is not an end in itself—our urban systems and modes of work and economic exchange must themselves become more sustainable.

- Sustainable transport—understood as functional transport systems delivered with reduced impacts—will not of itself deliver sustainable cities.

- Transport responds to, and in part generates, its context—it is both a derived demand and an agent of demand growth. Innovation within the sector needs to focus on encouraging change in the nature of demand by developing material and financial structures that encourage a community preference for sustainable transport options.

As Brindle has argued,

> To promise genuine reductions in resource consumption and impacts in the transport sector without acknowledging the need for substantial commensurate shifts in lifestyle, values and attitudes is … dishonest. Simply shifting our present patterns of exchange and interaction onto supposedly more friendly modes will not bring about the results we need. And it will not be possible to maintain our present system of production and consumption if we restrain transport and mobility enough to make a real difference. (1998, p. 74)

There are no simple answers that will deliver sustainable transport. We need to develop a better appreciation of what generates transport demand, to better identify responsibilities for the adverse impacts of transport, and to insist on a strategic approach that goes beyond the transport sector. We need to encourage and mobilise change at all levels—from government and industry to professionals, communities and individuals.

1.2 A vision for change

What is needed is a long-term vision for sustainable future transport systems, recognising the following imperatives:

- the total transport task being increasingly based on sustainable (non-polluting, non-depleting) energy sources and their enabling technologies;

- the need to reduce the growth in total transport demand in passenger and freight tasks, where levels of growth are unsustainable;

- infrastructure investments, transport technologies and modal options that can service transport requirements in as least carbon and pollutant intensive a manner as possible.

- evaluation of all transport infrastructure investment and industry development strategies based on total life–cycle assessment, incorporating full economic, energy and other resource impacts across the capital and operational life cycle of the proposed project.

The rationale for change

There are compelling reasons for directional change to our transport systems:

- to improve economic and environmental efficiencies;
- to counter escalating congestion costs and levels of anxiety;
- to redress the current lack of transparency in the pricing of transport facilities and services;
- to address pending resource scarcity and the ethics of resource conservation;
- to reduce escalating greenhouse emissions and emissions of other pollutants;
- to improve the sustainability of financial mechanisms necessary to meet the capital and maintenance cost requirements of infrastructure
- to reduce the deleterious health and environmental impacts of current patterns of energy consumption.

Directions for change

New directions need to be increasingly integrated into transport planning, investment decisions, and areas of policy that influence transport demand and our transport choices and options, for a variety of reasons:

- to reduce the fossil-fuel intensity of the total transport task through greater efficiencies, improved technologies, and fuel selections appropriate to the task;
- to reduce the total amount of, and growth in, resource-depleting and polluting transport tasks by fostering new work and business practices that obviate the need for travel or freight where appropriate and possible;
- to reorient passenger demand and demand growth to modes that are less fossil fuel and resource intensive;
- to reduce the growth in total passenger and freight demand where possible;
- to transport freight as efficiently as possible.

The vision and directions for change are supported by the principles for a National Sustainable Energy Strategy endorsed by the Institution of Engineers Australia at its Congress in April 1999.

1. Sustainable energy structures which balance energy production (supply) with the requirements of energy consumption (demand), wherein demand (need) growth is to be substantially reduced via new technologies and cultural change processes.

2. The ultimate goal for all sources of energy is to be based on non-depleting and non-polluting sources.

3. Energy production, delivery and consumption that yields sustainable ecological (environmental, social and economic) outcomes.

4. Recognition that the move towards a sustainable energy future is not about sustaining the present, but about actively creating new energy futures which:
   - draw upon our fossil fuel resource and technology base;
   - prioritise renewable energy sources, energy efficiency and transitional fuels and enabling technologies; and
   - recognise these technologies and areas of expertise as key growth areas to contribute to Australia's long term wellbeing.

5. Enhancing the sustainability of fossil fuels through increased efficiency in supply and end-use, and appropriate resource allocation wherein resources are identifiably in decline.

6. Continuous improvements must be stimulated in energy-related technologies across the spectrum of production, conversion, transmission, storage, distribution, demand management and use.

7. Continuous improvement of the environmental performance of the total sector must be stimulated.

8. A consistent and committed national and State approach must be taken in terms of market reform, environmental policies and regulation and investment and taxation policy.

Source: IEAust (1999).

1.3 Tools and tactics for change and the need for supportive environments

Many organisations are working hard to identify and move forward with a range of tools and tactics for change. The benefits of these initiatives can be more readily realised through supportive environments and the clear expression of strategic national objectives that give priority to sustainable transport and communicate to the community the rationale for and potential benefits of change. There are many such tactics and tools, among them the following:

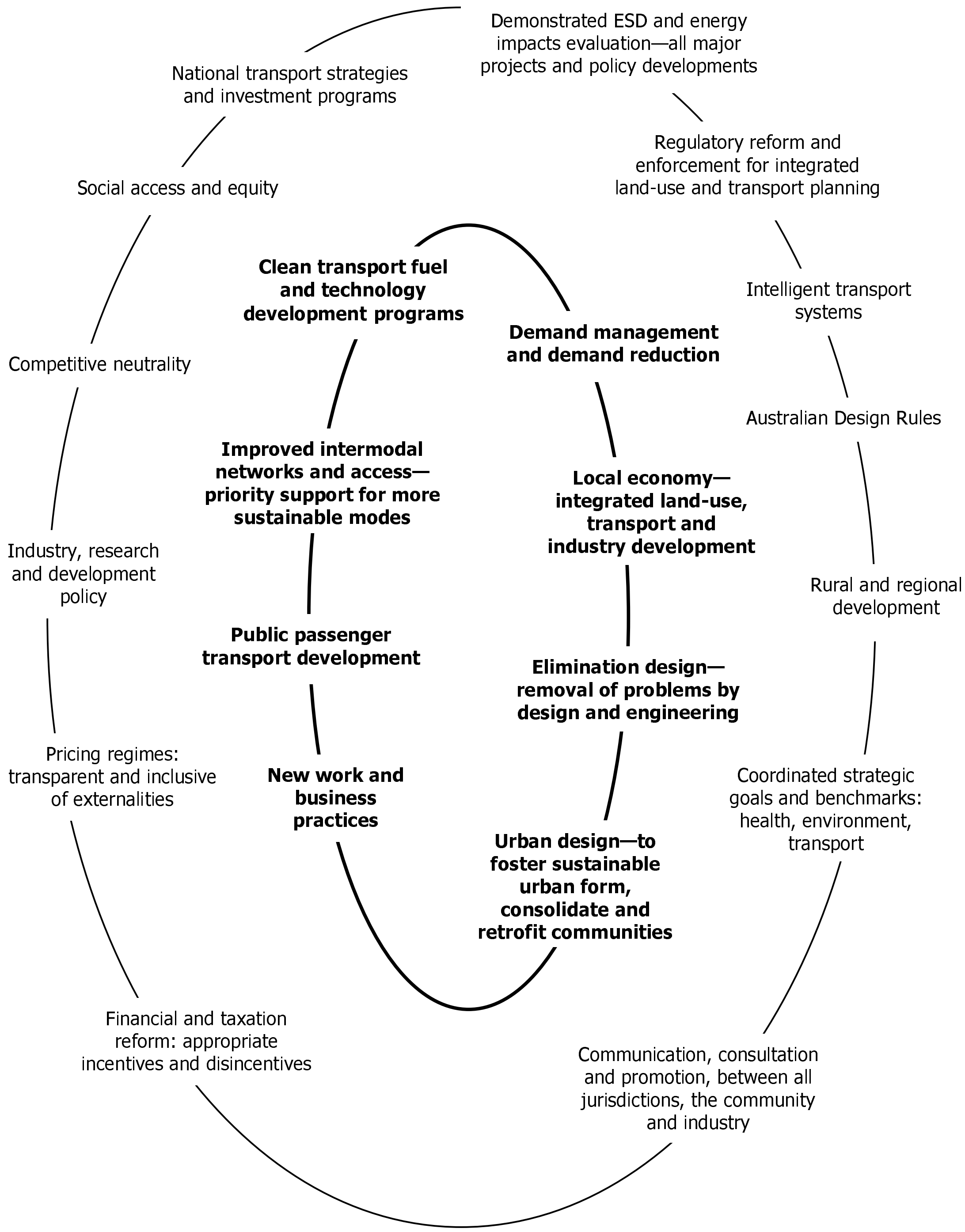
- travel-demand management and demand-reduction strategies;
- integrated land-use and transport planning;
- development and application of environmental and economic life–cycle methodologies and assessment criteria to competitive fuel options and proposed infrastructure developments;
- fuel-substitution and fuel-replacement strategies that assign priority to cleaner specification fuels and emerging clean fuels;

- identification of and giving priority to emerging technologies—vehicular, modal, fuel and conversion;
- improved planning of intermodal transport, to capitalise on the strengths of each mode;
- modal substitution in the performance of freight and passenger tasks;
- transport and urban design to increase pedestrian and bicycle movement where appropriate for health, lifestyle and amenity;
- better access upon existing road infrastructure for alternative transport modes—for example walking, cycling, buses and light rail;
- improved emission design standards and efficiency requirements across the transport fleet;
- air quality management plans to meet new air quality standards;
- design strategies to reduce growth in the transport task—through urban design, telecommuting, and so on;
- pricing strategies to sway demand towards more sustainable transport modes and options;
- pricing strategies to support cleaner fuel types and infrastructure requirements;
- identifying and dedicating transit ways to public transport, in the interests of safety and improved efficiency;
- 'intelligent transport systems'—integrated introduction and application consistent with clearly identified goals and priorities for public transport and demand management.

Energy use cuts across all of these tools and tactics. The respective benefits they may offer need detailed study and are beyond the immediate scope of this report. Connections need to be made between them and with the necessary supporting policies, knowledge and technologies.

To begin this process, a conceptual model that allows relations to be visualised and expressed may be useful—this is the function of Figure 1.1. In all areas of policy—the primary domain in which a supportive environment is created—we need to assign priority to sustainable transport futures and to integrate decision making to this end. Among the important policy areas that may require improved integration are transport planning, infrastructure development and approvals processes, financial and taxation regimes, health policy, land-use and urban planning, and industry, research and development policy.

Figure 1.1 Central elements of a more supportive environment for sustainable transport



Note: The outer circle represents the broader supporting environment; the inner circle represents transport priorities and pathways.

2 The challenges before us

The Task Force analysed recent trends in transport in Australia with a view to identifying the primary challenges posed by energy use in the transport sector and relating these to four broad problem areas in our transport systems:

- major city transport challenges
- growth in intercapital transport
- infrastructure funding—capital and maintenance priorities
- regional transport.

This chapter presents an overview of the broad challenges posed for the sustainability of energy use in the transport sector and the problem areas the Task Force, and the people it consulted, identified as being specific to the transport sector.

In preparing this overview the Task Force reviewed the literature and corresponded with and interviewed academics, transport specialists, road and rail operators, and representatives of transport companies, research institutions, government agencies, the petroleum industry and community organisations.

2.1 The broad challenges: greenhouse, health, energy and congestion

The problems of greenhouse gas emissions and urban air quality are focusing attention on sustainable transport. The Secretary of the Commonwealth Department of the Environment and Heritage has highlighted that dramatic changes are on the horizon in the international automotive and petroleum industries:

> They know and we know that, unless there is a miraculous turnaround on the science, the greenhouse density of transport will have to plummet if we are to maintain the growth in transport services. Similarly, individual vehicle emissions of particles, toxics and polluting gases will have to fall sharply if we are going to maintain, let alone improve, air quality. (Beale 1999)

The Commonwealth is sponsoring a range of initiatives designed to tackle some of the direct impacts of energy use in transport. These are discussed in Chapter 9; they include work being done by the Australian Motor Vehicle Environment Committee and the Australian Greenhouse Office to

- develop and promote alternative fuel programs;
- harmonise Australian petrol and diesel standards, in line with European and US standards;
- develop national fuel quality management and delivery systems to support these standards;
- implement fuel consumption labelling and consumption targets;
- advance the National Greenhouse Response Strategy.

The Task Force's consultations confirm that a scarcity of liquid fossil fuel is not currently regarded as a significant policy concern in Australia. In 1998, however, the International Energy Agency lent credibility to the emerging view that conventional oil production may peak between 2010 and 2020 (IEA 1998) and the Chartered Institute of Transport in Australia issued a communique declaring,

> We are at the climax of the fossil fuel age … We have reached a crucial stage in the development of our local, national and international transport services. Our present path is leading us into potentially serious economic, social and environmental problems. New directions are needed for our future transport fuels and vehicles. 'More of the same' in our current transport plans and ways of thinking is no longer tenable. (CITIA 1998)

Reducing greenhouse gas and pollutant emissions from the transport sector, reducing our dependence on cheap liquid fossil fuels, and looming congestion problems provide a powerful rationale for change in our transport systems.

Greenhouse gas emissions

The transport sector is one of the primary contributors to national greenhouse emissions, and it faces major hurdles if it is to contribute equitably to meeting Australia's national greenhouse gas–reduction targets.

Per capita transport-generated greenhouse gas emissions in Australia are among the highest in the world. One-third of the average family's greenhouse emissions are the result of transport activities. The greenhouse emission from an average car in a typical year of travel is about 4.3 tonnes; a flight to London and back generates more than 5 tonnes per passenger (Australian Greenhouse Office n.d.; McDonald 1999).

Chapter 7 discusses the greenhouse phenomenon, Australia's greenhouse gas–reduction targets under the Kyoto Protocol, and transport's profile in national greenhouse emissions. In summary, our national target is to reduce growth in greenhouse gas emissions to 8 per cent on 1990 levels by 2008 to 2012. This represents a reduction of about 30 per cent on anticipated 'business as usual' growth in total greenhouse gas emissions for the period (Beale 1999, PMSEIC 1999).

In 1996 the transport sector accounted for 17 per cent of Australia's total greenhouse emissions (71 million tonnes); it was the fastest growth sector from 1990 to 1996, during which emissions increased by 15 per cent on 1990 levels. In a 'business as usual' scenario emissions are forecast to increase by 42 per cent on 1994 levels by 2015, with emissions from road freight and domestic aviation doubling and those from international aviation trebling (Commonwealth of Australia 1998).

In 1996 road transport accounted for 87 per cent of greenhouse gas emissions from the transport sector; by 1997 this share had grown to 89 per cent (Australian Greenhouse Office 1999). Cars currently account for well over half of total greenhouse gas emissions from the road sector, but future growth in emissions from the sector is forecast to predominantly come from trucks and light commercial vehicles. In operational energy terms, rail is generally more energy and greenhouse efficient than road for long-haul freight, although in recent decades rail's share of many of its traditional markets has declined.

International aviation emissions are not included in our national emissions targets because the question of 'bunker' (international transport, aviation and shipping) fuel emissions is still being negotiated through the Kyoto mechanism and emissions are not at present attributed to individual nations. In spite of this, the impact of aviation emissions is significant: growth in emissions from the mode (national and international) is forecast to increase by 150 per cent between 1993 and 2015, and aviation is forecast to increase its share of transport fuel consumption from 15 per cent in 1997–98 to 20 per cent by 2014–15 (BTCE 1995; Bush et al. 1999). Much of the growth in aviation fuel consumption is for international flights departing from Australia, and in future we may be required to take account of these greenhouse emissions in our national targets.

Long-term strategies to reduce greenhouse gas emissions require full fuel–cycle analysis, which combines analysis of the energy efficiency and associated emissions impacts of end-use fuel consumption (direct fuel cycle) with analysis of the upstream and downstream impacts of energy used to extract, process and distribute fuels to end users. This area of study is gaining momentum, particularly since proponents of alternative fuels (such as natural gas and liquid petroleum gas) aim to present the ‘whole of life’ benefits of these fuels in relation to existing fuels. Full fuel–cycle analysis is also recognised as an area warranting further study in terms of urban rail systems that use electricity from coal-based power generators.

A strategic area where engineers may contribute to reducing greenhouse emissions from the transport sector is in the application of life–cycle analysis methodologies to the assessment and planning of transport infrastructure and maintenance projects.

Austroads and ARRB Transport Research have been investigating the development of a comparative resource consumption methodology that may be used to compare resource impacts (energy and other environmental resources) associated with different transport modes. The methodology incorporates an energy accounting framework that includes direct fuel–cycle, full fuel–cycle and embodied-energy impacts of infrastructure and rolling stock and vehicles. Further development and application of the methodology could improve the planning and evaluation of multimodal transport infrastructure within an ESD framework (Houghton & McRobert 1998). As yet, such methods are not systematically incorporated in transport planning, feasibility studies, or investment decision making.

The immediate challenge is to constrain total vehicle-kilometre growth and reduce operating greenhouse emissions from our existing transport fleet, details of which are provided in Chapter 7.

Different engine types, levels of tuning and driver behaviour will contribute to varying levels of greenhouse and other emissions from fuel consumption. On average, 1 litre of fuel consumed (petrol, diesel or aviation fuel) contributes approximately 2.5–3.0 kilograms of greenhouse gases, a figure that illustrates the direct greenhouse benefits that will accrue from greater vehicle efficiencies and reductions in fuel consumption (McDonald 1999).[1]

In conjunction with the Greenhouse Challenge Office, the Australian Trucking Association has recently developed and launched the *Road Freight Environment and Greenhouse Challenge Workbook*. This important resource provides a detailed framework and information for road freight operators to monitor, measure and improve their performance in terms of emissions of greenhouse gas and other pollutants across the spectrum of management and operational activities.

The rail freight sector has also made appreciable gains in energy efficiency, and the iron ore railways in Australia are the most efficient in the world. Other Australian freight railways do, however, have some way to go to lift their aggregate energy efficiency to IS Class I railroad standards (Laird 1998).

[1] Based on Australian Greenhouse Office estimates cited in McDonald (1999) and Task Force calculations for petrol, diesel and aviation fuel.

Health impacts

Health impacts have long been — for example the Sydney Area Transportation Study of the early 1970s — and promise to increasingly become, a central determinant of transport policy. Road trauma remains a significant public health concern: it is noteworthy that the 1998 National Road Safety Summit seriously considered adopting the Swedish 'Vision Zero' (that is, a target of zero road trauma) in Australian road safety thinking. The environmental health impacts of noise are a growing community concern and now increasingly affect transport planning. Vehicle dependence and associated sedentary lifestyles are also recognised as producing adverse health effects (in particular, diseases related to the human circulatory system); this area now being examined by bodies such as the World Health Organisation.

Vehicle-related air pollution and associated health effects rate highly among community concerns. This is a complex and rapidly developing field of study. The Task Force's review of energy-related health problems showed that, despite improvements in urban air quality in recent decades—assisted by the introduction of unleaded petrol and catalytic converters—these gains are being threatened by the increasing number of cars and diesel vehicles and of total vehicle-kilometres travelled in urban areas.

Particle emissions from diesel-engined vehicles are now recognised as a serious health concern. During 1999 the Commonwealth has taken considerable steps to improve fuel standards and so reduce particle emissions, to support realisation of new ambient air quality standards within 10 years, as discussed in Chapters 8 and 9. According to Dr David Brand, President of the Australian Medical Association,

> Fine particles (diesel) should be taken as seriously as lead has been, since medical evidence revealed the health impacts that it caused. If we create more particle pollution in urban centres there will be more premature deaths and increased health costs. (cited in Australian Conservation Foundation 1999)

Fine particles are those small enough to be inhaled into the respiratory system and they are associated with respiratory and cardiovascular diseases and asthma. Ultra-fine particles are small enough to be inhaled deep into the lungs and may enter the bloodstream, causing multiple chemical sensitisation and maladies such as nausea, rashes, changes in red and white blood cells, liver damage, and degeneration of the nervous system (Fisher 1999).

Among the common pollutants from transport are carbon monoxide, oxides of nitrogen (principally nitric oxide and nitrogen dioxide), ozone, lead, particles and sulphur dioxide and hydrocarbons. The health effects of air pollution can be short term (acute) or long term (chronic); they include cardiovascular and respiratory diseases, increased incidence of asthma and other respiratory illnesses, hypertension, stroke, heart disease, and damage to the IQs of children. In the case of air toxics and particulates, important health effects relate to an increased incidence of cancer. Estimates of the health costs associated with vehicle emissions range from 0.01 per cent to more than 1 per cent of GDP—some $5.3 billion a year (Brindle et al. 1999).

Transport is the biggest contributor to ambient air pollution in urban areas, and cars and light commercial vehicles are the dominant source. Diesel fuel emissions contribute approximately 80 per cent of total vehicle particle emissions in major centres. Comprehensive, conclusive data presenting the pollutant and greenhouse effects of existing Australian petrol and diesel, in comparison with Euro 2 petrol and diesel and alternative fuels such as natural gas and liquid petroleum gas, are not yet available. It is recognised that further research is necessary in this regard.

A further challenge for policy makers and transport operators lies in the fact that in some instances air quality concerns may conflict with greenhouse gas–reduction objectives. For example, low-sulphur fuels, which deliver benefits through reductions in fine particle emissions, may lead to losses in energy efficiency and increased energy consumption when compared with high-sulphur fuels. Diesel is generally more energy efficient than petrol, but until clean diesel is introduced and widely used it will continue to be responsible for relatively high particle emissions.

ARRB Transport Research has recently published *Transport-generated Air Pollution and its Health Impacts—a source document for local government*, which reviews much of the emerging literature on the health impacts of energy consumption in the transport sector and discusses a range of countermeasures that communities and engineers may usefully consider to remedy the problem (Brindle et al. 1999). The review highlights the need for the introduction of environmentally benign vehicles (such as low-emission hybrid cars) and clean fuels and technologies in conjunction with travel-restraint and demand-management strategies. It reiterates the view of many commentators that expected increases in the number of motor vehicles in growing economies will offset any improvement in individual vehicle-emission performance: demand reduction and cultural change will thus need to play an increasing role alongside technological innovation.

Growth in energy use

At present Australia meets a little over three-quarters of its need for liquid fuel from domestically produced crude oils. Much of our diesel production is, however, dependent on imported oils. Australia is a significant net importer of crude oil and refined feedstock: the level of imports is about twice that of exports. We have abundant resources of natural gas—over 100 years' production at current rates. Natural gas is generally considered to offer lower pollutant and greenhouse emissions when compared with existing liquid fuels. The comparative emissions benefits of natural gas, liquid petroleum gas, and current and Euro 2–standard liquid fuels is an area of much research and debate in the energy and transport industry. Current information suggests that natural gas may offer greenhouse-emission savings of somewhere between 10 and 50 per cent over traditional fuel emissions (the upper range is considered somewhat optimistic).

The vision of 'the total transport task being increasingly based on sustainable (non-polluting, non-depleting) energy sources and their enabling technologies' poses a considerable challenge when viewed in terms of growth projections for energy consumption in the sector. Table 2.1 shows current and projected levels of energy consumption within the sector, providing an indication of the challenge we face.

The highest rate of projected growth in total energy consumption is in air transport, while the highest rate of projected growth for a fuel type within a mode is for natural gas in road transport. The contribution of natural gas to the total road fuel task is projected to grow from 0.2 to 3.0 per cent of total consumption, this growth being largely attributed to increased consumption by the urban bus market. The use of natural gas in transport may need to be monitored in the light of the reductions in diesel excise to be introduced on 1 July 2000.

Table 2.1 Energy supply and disposal, by transport mode, 1997–98 and projections for 2014–15

(petajoules)

	1997–98					2014–15				
Transport mode	Black coal	Petroleum products[a]	Natural gas[b]	Electricity	Total	Black coal	Petroleum products[a]	Natural gas[b]	Electricity	Total
Road		933.9	2.0		936.0		1 106.7	34.6		1 141.4
Rail		22.4		7.0	29.4		25.4		10.3	35.7
Air		182.9	0.4	0.3	183.6		322.2	0.5	0.4	323.1
Water	4.2	48.2	0.1	0.9	53.4	5.3	65.0	0.1	1.2	71.6
					1 202.4					1 571.8

a. Includes naturally occurring LPG.
b. Figures are for transport modes excluding pipelines. Natural gas consumption will increase considerably for natural gas pipeline compressors.
Source: Bush et al. (1999).

Congestion Costs

Congestion is a serious and growing problem in most of Australia's large cities, and it imposes substantial economic, environmental and amenity costs on the economy and society.

Growth in the use of private cars is often pointed to as the principal component of the problem, but it is urban freight vehicles that now constitute the highest area of growth for most urban road systems. Although the high level of private car use remains an important contributor to urban congestion, saturation in the level of car ownership has been emerging in the 1990s and the average distance driven per car in Australia appears to have changed little in the past 25 years.

Growth in total private passenger car-kilometers does, however, remain a serious problem. According to the Bureau of Transport Economics (1998), urban public transport currently accounts for about 7 per cent of the urban passenger task in Australia, so even a doubling of its contribution would not obviate the coming congestion problems.

The Bureau modeled future congestion levels for major Australian cities, based on forecast levels of freight and passenger total vehicle-kilometer growth occurring on existing networks and projected probable increases in road capacity within the networks. The model draws on projected population growth levels for each city, makes assumptions about where population growth will occur (for example, at the city fringe), forecasts future levels of car ownership per person, and assumes a constant level of vehicle-kilometres per car. It also assumes increasing levels of growth in the vehicle-kilometre tasks of most classes of road freight vehicles travelling in cities (Bureau of Transport Economics 1998).

Table 2.2 shows projected costs of congestion from increases in traffic volume in Australia's main cities. These costs represent time costs and vehicle operating costs of delay: they do not take into account the externality costs of increased levels of emissions and noise and safety hazards resulting from increased traffic volume; nor do they take into account the economic costs of travel suppresion.

Table 2.2 Estimates for congestion costs for Australia's main cities, 1995 and projections for 2015

($ billion)

	Sydney	**Melbourne**	**Brisbane**	**Adelaide**	**Perth**	**Canberra**
1995	6.0	2.7	2.6	0.8	0.6	0.05
2015	8.8	8.0	9.3	1.5	1.9	0.2
Cost increase	2.8	5.3	6.7	0.7	1.2	0.15
2015:1995 ratio	1.5	2.9	3.5	1.8	3.4	3.7

Source: Bureau of Transport Economics (1999).

These figures are broadly indicative, based on a range of assumptions. The manner in which congestion costs increase in relation to the level at which systems carrying capacity is reached is exponential in character. Cities close to capacity or with relatively few or very concentrated central business areas may experience quite significant increases in congestion costs with relatively small increases in total vehicle-kilometres travelled.

The congestion cost rate (dollars per passenger car equivalent per kilometre travelled) estimated for each of the cities in the modelling of the above data vary considerably. For example, the congestion cost rate for Sydney in 1995 and 2015 is relatively constant, while for Melbourne and Brisbane it is projected to more than double. This, in part, may explain Sydney's relatively high congestion cost base in 1995 and the higher congestion cost increases projected for Brisbane and Melbourne. For further information on these cost projections see the Bureau's research publications *Forecasting Light Vehicle Traffic* and *Transport and Greenhouse: costs and options for reducing emissions*.

2.2 Challenges from within the transport system

The Task Force analysed growth trends in the transport task by mode and by energy efficiency and reviewed infrastructure maintenance and investment requirements. Chapter 10 provides data on historical trends in the transport sector. The main conclusions the Task Force reached are as follows.

- We have not—as individuals and as a nation—given priority to transport modes that offer greatest energy efficiency.
- All our existing transport infrastructure is under pressure, as a result of increased demand or lack of investment, or both.
- Funding for transport infrastructure has generally not been consistent across the various modes, in particular road and rail.
- Our transport system as a whole faces funding problems.
- The Commonwealth needs to coordinate and direct fiscal, regulatory and environmental legislation to better support sustainable transport outcomes.

Following its analysis the Task Force interviewed representatives from the transport sector to ascertain whether they concurred with its broad conclusions and what additional factors they considered important to improving the sustainability of our transport systems.

The following box presents the four basic problems the Task Force initially identified and the strategic concerns the people who were interviewed raised in relation to those problems and more generally in relation to improving the sustainability of our transport systems and cities. A number of additional strategic matters emerged in the course of the Task Force's research; these are also reflected in the box and in the summary of findings and the recommendations put forward in this report.

Problem area	Strategic concerns relating to the broad problem areas identified and the future sustainability of our transport systems
Major city transport challenges – growth in the passenger car transport task – growth in the urban freight task on roads – competing tasks on one system – the poor profile and task share of public transport	• The Commonwealth should play a greater role in addressing major city transport challenges. • Direct, transparent road pricing and charging for use are necessary to manage demand and so to combat congestion and to price and attribute externality costs to users. • Fuel-pricing regimes may need to be reconsidered, to improve demand-management outcomes. • Road pricing is now possible, with intelligent transport systems and non-proprietary E Tag technologies, to enable creation of 'time' corridors for freight, encourage public passenger transport, and constrain vehicle-kilometre growth. • The rationale and benefits of road pricing need to be communicated to consumers, and alternative modes (public transport, pedestrian, cycling) should be made readily accessible in conjunction with the introduction of direct road-use charges. • Public transport needs to become more flexible and more service oriented, and regulations should be developed and implemented to facilitate an increasing role for private sector providers of public transport. • Public transport faces serious difficulties in maintaining—let alone increasing—its share of the transport task, notwithstanding impressive new public transport targets and strategies recently developed by planning and transport agencies in most cities. • Improved vehicle technologies (noting the current Commonwealth target of 15 per cent efficiency improvements for new cars) will not sufficiently combat the growth in emissions from the vehicle fleet if the technologies are unaccompanied by demand-management strategies to retard the increase in total vehicle-kilometres in areas of high congestion. • The central infrastructure challenges are to facilitate increased access for different modes and new services (bus, pedestrian, cycling, light rail) to existing infrastructure networks, to provide funding for non-road solutions to transport needs in urban areas, and to introduce equitable and efficient pricing and charging regimes. • Urban freight vehicles and buses are priority segments of the road sector on which to focus measures designed to encourage the adoption of clean fuels and clean-fuel technologies.

Problem area	Strategic concerns relating to the broad problem areas identified and the future sustainability of our transport systems
Intercapital transport growth – rate of freight transport growth on roads – rate of passenger growth: air – declining growth of rail freight and passenger use	• We are all paying 'too little for transport', particularly long-distance heavy vehicles in the road sector. ITS (using GPS and 'weigh in motion') trials for road-wear and real-time charging are pricing mechanisms that are now on the horizon. • The principal challenge is to devise and introduce effective and competitive pricing and charging systems for road and rail. • The Commonwealth should seriously consider funding and investment mechanisms designed to boost the upgrade of the national rail track to the point where it can begin to compete with road freight and for further private sector investment. • For long-haul freight there is consensus that economic and environmental benefits would accrue if the national rail system were improved. The flow-on effect would be greater competitive viability of rail for interstate and intrastate freight. • Our intermodal connections need to be improved and rationalised. • The decline in long-distance passenger use of rail is not considered a serious concern. • Demand-management and modal-substitution strategies for growth in air transport are not yet being tackled: growth in greenhouse emissions from the sector suggests they should be. • On the whole and with the exception of rail, our intercapital transport systems are adequate—the main challenges lie in the systems interfaces between the major modes (road, rail and port infrastructures) and the need for improved circumferential transport networks and intermodal connections.
Infrastructure funding—capital and maintenance priorities – immensity of maintenance projections – lack of investment neutrality between modes	• The traditional split between public and private ownership and operation of most modes of transport is disappearing, and increasing private sector participation in the provision of transport infrastructure and services is regarded as a means of redressing funding shortfalls and increasing the efficiency of resource allocation and operation. • There is, however, a continuing role for efficient public enterprise. • Competitive neutrality in investment and pricing regimes and between government agencies and the private sector needs to be further pursued, particularly in relation to road and rail, and with regard to rural and urban resource allocation. • The Commonwealth should take a leading role in developing a national transport strategic framework and facilitating more sustainable transport systems and outcomes by acting to – give priority to sustainability matters in transport planning and decision making; – encourage an investment environment in which projects of national significance receive priority and competing private sector investment proposals are better evaluated, in relation to overall national intermodal

Problem area	Strategic concerns relating to the broad problem areas identified and the future sustainability of our transport systems
	systems requirements; – remove the impediments to sustainable transport planning created by the three-tier system of government; – develop and enable competitive evaluation of project proposals in relation to external benefits and costs and associated cumulative impacts. This requires that .. environmental impact assessment processes more explicitly seek assessment of energy and greenhouse impacts, .. project evaluation processes incorporating life-cycle evaluation of capital and operating costs and energy impacts be developed, .. 'post-project' cumulative impact evaluations be introduced, so that projects' impacts on consumer behaviour and intermodal efficiencies are better understood; – improve preliminary project-assessment and project-development (from pre-feasibility through to full bidding and operation) processes for projects in which the private sector is involved and for which government support is required; – better facilitate, manage and increase private sector participation in transport operations, infrastructure, finance, planning and research. The Commonwealth may need to reinvest in securing professional skills, knowledge and new management structures—across relevant portfolios, such as finance, treasury, health, transport—to this end. • State and Territory departments of transport face road-maintenance budgets of up to 75 per cent of total transport-related expenditure. Major city congestion problems and infrastructure investment requirements cannot be adequately dealt with by State and local governments alone. These are matters of national significance in terms of the economy and the environment, and they call for Commonwealth leadership to help fund and facilitate strategic projects. • Improved integrated land-use and transport planning is required if we are to stem the growth in transport demand. Governments can no longer be required to guarantee transport services irrespective of the pattern of development that occurs. There are increasing moves to strengthen Integrated Planning Acts and to support infrastructure funding beyond the local level by extending developers' contributions to feeder transport systems.

Problem area	Strategic concerns relating to the broad problem areas identified and the future sustainability of our transport systems
Regional transport—intrastate transport, satellites and major regional centres – service appropriateness: telecoms, pipelines, roads/rail/air – decentralisation	• Regional transport is generally regarded as being adequately serviced intermodally; that is, most major regions have good access to road, air and/or rail services. • In major conurbations the extension of public transport feeder services to existing public transport services remains a major challenge • Local governments face increasing difficulty with road-maintenance and infrastructure funding—particularly in rural areas, where agricultural freight is causing considerable deterioration in regional road systems. • State governments are transferring the cost of freight transport to local government as a result of the closure of regional rail branch lines. This problem is exacerbated by increasing reliance on road freight. • Local government is being increasingly called on to fund and deliver transport infrastructure, but there are inadequate mechanisms by which to publicly or privately fund these initiatives. • Decentralisation planning strategies to alleviate pressure on major cities or to facilitate the supply of goods and services from local centres of production (and thus reduce the transport task) are not a current policy focus and need attention. • The current Commonwealth approach to regional development focuses on the creation of supporting environments and industry development, rather than on transport services. The possible inadequacy of transport services to regional areas does not appear to be considered a significant impediment to regional development. • Greater integration of land-use and transport planning is an important challenge for high-growth areas such as south-east Queensland.

3 Responding to the challenges—the Task Force's findings and recommendations to government

There is growing concern about the sustainability of our transport systems and the environmental, social and health impacts of transport. The National Greenhouse Response Strategy, released in late 1998, incorporates a comprehensive range of transport and urban form strategies that are designed to involve all levels of government in initiatives to explore opportunities to reduce greenhouse emissions from the transport sector. Most of the proposed strategies and studies were initiated in 1998–99 and are continuing or will report in the next one to three years with specific recommendations. Considerable progress has already been made to improve fuel quality and vehicle emissions and to increase the use of alternative fuels, as discussed in Chapter 9.

In what is a rapidly moving field, the Task Force puts forward its recommendations with due recognition that government is already working to resolve problems in many of the areas discussed. In some areas, however, the Task Force considers that further, more immediate action may be required. Nevertheless, the Task Force is impressed with the broad range of government initiatives currently under way, and it urges governments to continue to focus on aspects of sustainable transport as matters of national significance and to foster supportive environments in which engineers and industry can use their expertise to develop, improve and promote sustainable transport systems.

Governments, planners, engineers and the community can focus on the following actions to enhance the sustainability of our transport systems.

- Increase urban consolidation by encouraging greater density of development and facilitate integrated land-use and transport planning to improve access, reduce the need to travel, and deliver urban environments that support walking, cycling and public transport.

- Accelerate the introduction of cleaner fuels and more efficient vehicle technologies across the transport fleet.

- Improve the environmental performance of the existing fleet through better operating and maintenance standards.

- Promote and deliver improved, more passenger friendly public transport to reduce private car use.

- Encourage new work and business practices to reduce growth in the passenger and freight task.

- Give priority to and promote investment in and use of transport modes that are less carbon and pollutant intensive in their manufacture and operation.

- Educate the public and stakeholder groups about sustainable transport and provide incentives to encourage change in our travel behaviour and transport expectations.

3.1 Findings

The Task Force's recommendations are based on the following findings.

- It is in the interest of all Australians that the Commonwealth and State and Territory and local governments confront the challenge of greenhouse gas emissions in a coordinated and cooperative manner, using all methods at their disposal, including raising the community's understanding of the subject. Initiatives need to go beyond the transport sector, to include instruments in the following policy areas: industry and innovation, taxation and fiscal reform, infrastructure and investment policy, health, environment, transport and regional development, and community services.

- Structural change—based on greenhouse performance as the common denominator in transport planning, investment and operation—is essential to achieving positive outcomes for the wellbeing of all Australians and their environment.

- Unsustainable levels of growth in pollutant and greenhouse gas emissions from transport must be reversed. This requires action through technological innovation and travel demand–management strategies, as well as the setting of ambitious targets and incentives for the introduction of low-emission vehicle technologies, clean fuels, and appropriate modal choices.

- Transport pricing regimes should be reformed, to better allocate economic and environmental costs and to encourage people to change their travel behaviour and choose more sustainable transport modes.

- Integrated land-use and transport planning should be further encouraged and be supported by clear national transport priorities.

- The intermodal competitiveness of our freight systems should be improved, to produce efficient environmental and economic outcomes by increasing the contribution that rail and shipping make to the national freight task.

- The Commonwealth should provide increased seed funding to meet major city transport infrastructure requirements and support private sector participation in the provision of transport services and infrastructure. The investment and project development and approvals framework must require comprehensive sustainability impact statements and evaluative procedures from project inception.

3.2 Recommendations to government

1 Taxation and fiscal policy instruments should encourage sustainable transport.

The 1998 National Greenhouse Response Strategy lists economic policy instruments (Measure 5.1) as the first additional measure to be considered in relation to transport. The Task Force recommends the following areas for consideration.

1.1 Review taxation policies that favour the use of private motor vehicles through salary packaging and company-provided parking and potentially discourage use of urban public transport.

1.2 Review the GST package, which will have the effect of decreasing the perceived cost of car ownership, operation and parking and increasing the perceived cost of urban public transport fares.

1.3 Accelerate the introduction of transparent user-pays pricing regimes that focus on direct charging for use rather than indirect taxation. Charges should reflect and communicate the full environmental, health and economic costs of our transport systems, fuels and choices.

1.4 Expand the clean-fuel credits program recently announced in ‘A New Tax System’ to commercial vehicles and buses (under 20 tonnes) operating in urban areas where they are currently precluded from clean-fuel credits (subject to further study conclusively proving the benefits of compressed natural gas and liquid petroleum gas).

1.5 Encourage development of intelligent transport systems that will allow for effective congestion pricing in urban areas and mass–distance charging for heavy vehicles.

2a There is a strong case for increased investment in transport infrastructure that offers the opportunity to develop a transport system that is integrated, more sustainable and less greenhouse gas intensive.

2b The market is the appropriate mechanism to allocate resources between individual transport modes, but where market forces fail to deliver environmental and social objectives governments should intervene.

2.1 Initiatives designed to produce competitive investment neutrality between modes should be progressed.

2.2 Transport in urban areas is of national significance. City–port connections and road and rail connections with ports require improved planning and coordination across all levels of government, to obviate duplication of services and local zoning decisions that may result in urban residential encroachment on priority corridors and major ports and airports. This calls for the early identification of future transport corridors.

2.3 Greater intermodal integration is becoming increasingly critical to improve freight and transit efficiency.

2.4 The strong case for increased investment in infrastructure is exemplified by

- the recommendations of *Revitalising Rail*, the report of the Rail Projects Taskforce (1999) to bring the national track to such a standard that it can begin to provide a competitive and sustainable alternative to road transport;

- investment in regional transport systems to improve the competitiveness of rural industry.

2.5 Greater Commonwealth investment in urban transport is necessary because of the central role cities play in the national economy. Investment is specifically required to improve intermodal connections, to help fund circumferential road networks linking with the national highway system, and to provide seed investment funding for infrastructure that will enable greater public transport provision.

2.6 In view of the increasing level of private sector participation in transport planning, operations, infrastructure and research, the Commonwealth should review and augment public sector professional expertise across all relevant departments (finance, treasury, transport, health), to better coordinate and evaluate private sector proposals and participation in the transport sector.

3 More holistic approaches that integrate environmental considerations into transport policy, planning and investment decisions are needed. They should go beyond current Commonwealth and State and Territory environmental impact evaluations in order to examine wider impacts on health, sustainability and greenhouse gas emissions.

3.1 The Task Force supports the National Greenhouse Response Strategy requirement (Measure 3.3) that all jurisdictions review and amend environmental impact assessment processes to incorporate greenhouse gas emissions from proposed projects by the end of 1998–99.

3.2 The Task Force encourages the Commonwealth and the Council of Australian Governments to include greenhouse factors as a trigger for environmental assessment and approval (under Commonwealth legislation) of all new projects that have the potential to be major emitters of greenhouse gases in their construction or operation, or both.

3.3 The Task Force recommends that the comparative energy consumption and greenhouse emission impacts of competitive project proposals and alternative transport options be given greater consideration in the determination of Commonwealth and State and Territory infrastructure investment priorities.

3.4 Feasibility studies and approvals processes for major projects should be based on common, comparative evaluation procedures that incorporate economic and environmental life-cycle cost–benefit analysis.

4a There is a need for industry, innovation, and research and development policies and commitments to support the development of cleaner transport fuels and technologies.

4b Additionally, there is a need for research into transport pricing, economics and demand-management technologies.

4.1 Full fuel–cycle analysis of Euro 2 and 4 diesel, Euro 2 and 3 petrol, compressed natural gas and liquid petroleum gas is necessary to provide more conclusive information about the comparative pollutant and greenhouse gas–emission benefits of these fuels, to assist decision making relating to sustainable transport options.

4.2 If necessary, additional measures should be implemented to ensure that the Australian refining industry can deliver fuels compliant with Euro 4 diesel and Euro 3 petrol standards by 2006 on a national basis.

4.3 Australian refining industries should be supported to maintain Australian production capability, with due regard to defence needs and requirements for flexibility in competition policy that may be necessary to ensure national production capability.

4.4 Incentives should be provided to encourage accelerated market introduction and demonstration of low-emission hybrid vehicles and dedicated natural gas vehicles (cars, trucks and buses) that are now commercially available internationally but are costly to import in limited numbers.

4.5 The harmonisation of Australian Design Rules with European Design Rules should be accelerated, to remove impediments to the commercial introduction of innovative, clean-vehicle technologies.

4.6 Research and commercialisation funding should be increased for Australian innovation in new vehicle and fuel technologies, such as the CSIRO aXcess hybrid electric car and associated automotive research in hybrid vehicle systems and componentry, natural gas vehicle technologies, high-volume ethanol production, and fuel cell innovation.

4.7 Research into the development, application and administration of road pricing, charging and associated demand-management technologies made possible by intelligent transport systems should be supported.

4 Responding to the challenges—the role of engineers

The Task Force considers that sustainable transport is an important consideration for the engineering profession and the community it serves. It encourages the Institution of Engineers Australia and the engineering community to consider the following recommendations.

The Institution can take the following actions:

- Review its structure in relation to transport, to reflect the fact that transport is an important area of engineering practice, involving a range of disciplines and industry skills.
- Convene a multidisciplinary expert team to review and comment on proposed major projects and policy developments in the transport sector.
- Draw on the Task Force’s recommendations to government to contribute to sustainable transport policies and the development of a national sustainable energy strategy.
- Plan and implement a process for presenting the findings of this report and promoting sustainable transport matters to Institutional stakeholder groups.
- Liaise with government and private organisations that are developing policies, and/or projects which relate to sustainable transport.
- Provide public comment on government policies relating to sustainable transport.
- Press for a more coordinated approach, on the part of all levels of government and industry, to sustainable transport.
- Promote and support public events, forums and research initiatives relating to sustainable transport.
- Inform and encourage members to be aware of the challenges and of action they can take in their professional and personal lives.

The Task Force encourages the Institution to do the following:

1. Give due consideration to the Task Force's recommendations to government when making representations to government, specifically including

- to establish a National Infrastructure Advisory Council;
- Submissions the Institution may make to government on energy, innovation and investment policy;
- Participation in the expanded strategic investment coordination process for large capital-intensive projects, as recently announced by the Commonwealth Government as part of the New Business Tax system.

2. Establish mechanisms for the Institution, through its policy area, committees and societies, to nominate and offer a representative or representatives to participate in and/or report to members on initiatives of the National Greenhouse Response Strategy that relate to sustainable transport. Among the specific initiatives under the Strategy that are of interest to the engineering community and in which the Institution and its members might constructively participate are

- the Cities for Climate Protection local government initiative, commenced in mid-1999;
- the Promoting Best Practice in Transport and Landuse Planning initiative—led by the Queensland Department of Transport and begun in June 1999—to deliver materials and recommendations for implementation by 2001–02;
- the review of economic policy instruments relating to transport, an inquiry being conducted under the auspices of the Australian Transport Council and due for completion by 1999–2000;
- a Forum established in July 1999 to investigate new public transport modes and technologies;
- a study of opportunities to reduce freight transport emissions, a work program of a National Task Force established under the Australian Transport Council and due to report by July 2000;
- a study into intermodal integration, to be conducted during 1999–2000.

3. **Explore and seek opportunities to develop collaborative initiatives—such as joint forums, research and educational activities—on sustainable transport and engineering aspects with leading industry and research organisations and programs. Among the organisations at the forefront of sustainable transport innovation and with whom the Institution might develop further cooperative initiatives are**

   – the Warren Centre for Advanced Engineering, whose Sustainable Transport in Sustainable Cities program, a three-year research program, started in mid-1999 and may be reported on in late 1999;

   – ARRB Transport Research;

   – Austroads—the association of road transport and traffic authorities in Australia and New Zealand;

   – the Society of Automotive Engineers Australasia and Automotive Training Australia, which in 1999 held a conference on the 'Great Eco-Auto Challenge';

   – the Chartered Institute of Transport in Australia Inc.;

   – the Australian Natural Gas Vehicle Council, which is soon to publish a detailed report on alternative-fuel vehicles and their economic and environmental benefits;

   – the Greenhouse Challenge Office and the Australian Trucking Association, which recently jointly launched the *Road Freight Environment and Greenhouse Challenge Workbook*;

   – the Australasian Railway Society and the Railway Technical Society of Australasia.

   – the International Association of Public Transport (Australia/New Zealand)

Further, there are a number of important things the profession as a whole and individual engineers can do.

The profession can encourage:

- engineers to consider and promote the adoption of engineering and design solutions and travel demand–management principles—as detailed in the Institution's Policy on Travel Demand Management in Urban Areas—to support transport sustainability;

- participation in the development and implementation of sustainable transport strategies;

- development of engineering degrees, courses and training programs that foster a holistic approach within the profession, including an appreciation of all aspects of ecologically sustainable development and sustainable energy that pertain to transport.

Individually, engineers can

- promote sustainable transport design principles and technologies and clean fuels in the projects in which they are involved and in the transport operations of their organisations;
- explore opportunities to take advantage of the Alternative Fuel Conversion Program and the Alternative Fuel Grant Scheme, which will come into effect in July 2000;
- encourage their organisations to join the Greenhouse Challenge, conduct annual energy audits of their operations, and develop transport procurement guidelines that assign priority to the purchase of fuel-efficient vehicles;
- review their personal and professional transport requirements and encourage employers to offer increased access to or salary packaging of sustainable transport options;
- support local sequestration initiatives such as the Foster Foundation's GreenFleet program;
- support integrated land-use planning and urban design initiatives that aim to promote sustainable transport options;
- make recommendations to the Institution in relation to continuing professional development, information and resource requirements in areas of sustainable transport that they consider are insufficiently accessible or available and that the Institution could help to promote.

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Part Two Supporting information

5 Energy use in the transport sector

In Australia energy consumption by the transport sector accounts for about 25 per cent of total primary energy consumption and about 36 per cent of total final energy consumption. As Table 5.1 shows, transport's share of total energy consumption is anticipated to remain about the same to 2014–15. The table is based on projections that do not take into account proposed greenhouse initiatives across all sectors to 2014–15. Transport is forecast to surpass the electricity-generation and manufacturing sectors, to become the largest final energy consumer. This view derives from industry surveys, which suggest that the electricity-generation sector will be the most important area in which energy efficiency improvements can be expected (in large part because of increased efficiencies from more extensive use of gas), thus increasing transport's relative share of total consumption.

What is perhaps most interesting in the picture presented by Table 5.1 is that, in terms of annual rates of growth in energy consumption per sector, transport will move from having an annual rate of growth below the overall average to one that exceeds the average across the economy as a whole.

Table 5.1 Energy consumption, by sector, 1973–74, 1997–98 and projections for 2014–15

	Consumption (petajoules)		Sector share (per cent)			Annual growth in consumption (per cent)			
						1973–74 to	1993–94 to	1996–97 to	1997–98 to
Sector	1997–98	2014–15	1973–74	1997–98	2014–15	1997–98	1997–98	1997–98	2014–15
Agriculture	68.8	89.2	1.5	1.4	1.5	2.4	2.5	2.7	1.5
Mining	263.8	457.8	2.3	5.5	7.5	6.4	7.8	6.0	3.3
Manufacturing	1 197.0	1 523.3	35.1	24.9	25.0	1.1	1.9	3.6	1.1
Electricity generation	1 359.0	1 510.7	19.5	28.3	24.8	4.2	5.2	9.4	0.6
Construction	46.9	56.2	1.0	1.0	0.9	2.5	2.2	3.1	1.1
Transport	1 210.7	1 593.5	26.2	25.2	26.2	2.4	2.9	0.6	2.4
Comm. & services	205.7	333.0	3.2	4.3	5.5	3.7	5.2	5.1	3.7
Residential	384.6	431.7	8.8	8.0	7.1	2.1	2.7	1.7	0.7
Other	73.6	91.4	2.4	1.4	1.5	0.7	1.7	2.2	2.1
Total	4 810.1	6 086.9	100.0	100.0	100.0	2.6	3.6	4.3	1.4

Source: Bush et al. (1999).

Table 5.2 shows historical and projected growth in total energy consumption by transport mode. Of note is the dramatic increase in energy consumption by air transport. The recent decline in rail and water transport energy consumption is projected to be slowly reversed to 2014–15.

Table 5.2 Energy consumption, by transport mode, 1986–87, 1997–98 and projections for 2014–15

(petajoules)

Transport mode	1986–87	1997–98	2014–2015
Road transport	729.3	936.0	1 141.4
Rail transport	32.7	29.4	35.7
Air transport	97.7	183.6	323.1
Water transport	58.3	53.4	71.6
Total	918.0	1 202.4	1 571.8

Source: Extrapolated from Bush et al. (1999).

6 Some perspectives on the future outlook for oil

In 1998, following the symposium ‘Beyond Oil: transport and fuel for the future’, the Chartered Institute of Transport in Australia Inc. issued a communique that declared,

> We are at the climax of the fossil fuel age … We have reached a crucial stage in the development of our local, national and international transport services. Our present path is leading us into potentially serious economic, social and environmental problems. New directions are needed for our future transport fuels and vehicles. ‘More of the same’ in our current transport plans and ways of thinking is no longer tenable … (CITIA 1998)

The communique identified the following matters as of vital importance:

- key factors affecting oil based transport are congestion, pollution and oil supply,
- the real cost of transport is going to increase and must be considered as a major factor in setting the economic agenda for the 21st century,
- the need for Governments to support the introduction of viable alternative fuels, more efficient vehicles and alternative transport systems which are environmentally acceptable and fuel efficient,
- the need for greater transport industry and public awareness of the need to prepare for the decline and end of the ‘Petroleum Age’,
- it is essential that care of people and of the environment be recognised as the principal standards for addressing these issues.

At the opening of the symposium the Honourable Sir Guy Green AC KBE, Governor of Tasmania, expressed a forward-looking approach to change and the question of ‘scarcity’:

> Debate about that issue [oil scarcity] sometimes gets bogged down by inconclusive discussions about the exact size of the remaining oil resources and exactly how long they will last. I suggest that it is more fruitful to proceed, as I understand this symposium will proceed, on the basis that although we don’t know exactly when the reserves will run out or at least when they will become so scarce or costly that large scale reliance on them becomes untennable - it will happen. The question we ought to be concentrating upon is what we can do to prepare for and to cope with the revolution in transport which that will create. I would suggest that it doesn’t greatly matter if it turns out that our forecasts about the rate at which the changes will take place are unduly pessimistic. The magnitude of the adjustments we shall have to make is so great that we need all the lead time we can get. (Green 1999)

The Task Force agrees with the spirit of this message. Many people now believe it is time to plan to reduce our dependence on oil. The following discussion provides an overview of some current perspectives in the oil debate and Australia’s status in relation to the resource.

Internationally, and increasingly, the role of oil in the global energy mix is becoming more concentrated in the transport sector. This trend is occurring in parallel with growing international recognition that oil—of all the fossil fuels—may be close to reaching peak conventional production. One of the International Energy Agency’s main findings in *World Energy Outlook 1998* was the projection that *conventional* oil production may peak during the period 2010 to 2020. This is certainly the view of industry analysts such as Campbell and Laherrere (1998), who argue that world production of conventional oil could peak even earlier (perhaps by 2010) for reasons that include historical overestimation of reserves by OPEC nations to boost export quotas.[2]

The dramatic slide in world oil prices since 1997 suggests oil supply and demand profiles that appear to contradict these projections. Various factors are seen as determinants of the trend, among them OPEC's inability to control the production rates of its members, increased exploration and production, and the Asian downturn resulting in a glut of supply (Krzus 1998). Conversely, some in the industry attribute the rapid decline in prices in part to incorrect market information and supply over-projections, which may result in dangerously tighter inventories and shortfalls.[3]

One potential outcome of the decline in oil prices since 1997—a range of industry observers seem to hold this view—is that there will be a significant reduction in Australian petroleum exploration and development (at least in the short term), which may adversely affect the development of 'greenfield' sites for new petroleum resources in Australia (Waring 1998, Krzus 1998). In 1999 world oil prices have again increased. Subject to industry expectations about whether such prices will be sustained, the recent trend of declining Australian investment in onshore petroleum exploration may be slowly reversed.

Australia is, and is projected to continue to be, a significant net importer of crude oil and other refinery feedstocks: the level of imports is about twice that of exports (Bush et al. 1998). On the basis of current trends, over 95 per cent of transport energy will be supplied by petroleum-based products. Australia meets a little over three quarters of its domestic needs for liquid fuels from domestically produced primary crude oils. In an international context of medium-term projections that cheap world oil production is drawing closer to an end, and a short-term environment in which there has been a 30 per cent drop in investment in domestic petroleum exploration, Australia may face smaller domestic reserves and greater import requirements.

In comparison with our other major energy commodities, Australia does not have vast oil reserves, as Figure 6.1 illustrates. The reserves shown are calculated by dividing known reserves of conventional oil (that is, oil currently in commercial production and oil reserves identified for possible commercial production) by current production levels in the given year. On average, Australia has about 10 years of reserves available.

Relative to other fossil-fuel supplies, conventional liquid fuels may in time become an area in which managing for longer term security of supply may pose some challenges. The Bureau of Resource Sciences claims that Australia has abundant hydrocarbon reserves. In particular, natural gas reserves are estimated to be around 120 trillion cubic feet, which equates to over 100 years' production at current rates (Dean 1998).

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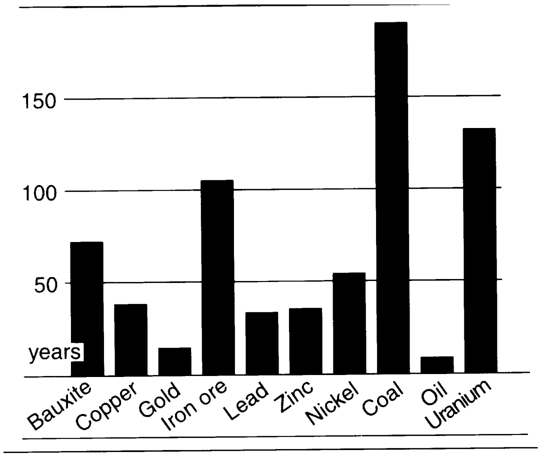
[2] For a full discussion of the respective arguments of the 'pessimists' and the 'optimists' in relation to conventional oil reserves, see International Energy Agency (1998, pp. 83–109) and Campbell and Laherrere (1998, pp. 78–83).

[3] In October 1998 the Independent Petroleum Association of America asked the US General Accounting Office to examine the International Energy Agency's forecasts of worldwide oil supply and demand during 1997 and 1998 on the basis of concern that the Agency may have significantly overestimated the magnitude of oversupply, resulting in dangerous pricing signals and an unwarranted slowdown in production and exploration.

Figure 6.1 Years of reserves for Australia's major commodities



Note: Figures are based on 1997 production.
Source: Waring (1999, p. 39).

The question of continued access to cheap, conventional oil is obviously something about which there is and will continue to be a range of views. One senior member of the petroleum industry sees a horizon of abundance for the next 20 and potentially 40 years, when biomass may be expected to play a greater role. The Task Force's discussions suggest that fuel scarcity is not at present considered a serious policy concern. There seems to be consensus that we are at or may soon reach peak production of conventional oil; supply shortages are generally not anticipated (as non-conventional modes of production come into play), although it is possible that we may eventually have to pay more for our liquid fossil fuels.

7 The transport sector and greenhouse gas emissions

Scientists have provided clear evidence that industrial and agricultural activities in recent centuries have contributed to a change in the composition of the atmosphere, resulting in increased concentrations of greenhouse gases, which contribute to atmospheric warming. Significant changes in the global climate are predicted. It is expected that there will be temperature increases of some 0.3 to 1.4 per cent in some parts of Australia in the next 30 years. These changes are projected to affect regional rainfall patterns and increase the severity and frequency of storm events, with wide-ranging implications for urban and rural infrastructure, health, land management and agriculture (PMSEIC 1999).

In sum, the greenhouse phenomenon has been widely acknowledged by a number of international forums in the last decade as a matter for global concern.

In 1995 the Intergovernmental Panel on Climate Change presented the following conclusions to policymakers.

- Increases in greenhouse gas concentrations since pre-industrial times have led to a positive radiative forcing of climate, tending to warm the surface of the earth and produce other climate changes.
- The atmospheric concentrations of the greenhouse gases carbon dioxide, methane and nitrous oxide, among others, have grown significantly: by about 30 per cent, 145 per cent and 15 per cent respectively (values for 1992). These trends can be attributed largely to human activities, principally fossil-fuel use, land-use change and agriculture.
- Many greenhouse gases remain in the atmosphere for a long time—in the case of carbon dioxide and nitrous oxide, many decades to centuries. As a result, if carbon dioxide emissions were maintained at near 1994 levels they would lead to a nearly constant rate of increase in atmospheric concentrations for at least two centuries, doubling pre-industrial concentration levels by 2100. (IPCC 1999)

7.1 Australia's Kyoto commitment

Australia signed the Kyoto Protocol in April 1998, accepting as realistic a negotiated target of 8 per cent growth in greenhouse emissions by 2008 to 2012 over the 1990 baseline. Many other developed countries have signed the Protocol, agreeing to reduce their collective greenhouse emissions from 1990 levels by at least 5 per cent by 2008 to 2012. To meet the Australian target, our 'business as usual' projections of emissions growth will need to be cut by some 25–30 per cent, or by 100 million tonnes of carbon dioxide equivalent (PMSEIC 1999, Beale 1999).[4] Australian greenhouse emissions increased from 385 to

[4] Estimates of the percentage reductions on 'business as usual' emissions growth sometimes vary, usually because of differing baseline assumptions and variations resulting from the continuing development of inventory methodologies and data-collection processes. The task is generally understood to be to rein growth in emissions back from a 'business as usual' estimate of over 40 per cent growth by 2010 on 1990 levels to growth of only 8 per cent on 1990 levels.

419 megatonnes of carbon dioxide equivalents between 1990 and 1996 (an increase of about 9 per cent), stationary energy, transport and agriculture being the three largest emitters. More recent data, from the 1997 National Greenhouse Gas Inventory, shows that total net greenhouse gas emissions (not including land clearing) have increased by 11 per cent over the period 1990 to 1997.

7.2 Greenhouse gases

Greenhouse gas emissions are emissions that contribute to global warming; they are frequently referred to as ‘carbon dioxide equivalent’ since carbon dioxide is the most abundant greenhouse gas (followed by methane). Carbon dioxide is attributed a global warming potential (GWP) over a 100-year time horizon of 1. It is against this that the GWP of other gases is measured: for example, methane GWP = 21; nitrous oxide GWP = 310; and hydrofluorocarbons range from GWPs of 140 to 11 700. GWP is an index, defined to be the warming effect over a given period caused by an emission of a particular gas relative to an equal mass of carbon dioxide. Thus 1 kilogram of methane emissions has an average global warming effect of 21 kilograms of carbon dioxide emissions.[5]

The transport sector generates both direct (radiatively active) and indirect greenhouse gases. The main direct greenhouse gases emitted from the sector are carbon dioxide (CO_2), which is the largest contributor, methane (CH_4), nitrous oxide (N_2O) and chlorofluorocarbons (CFCs). Indirect greenhouse gases such as carbon monoxide (CO), oxides of nitrogen (NO_x) other than nitrous oxide, and non-methane volatile organic compounds (NMVOCs) do not have a strong radiative effect themselves but do influence atmospheric concentrations of the direct greenhouse gases. Sulphur oxide emissions are also known to influence climate change, although the exact nature and magnitude of the effects of atmospheric sulphur oxides are still very uncertain and so are generally not included in most greenhouse inventory or projection data.

Water vapour is the primary contributor to the greenhouse effect but it is not normally considered in greenhouse gas inventories because human output is negligible when compared with the day-to-day precipitation cycle. Carbon dioxide is the next most significant greenhouse gas and is the major gas associated with the human-induced greenhouse effect (BTCE 1995).

7.3 The transport sector’s role in Australian greenhouse emissions

In 1996 the Australian transport sector accounted for 71 million tonnes of Australia’s total net greenhouse gas emissions, which is just over 17 per cent of Australia’s total emissions. Greenhouse gas emissions from the transport sector are the fastest growing emissions of any sector, rising by 15 per cent from 1990 to 1996. The Bureau of Transport Economics projects that, without reduction measures, emissions from the transport sector will rise by 42 per cent on 1994 levels by 2015 (cited in Commonwealth of Australia 1998, p. 55).

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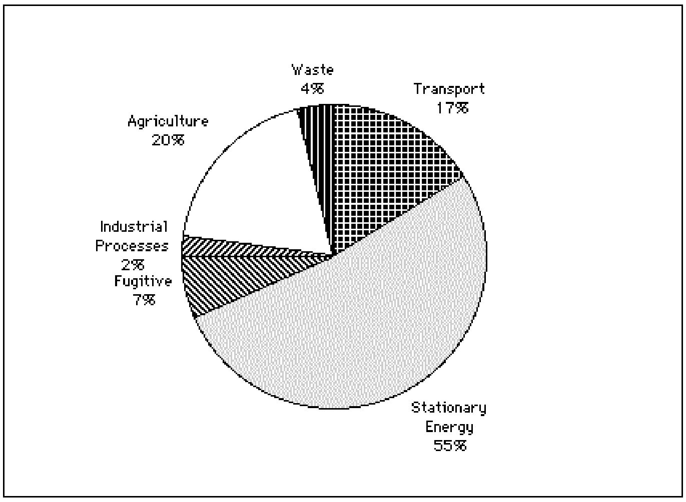
[5] These GWP figures are from Greenhouse Challenge workbooks, whose data source is the Intergovernmental Panel on Climate Change’s 1996 document *Climate Change 1995: the science of climate change. Contribution of Working Group 1 to the Second Assessment Report of the Intergovernmental Panel on Climate Change*. Other references sometimes quote variations on these GWPs.

Per capita, Australians have the third highest greenhouse gas emissions from transport use in the world, ranking behind the United States and Canada. Approximately one-third of the average Australian family's greenhouse emissions are attributable to transport activities.

The Foster Foundation GreenFleet initiative calculates that to combat the annual emissions generated by the average vehicle in one year of travel (approximately 4.3 tonnes of carbon dioxide) seven fast-growing pine trees would need to be planted and their life-cycle cleansing properties (of the first 20–30 years of growth) dedicated to the task. Sequestration is a valuable medium-term tactic to neutralise emissions, but the real challenge is to tackle growth in emissions at their source.

Figure 7.1 shows sectoral contributions to total national greenhouse emissions. Stationary energy, the dominant contributor, includes all energy used in electricity generation, manufacturing, construction, and other non-mobile uses other than industrial processes (emissions from byproducts of various production processes). Fugitive emissions are those that occur as a result of losses and leakages during extraction and storage of energy for use—for example, methane emissions from coal mining and emissions caused by breakages in pipelines. Transport's share of total emissions is the sum of all domestic energy consumed across all modes. Fuels used by the military and by international air and shipping generated from Australia are excluded.

Figure 7.1 Shares of net carbon dioxide equivalent emissions, by source: Australia, 1996



Noted: Excludes emissions resulting from land clearing.
Source: Australian Greenhouse Office (1999).

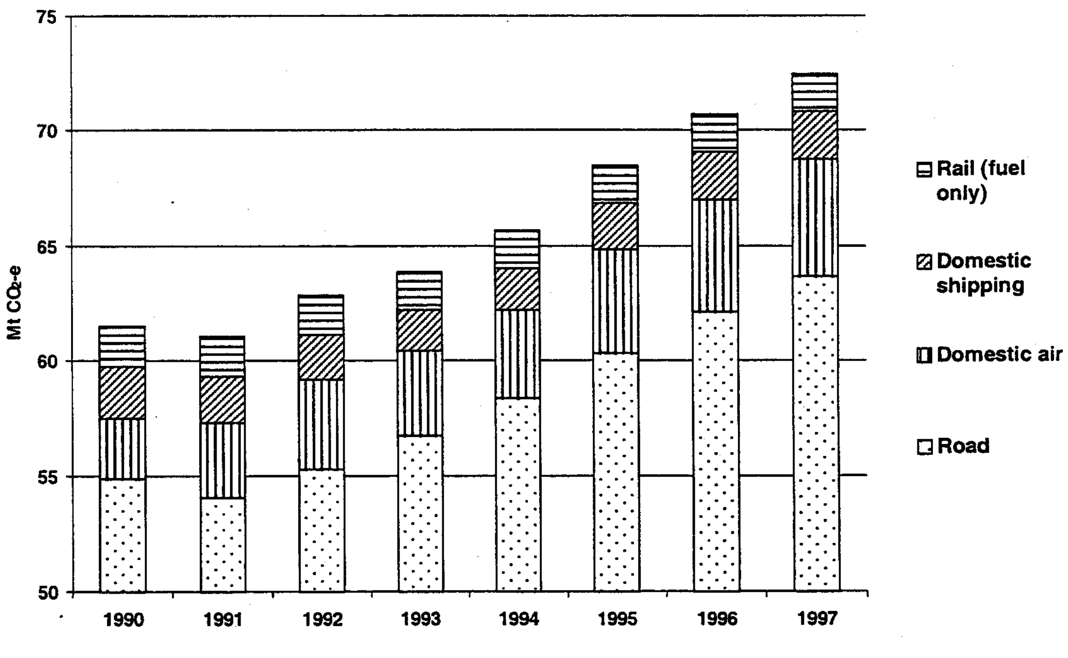
Fuels used for international transport—air and shipping—are referred to as 'bunker fuels'. National greenhouse inventory data record energy used in these activities but under the current terms of the Kyoto Protocol, this energy consumption is not yet required to be attributed to national greenhouse performance targets. During the Kyoto negotiations in November 1997 the question of how to attribute to individual nations greenhouse emissions arising from international transport tasks was not resolved. Mechanisms were, however, then established to work towards a means of attributing international emissions to responsible countries and working groups charged with responsibility for reporting on those mechanisms are due to report in late 1999. It is foreseeable that countries will eventually be required to include international transport emissions in their national performance targets.

7.4 Modal emissions

In 1996 about 87 per cent of domestic greenhouse gas emissions from the transport sector were from road transport (all vehicles), a figure that grew to almost 89 per cent in 1997. The remaining greenhouse gas emissions from the transport sector are derived from rail, air and sea. In the period 1990 to 1997 the contribution of both shipping and rail declined to percentage levels below their respective 1990 levels, while total emissions from the road sector continued to grow and domestic air transport emissions grew at a rate of 10 per cent a year.

The breakdown of emissions between the various transport modes is expected to remain largely the same until 2010. Accordingly, increases in greenhouse gas emissions from road transport will account for much of the growth, and growth in this mode will be dominated by emissions from trucks and light commercial vehicles. Emissions from domestic aircraft movements are also expected to grow strongly. Figure 7.2 shows emissions from domestic transport modes for 1990 to 1997.

Figure 7.2 Domestic transport greenhouse gas emissions, by mode, 1990 to 1997

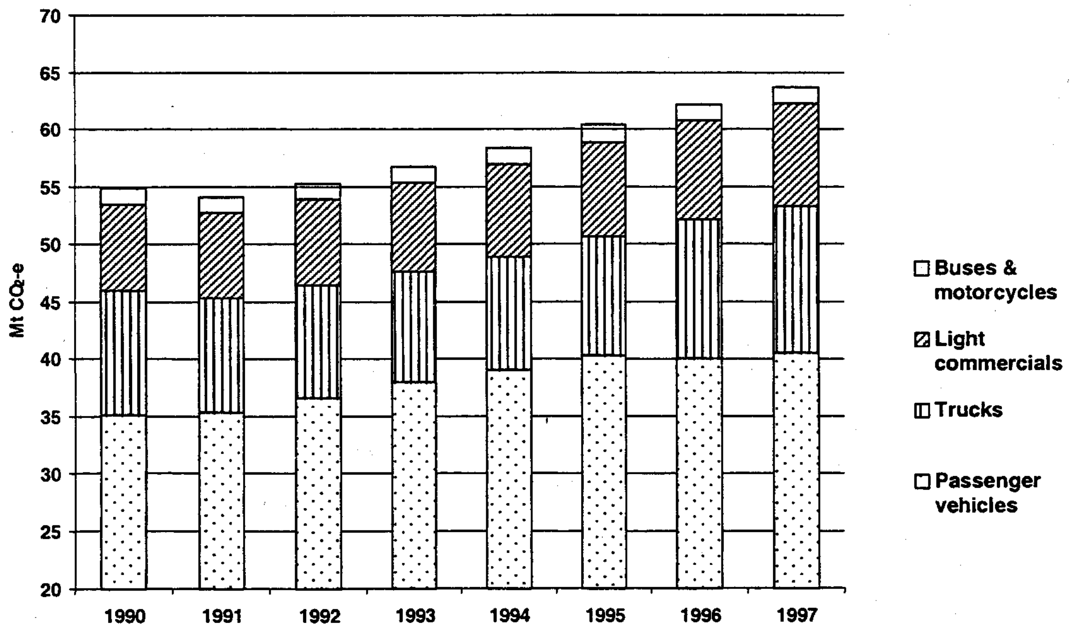


Source: National Greenhouse Gas Inventory Committee (1999).

Road transport: the dominant contributor to transport greenhouse emissions

Figure 7.3 shows emissions by type of road vehicle for 1990 to 1997. The main sources of emissions growth have been trucks and light commercial vehicles, respectively growing 18 per cent and 21 per cent during the period, while passenger vehicle emissions growth has recently begun to slow.

Figure 7.3 Road transport greenhouse gas emissions, by vehicle type, 1990 to 1997



Source: National Greenhouse Gas Inventory Committee (1999).

The outlook for the road sector is that emissions growth will increasingly be determined by trucks and light commercial vehicles.

Forecasts that the rate of growth in car traffic in most cities will halve from current levels by 2020 (as population growth slows and saturation levels of per capita car ownership are reached), coupled with new car fuel-performance targets scheduled in automobile industry product plans, may, however, result in a decline in greenhouse emissions growth from the Australian car fleet.

In contrast, there is limited scope to reduce the fuel intensities of truck engines within the period and truck emissions will probably continue to grow in line with expected economic growth in the Australian economy (BTCE 1995). Emissions from trucks (along with emissions from domestic aviation) are projected to be among the fastest growing emission categories in the transport sector to the year 2015.

Table 7.1 shows the projected outlook for emissions from the road sector to 2015.Two series of projections are given, reflecting changed assumptions for projected light commercial vehicle growth, as revised in 1999.

Table 7.1 Road-based transport: projected carbon dioxide equivalent emissions, 1995 to 2015

(per cent)

Road vehicle type	Growth in CO_2 equivalent emissions 1995 to 2015[a]	Percentage contribution to CO_2 equivalent emissions in 2015[a]	Growth in CO_2 equivalent emissions 1995 to 2015[b]	Percentage contribution to CO_2 equivalent emissions in 2015[b]	Comment
Cars	10	53	10	57	70% urban
Buses	16	2	16	2	Mainly urban
Rigid trucks	33	7	33	8	Mixed
Articulated trucks	75	13	75	14	Mainly country
Light commercial vehicles	148	25	73	19	Mainly urban
Road transport		100		100	

a. Data in these columns is drawn from BTCE report 94, in which average annual growth in light commercial vehicle ownership of 4.3 per cent was projected for the 20-year period.

b. Data in these columns is drawn from BTCE report 94 and incorporate revised assumptions for light commercial vehicle ownership. Average annual growth in light commercial vehicle ownership is now projected to be 2.5 per cent throughout the period.

Source: BTCE (1996, Table III.1) and based on discussion with BTE in 1999.

8 Health-related effects of energy use in the transport sector

Air quality rates highly on the community's list of concerns about traffic and there is general awareness that the health effects from motor vehicles are directly related to air quality. The following provides a summary of some of the main impacts and action now being taken to tackle vehicle-related pollution.

Although air quality in Australian cities is relatively high in comparison with some cities in the United States and Europe there is concern that improvements made in recent decades are now under threat. The Australian Academy of Technological Sciences and Engineering's study of urban air pollution in Australia found that transport activities are the most important contributor to ambient air pollution in urban areas and that road vehicles are the dominant source of transport pollutants. Table 8.1 shows transport's contribution of specific pollutants to urban air.

Table 8.1 Contribution of transport to urban air pollution

(per cent)

Pollutant	Contribution by transport
Carbon monoxide	70–95
Hydrocarbons	40–50
Oxides of nitrogen	70–80
Particulates	10–50

Source: Australian Academy of Technological Sciences and Engineering (1997).

The primary areas of concern are particulates and other air toxics from diesel-engined vehicles, and nitrous oxides and hydrocarbons. Carbon monoxide levels are not considered a primary concern. Vehicle emissions account for over 90 per cent of airborne lead. Although no longer regarded as a serious problem in terms of increasing levels of concentration, lead emissions are still sufficient to justify continuing acceleration of the changeover to unleaded petrol, given uncertainties relating to the latent and cumulative health effects of exposure to lead and consequent adverse health effects occurring in environments where daily concentrations may themselves be acceptable.

Per capita transport emissions in Australia are among the highest in the world. Per capita emission rates for some of the main pollutants, foremostly particulates, are similar to or higher than those in many cities in the United States and Europe. Petrol engines account for most of the carbon monoxide and hydrocarbons and about half the oxides of nitrogen. Diesel-engined vehicles are a significant source of nitrogen oxides and particulate emissions and the main offenders in terms of visible smoke. The National Environment Protection Council has noted that diesel fuel emissions contribute approximately 80 per cent of total vehicle particle emissions in most major centres. As noted by the Australian Academy of Technological Sciences and Engineering, up to 80 per cent of vehicle emissions are generally caused by the 20 per cent of vehicles that are the heaviest polluters. Estimates of the health costs of vehicle emissions range from 0.01 per cent to more than 1 per cent of GDP—some $5.3 billion a year (Brindle et al. 1999).

Internationally, there is growing concern about the potential impact of transport pollutants. For example, the California Air Resources Board now categorises particle exhaust emissions from diesel as a toxic air contaminant (along with 40 other substances from diesel exhaust emissions) because of their detrimental effects on respiratory health and the possible causal relationship with cancer. In late 1998 the World Health Organisation (European region)

Ministerial Conference on Environment and Health urgently called for policies on environment, health and transport to be better coordinated and has drafted a charter to redress the environmental and health costs of transport (WHO Regional Office for Europe 1998).

In Australia, the Commonwealth and State and Territory governments have collaborated to develop new national air quality standards, which are set out in the *National Environment Protection Measure for Ambient Air Quality* (National Environment Protection Council 1998). The measure sets standards and goals to be met within 10 years, providing an ongoing focus for the States to develop and implement long-term air quality management (see, for example, the New South Wales Government's comprehensive Action for Air plan).

The National Ambient Air Quality Standards cover six major pollutants: carbon monoxide, nitrogen dioxide, photochemical oxidants (as ozone), sulphur dioxide, lead, and fine particles as PM_{10} (National Environment Protection Council 1998). Australia has not yet set ambient standards for air toxics such as benzene, acetaldehyde and 1,3 butadiene and formaldehyde because their concentrations in outdoor air are generally very much lower than the levels at which adverse health effects occur. Some of them are, however, known or suspected carcinogens. Greater attention may be given to them in future, as more is learnt about how they are absorbed onto fine particles in the vehicle exhaust stream and in turn can be breathed in as fine particles.

The new Australian standards for fine particles (PM_{10}—particles 10 micrometers or less in diameter) are commensurate with European Union and Californian standards. These fine particles are small enough to be inhaled into the respiratory system and are associated with respiratory and cardiovascular diseases and asthma.

Because of insufficient data, standards have not yet been introduced for ultra-fine particles ($PM_{2.5}$), although it is understood further work is being done in this very complex area of pollutants. Ultra-fine particles are small enough to be inhaled deep into the lungs and may enter the bloodstream, causing multiple chemical sensitisation and maladies such as nausea, rashes, changes in red and white blood cells, liver damage, and degeneration of the nervous system. Fine and ultra-fine particles are believed to have cumulative, interactive health effects and, once released into the urban environment, may interact and be recirculated through other vehicle engines to create a potent cocktail of compounds with potentially high carcinogenic properties (Fisher 1999).

Diesel and petrol both contribute to photochemical smog, or white haze (a complex mixture of chemicals that includes ozone and is created when reactive organic compounds and oxides of nitrogen react under sunlight), and diesel is largely responsible for brown smog and particle emissions in urban areas.

Important steps are being taken to improve Australian fuel quality. Petrol and diesel standards will progressively be brought into compliance with European fuel standards by 2005–06. In the case of diesel, the change required is considerable: Australian diesel, on average, currently contains 1300 parts per million of sulphur, in contrast to new Euro 4 diesel standards to be introduced by 2006, which allow a maximum sulphur content of no more than 50 parts per million.

The introduction of clean diesel will bring considerable improvements in diesel exhaust emissions. The introduction of Euro-compliant diesel and petrol may, however, deliver some competing pollutant and greenhouse outcomes. For example, desulphurisation technologies and low-sulphur fuels can lead to losses in energy efficiency and increased energy consumption. Low-sulphur fuels may reduce total particle emissions but could lead to a relative increase in the number and amount of very fine particle emissions.

Comprehensive data presenting the comparative pollutant and greenhouse emission benefits of existing Australian petrol and diesel, in comparison with Euro 2 petrol and diesel and alternative fuels such as natural gas and liquid petroleum gas, are lacking and further research is necessary. It is anticipated that this problem will be redressed by industry and government in the lead-up to the introduction of the Alternative Fuel Conversion and Grant programs, to commence in July 2000.

In summary, the health effects of vehicle-related emissions are significant and there is still much that is unknown about the cumulative and synergistic impacts of pollutants in combination with one another and on human health. The air quality of Australian cities has generally improved in recent decades, but we may be in danger of losing the gains that have been made and we may eventually experience higher levels of pollution than in the past, largely as a result of growth in the transport sector. As Table 8.2 shows, the health effects of road vehicle–related emissions are wide-ranging.

Table 8.2 Road vehicle–related emissions and their effects on health: a summary

Pollutant	Proportion emitted from motor vehicles	Impacts on human health
Carbon monoxide	Around 90% in summer and 70% in winter in Melbourne (EPAV 1997). Diesel vehicles emit less than petrol vehicles	At high concentrations symptoms include headache, reduced mental acuity, vomiting, collapse, coma and death
Lead	Motor vehicles contribute around 90% of airborne lead in urban areas (ABS 1997)	Toxic effects include chronic renal disease, chronic anaemia and neurological disorders. Children particularly susceptible
Nitrogen dioxide	Around 78% in summer and 73% in winter (EPAV 1997). Diesel emits less than petrol vehicles.	Can lead to respiratory infections, asthma, chronic obstructive airway disease and chronic lung damage
Ozone	Secondary pollutant not directly emitted from vehicles	Causes itchy and watery eyes, sore throats and nasal congestion. Also irritates the lower respiratory tract
Respirable particles	Up to 90% (by diesel vehicles) in some urban areas	Carry acidic gases and polycyclic aromatic hydrocarbons into the lungs. Can also trigger asthma attacks
Sulphur dioxide	Around 11% in both summer and winter (EPAV 1997)	Aggravates existing respiratory conditions such as asthma and chronic bronchitis, increasing cough and mucous secretion. Also acts in combination with other environmental factors
Hydrocarbons	Around 50% in summer and 44% in winter. Vehicles without catalytic converters are high emitters of benzene	Known carcinogen. Cause leukaemia.
	Diesel exhaust is a rich source of polycyclic aromatic hydrocarbons	Benzo(a)pyrene, a common constituent of PAH mixtures, is a major initiator of lung cancer

Note: Figures are largely for Melbourne but provide an indicative overview of transport source contributions.
Source: NRMA (1998, cited in Brindle et al. (1999)).

9 Commonwealth initiatives in sustainable transport

Many Commonwealth government departments and agencies are working in the area of sustainable transport. *The National Greenhouse Response Strategy—strategic framework for advancing Australia's greenhouse response* sets out a detailed program of activities involving all levels of government, industry and the community (Commonwealth of Australia 1998). This chapter provides an overview of the main initiatives to improve the environmental impact of road transport, specifically in the areas of clean and alternative fuels and improved efficiency and emissions performance.

9.1 The Environmental Strategy for the Motor Vehicle Industry

A national strategy to combat the environmental impacts of motor vehicles was developed during 1998 and endorsed in late 1998. The National Road Transport Commission and National Environment Protection Council are signatories to a Memorandum of Understanding whereby the national Motor Vehicle Environment Committee is established, with responsibility for carriage of the Environmental Strategy for the Motor Vehicle Industry. The Strategy involves a number of priority programs and a wide range of government departments and agencies and industry groups.

The Committee's primary objectives are to reduce motor vehicle emissions to improve air quality, to ensure that vehicle noise is within acceptable levels, to minimise greenhouse gas emissions, and to investigate options for improved waste-stream effects.

Among the central elements of the Strategy, are the following:

- harmonisation of noxious emission standards with international standards by 2006;
- bringing forward the phasing-out of leaded fuels;
- accelerated introduction of high-octane fuel to boost both vehicle performance and efficiency;
- negotiations to improve national average fuel consumption targets for all new vehicles by 2010, with an expectation of at least a 15 per cent improvement over 'business as usual' levels by 2010;
- extension of fuel consumption targets to include (for the first time) light commercial vehicles and four-wheel-drive vehicles up to 3.5 tonnes;
- mandatory model-specific fuel efficiency labelling through the Australian Design Rules;
- fuel efficiency targets for the Commonwealth fleet from 2003;
- the development of partnerships with consumer groups (both private and fleet) to encourage attention to fuel efficiency—for example, through the Greenhouse Challenge (Commonwealth of Australia 1998, Beale 1999).

During 1999 there have been two important initiatives in relation to our diesel and petrol standards, with major implications for Australia's refining industry. The Federal Office of Road Safety and the National Road Transport Commission have reviewed how to bring Australia's petrol and diesel emission standards into line with current European and US standards and their recommendations are now reflected in legislation—the *Diesel and Alternative Fuel Grant Scheme Act 1999*. In parallel, Environment Australia is investigating Australia's petrol and diesel quality with a view to developing standards to ensure a nationally consistent approach to fuel-quality management and delivery. This study is investigating a range of refining industry matters and the anticipated environmental benefits associated with transition to Euro-compliant fuel standards. Improved procedures for emissions performance inspection and maintenance performance are integral to the plan and a National Environment Protection Measure for diesel emissions is being developed.

At this stage, improved traffic management and vehicle or fuel pricing signals are approaches that may be considered in the longer term but are not currently on the agenda. Similarly, waste-stream effects (such as new options for waste management, recycling and associated embodied energy considerations), while generally noted in the Motor Vehicle Environment Committee's strategic plan framework, have not yet been formulated into project plans but are noted as possible areas for investigation (National Environment Protection Council & National Road Transport Commission 1999).

The new fuel standards

Although there is some dispute about the extent of the relationship, sulphur content in fuels is linked to the emission of potentially carcinogenic fine particulates from exhaust emissions. Europe will move to a diesel standard of sulphur content of 50 parts per million in 2005 (Euro 4). In Australia sulphur levels in diesel are currently on average 1300 parts per million and our refinery industry faces big challenges to make the transition to production of low-sulphur diesel. A strategy to encourage the industry to move progressively towards European standards in both diesel and petrol production has been developed through the work of the Motor Vehicle Environment Committee and incentives offered through 'A New Tax System—measures for a better environment' (Office of the Prime Minister 1999). Table 9.1 shows the timetable for change.

Table 9.1 Scheduled reforms for diesel and petrol standards

Fuel	Main fuel characteristic	Timetable for standards introduction	Requirement upon new vehicles
Diesel			
Current diesel	Sulphur 1300 ppm		
Euro 2	Sulphur 500 ppm	2002–03	All new diesel vehicles
Euro 3	Sulphur 350 ppm	2002–03	New medium and heavy diesel vehicles
Euro 4	Sulphur 50 ppm	2006–07	All new diesel vehicles
Petrol			
Euro 2	Virtually equivalent to current premium unleaded	2003	All new petrol models and continuing models from 2004—new engine technology required and on track
Euro 3	Some further sulphur reduction; higher octane rating; facilitates high-efficiency direct-injection engines	2005	All new petrol models and continuing models from 2006—enhanced efficiency and onboard car diagnostic performance
Euro 4	Currently not clearly defined	n.a.	Lack of definition prevents adoption date being set

At present Australia has little capacity to meet the Euro 4 diesel standards. The earliest date at which any significant domestic production of diesel at 50 ppm will occur is in January

2000, when the BP refinery in Brisbane will begin production, although it is unlikely to be able to meet more than one-eighth of Australian demand. Design and construction of a desulphurisation plant takes about four years, so other significant domestic capacity to produce Euro 4–standard diesel will probably not be available before 2003.

The Commonwealth Government has determined that Australia will move to Euro 4–compliant or ultra–low sulphur diesel (ULSD—50 ppm) by 2006. Differential excise treatment of low- and high-sulphur diesel will be used to provide incentives to switch demand and speed the introduction of new refinery capital investment between 2000 and 2005 and to restrict diesel eligible for fuel credits to ultra–low sulphur diesel from 2006.

The Government's strategy is to work with major oil companies to achieve voluntary introduction of diesel at 500 ppm (Euro 2) in urban areas in 2000, on a best-endeavours basis, and to then establish a diesel standard set at 500 ppm for road transport fuel by the end of 2002.

From 1 January 2003 differential fuel excises will be introduced to provide further incentives for the oil industry and consumers to move to ultra–low sulphur diesel—in preference to what will then be 'high' sulphur (at that point the new standard sulphur 500 ppm and any sulphur 350 ppm production that may be made available at that time).

The diesel excise for high-sulphur fuel above 50 ppm will increase by 1 cent per litre from 1 January 2003 and 2 cents per litre from 1 January 2004. Industry will draw from the 1–2 cents per litre subsidy to fund the additional investment required for it to make the transition to production of ultra–low sulphur fuel.

The investment cost for the industry to move to ultra–low sulphur diesel and Euro 3–standard petrol has been estimated within the range of $400 million to $1000 million. One major producer has estimated the cost of upgrading just one facility to Euro 4 diesel and Euro 3 petrol to be within the vicinity of $500 million. Quite different types and scales of investment are required to get to Euro 2 (with existing plant, which is often quite old and small) compared with the sort of investment needed to reach the higher standards. A critical issue associated with the proposed initiatives may be whether or not major international oil companies in Australia elect to update the spectrum of Australian refining facilities or elect to import high-quality refined products.

9.2 The Australian Greenhouse Office

The Australian Greenhouse Office is the Commonwealth's lead agency in coordinating transport responses to greenhouse matters and is involved in important elements of the Environmental Strategy for the Motor Vehicle Industry.

The Office's Sustainable Transport Team is responsible for the following initiatives announced as part of the Prime Minister's Statement on Climate Change in 1997:

- elements of the Environmental Strategy for the Motor Vehicle Industry
- the Compressed Natural Gas Infrastructure Program.

In response to community and industry representations (including from the Institution) to the Senate Committee on the proposed new tax system, two further important alternative fuel programs were integrated into 'A New Tax System' for which the Sustainable Transport Team has responsibility:

- the Alternative Fuel Conversion Program
- the Alternative Fuel Grant Scheme.

Also located within the Australian Greenhouse Office is the Greenhouse Challenge program. Initiated in 1995, this is a program of cooperative agreements with industry participants, covering all sectors, whereby industry voluntarily undertakes to develop greenhouse emission–reduction strategies and to report on these to government.

The Environmental Strategy for the Motor Vehicle Industry

The Sustainable Transport Team supports the Environmental Strategy for the Motor Vehicle Industry in several areas.

A fuel consumption labelling scheme is being developed for new passenger cars, to help consumers make more informed choices. Under the scheme a fuel consumption label will be placed on the windscreen of all new cars sold in Australia. These model-specific labels will show the car's fuel consumption in numerical terms, such as litres per 100 kilometres. To develop the scheme, the Australian Greenhouse Office is working with the car industry to develop Australian Design Rules on Fuel Consumption Labelling for New Passenger Cars.

Published annually since 1980, the *Fuel Consumption Guide* provides reliable information based on tests conducted in accordance with Australian Standard 2877. The guide is a reliable source of comparative information on the fuel consumption of new passenger cars, four-wheel drives and light commercial vehicles. This information enables consumers to compare the fuel consumption of different vehicle models across various city and highway driving conditions, considering fuel systems, engine size, and seating capacity. Comprehensive information on models from 1986 to 1998 will soon be accessible on the Office's Internet site (http://www.greenhouse.gov.au/transport/fuelguide).

Additional consumer information is also being developed independently in New South Wales, where the Premiers Department—working in conjunction with the Road Transit Authority, the NRMA, the Australian Consumers Association and the Environment Protection Authority—is leading a project to prepare and publish a 'Green Car Guide'. The guide will provide detailed information on all car models, rating them against efficiency and overall emissions performance. It will also rate the models against broader environmental criteria such as whether the vehicles are recyclable.

The Compressed Natural Gas Infrastructure Program

Compressed natural gas is a cleaner fuel option for virtually all vehicles, but especially light commercial vehicles. It can contribute to improved air quality, particularly through the reduction of particulates, sulphur oxides, carbon monoxide, non-methane hydrocarbons and nitrous oxides and virtual elimination of lead and sulphur emissions. According to Australian Greenhouse Office factsheets, typical savings in tailpipe pollutant emissions range from 50 to 90 per cent and reductions in greenhouse gas emissions may be up to 50 per cent when compared with existing diesel and petrol options.[6]

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[6] This information is from the Sustainable Transport section of the Australian Greenhouse Office website, viewed in August 1999. The site is regularly updated and changed. The data is indicative. It is recognised that there may be a need for comparative full fuel–cycle analysis of different fuel options, operating with varying technologies and operating conditions, to better assess pollutant and greenhouse emission performance.

To encourage companies to switch their fleets to compressed natural gas, $3.8 million was allocated over four years in the Prime Minister's statement in 1997 and a further $3.8 million is under consideration for the 1999–2000 budget. The funding will facilitate the establishment of a distribution network of service stations in collaboration with natural gas companies and local government authorities. The program aims to establish a minimum refuelling network within urban regions; for example, it hopes to encourage initiatives such as the Greater Western Sydney Natural Gas Vehicles Trial, whereby the goal of Liverpool City Council is to convert its entire vehicle fleet to compressed natural gas over five years.

The Alternative Fuel Conversion Program

The Alternative Fuel Conversion Program, scheduled to come into operation in July 2000, is part of the 'Measures for a Better Environment' in 'A New Tax System'. It provides for all buses and other commercial vehicles above 3.5 tonnes gross vehicle mass to be eligible for grants to assist in converting to compressed natural gas or liquid petroleum gas technology. Subject to strict environmental conditions (currently being defined but likely to require parity with Euro 2 petrol and diesel emissions standards to be introduced in 2002–03), the Program will provide either

- a grant of up to 50 per cent to purchasers for the difference in the purchase price between original equipment manufacture alternative-fuel vehicles and conventionally fuelled vehicles; or

- a grant of up to 50 per cent towards the cost of converting vehicles to alternative fuels such as compressed natural gas or liquid petroleum gas.

The Program is capped at $15 million in the first year and $20 million in the subsequent three years of its operation.

Conversion costs vary widely depending on vehicle classes. Smaller commercial vehicle conversions may cost from $2500 to $4000; heavy vehicle conversions may cost from $4500 to $25 000 plus the cost of tanks (Cairney 1999; see also Attachment D). Cars and light commercial vehicles that do not comply with the 3.5-tonne gross vehicle mass provision will not be eligible. According to the 'Measures for a Better Environment' statement, the Program hopes to encourage the conversion of 800 buses and 4000 commercial vehicles a year in the first four years.

The Alternative Fuel Grant Scheme

The Alternative Fuel Grant Scheme is scheduled to come into operation in July 2000. It is intended to maintain the current price relativities between diesel and alternative transport fuels (compressed natural gas, liquid petroleum gas and other potential fuels such as ethanol) by allowing transport modes that are eligible for the diesel fuel credit (including eligible rail and marine modes) to also be eligible for alternative fuel grants.

Grants for the use of alternative and renewable fuels will be restricted to rural and regional areas and circumstances in the transport sector where the diesel fuel rebate element of the Scheme operates. As noted in the Prime Minister's statement on 'A New Tax System', alternative fuels such as compressed natural gas and liquid petroleum gas, recycled waste oil, and renewable fuels such as ethanol and canola oil will attract alternative fuel grants.

By focusing on the maintenance of current pricing relativities between diesel and alternative fuels, the Scheme does not provide a price incentive to urban vehicles to switch to alternative fuels in areas where the diesel fuel rebate does not apply. While the Compressed Natural Gas Infrastructure Program and the Alternative Fuel Conversion Program do encourage urban transport operators to make the switch to alternative fuels, the question of providing price incentives to do so has been raised by various industry participants as a matter that might be usefully taken into account in the future.

The Programs do, however, open new pathways to encourage greater use of alternative fuels in commercial and public transport fleets and offer mechanisms (further to the new diesel standards) for tackling increasing diesel emissions in urban areas. As yet private cars and commercial vehicles under 3.5 tonnes (GVM) are not being focused on in the alternative fuel programs, although greenhouse and pollutant emissions from these sources are being tackled through the new fuel efficiency standards and labelling programs just discussed.

Details of the Alternative Fuel Conversion Program and the Alternative Fuel Grant Scheme are currently under development, following the distribution of an issues paper in July 1999 and industry consultation. The issues paper and information about the consultative forums are available on the Australian Greenhouse Office's Internet site (http://www.greenhouse.gov.au).

The Greenhouse Challenge

An important initiative in the road transport sector is the recent cooperative development and release of the *Road Freight Environment and Greenhouse Challenge Workbook*, which provides guidance and information on measuring and managing greenhouse emissions in the road freight sector. The workbook is a joint initiative of the Australian Trucking Association and the Greenhouse Challenge and is a valuable resource for freight organisations wishing to establish programs to reduce greenhouse gas emissions and minimise other environmental impacts associated with their activities.

Copies of the workbook and information on the Greenhouse Challenge program can be obtained from the Greenhouse Challenge office
(email: greenhouse.challenge@greenhouse.gov.au).

10 The Australian transport task: a review of recent trends in energy use, efficiency and modal share

The future for the Australian transport task can in part be clarified by a review of recent trends in the sector. Although it would be misleading to suggest that past trends will be simplistically replicated in the future—for example, significant energy efficiency improvements are on the horizon for passenger cars, growth rates in per capita car ownership may reach saturation point in the next 20 years, and travel behaviour may change in response to travel demand–management measures and changes in urban form—a review of recent trends can help us to begin to map the 'state of play' in the transport sector and identify areas for further consideration in the light of sustainable transport and sustainable energy considerations. This chapter presents data that may be useful in this process.[7]

The following are among the broad conclusions that may be drawn from the data presented in the tables that follow.

- Growth in the total transport task (passenger and freight) has been characterised by high rates of growth in modes that are comparatively more energy intensive in the performance of their task (passenger-kilometres travelled or tonne-kilometres moved) than alternative modal options.
- Cars, road freight and air travel are assuming an increasing role in the total transport task.
- Urban public transport modes are generally declining in their contribution to the total passenger transport task.
- Cars, other passenger vehicles and planes dominate the total passenger transport task, with growth in air passenger-kilometres outstripping growth in any other mode, although air travel is the least energy efficient mode (with the exception of ferries).
- Growth in road freight has exceeded growth in rail or sea freight and each mode now shares the total freight task roughly equally. Road freight is, however, much less energy efficient than rail or sea in terms of net tonne-kilometres per megajoule.
- Most energy used by road vehicles is used in urban areas.
- The rate of growth in diesel use has been considerably greater than the rate of growth in petrol use.
- While passenger vehicle-kilometres have roughly doubled in the 20 years to 1994–95 (growing most strongly in urban areas), road freight tonne-kilometres almost tripled (with strong growth in urban and non-urban areas).

[7] The tables have been prepared by Philip Laird and colleagues and will appear in *Changing Tracks*, which is scheduled for publication in 2000.

10.1 The data

The data presented in the tables that follow are rounded from data provided by the Apelbaum Consulting Group and differ, in most cases, from similar data provided by the Bureau of Transport Economics. In addition, Apelbaum's estimates of energy use are for primary energy and so are necessarily higher than the Bureau's estimates of end-use energy.[8]

The Australian passenger transport task

Tables 10.1 and 10.2 show the dominance of cars and other passenger vehicles in Australia's domestic passenger task. (Here, 1 passenger-kilometre occurs when one person moves 1 kilometre.) This dominance increased in the 19 years to 1994–95: car passenger-kilometres show an average (compound) rate of increase of about 3 per cent a year. Urban rail has shown limited overall growth, while buses, trams and ferries have shown even more limited growth.

Table 10.1 Australian domestic passenger tasks, selected years, 1970–71 to 1994–95

(billion passenger-km)

Year	Cars etc	Buses	Trains	Planes	Sea
1970–71	108.4	6.6	12.8	5.20	0.70
1975–76	131.2	7.6	8.2	7.64	–
1984–85	171.6	13.3	8.4	10.34	0.70
1987–88	189.1	16.3	9.7	13.27	0.50
1990–91	203.4	17.0	9.3	14.50	0.50
1994–95	225.3	15.5	9.2	25.27	0.46

Source: BTCE (1996); Apelbaum Consulting Group (1997, Tables 3.6, 3.12, 3.17, 3.25).

Table 10.2 Australian urban passenger tasks, selected years, 1970–71 to 1994–95

(billion passenger-km)

Year	Cars etc	Buses	Trains	Trams etc	Ferries
1970–71	67.0	3.5	6.7	0.60	0.16
1975–76	87.8	4.0	5.8	0.53	–
1984–85	116.1	4.3	5.6	0.58	0.08
1987–88	134.8	4.5	6.4	0.66	0.10
1990–91	140.9	4.3	6.8	0.59	0.10
1994–95	155.9	4.4	7.3	0.59	0.12

Notes: Some rail journeys (for example, Newcastle–Sydney) earlier classified as non-urban are now urban. 'Trams' includes Adelaide (0.015 bpkm in 1994–95) and the Sydney monorail (0.012 bpkm in 1994–95). The BTE series gives data that differ from Apelbaum for 1975–76 and later years in some cases, and its estimate for trams in 1970–71 is broad.
Source: BTCE (1996); Apelbaum Consulting Group (1997, Tables 3.6, 3.11, 3.12, 3.25).

As Table 10.3 shows, in the case of non-urban (including intercity) transport the car is again dominant. But the real growth is shown by domestic aviation, where air passenger-kilometres more than tripled in the 19 years to 1994–95 (and almost doubled in the five years to 1994–95). Non-urban bus travel, which showed strong growth in the 1980s, has declined in the 1990s. Overall, non-urban rail travel has declined (except in Queensland

[8] The data are drawn principally from Apelbaum Consulting Group (1997), BTCE (1996) and the Australian Bureau of Statistics. Apelbaum provides data, from ABARE, ABS, BTCE and elsewhere, on energy inputs and transport outputs from 1975–76 to 1994–95. BTCE includes data from 1970–71 to 1992–93 and uses estimates of end-use energy (energy used at end use, excluding energy used in processing and refining), whereas Apelbaum's estimates of energy used are for primary energy (which includes energy used in processing and refining and end use). A further reference, with data and discussion, is the Australian Bureau of Statistics (1997).

since 1995). Note also that on most intercapital corridors (excluding Sydney–Canberra) air is now the dominant mode (Bureau of Transport Economics 1998).

Table 10.3 Australian non-urban passenger tasks, selected years, 1970–71 to 1994–95

(billion passenger-km)

Year	Cars etc	Buses	Trains	Planes	Sea
1970–71	41.0	3.0	6.0	5.20	0.54
1975–76	43.4	3.6	2.4	7.64	–
1984–85	55.4	9.0	2.8	10.34	0.62
1987–88	54.3	11.8	3.3	13.27	0.40
1990–91	62.5	12.7	2.5	14.50	0.40
1994–95	69.5	11.1	1.9	25.27	0.35

Note: 'Planes' refers to scheduled domestic flights. Excluded are unscheduled domestic flights, general aviation and commuter flights, which in 1994–95 amounted to 0.212 bpkm.
Source: BTCE (1996); Apelbaum Consulting Group (1997, Tables 3.6, 3.12, 3.17, 3.25).

Table 10.4 shows use of diesel having an average growth rate of about 3.6 per cent a year compared with petrol's average growth rate of about 1.5 per cent a year in the 19 years to 1994–95. Table 10.5 shows urban vehicle-kilometres doubling. Most car and vehicle use occurs in urban areas and over half of all energy use in Australian domestic transport is accounted for by vehicle movements in urban areas.

Table 10.4 Australian road transport and energy use, selected years, 1975–76 to 1994–95

Year	Passenger veh-km (billion km)	Total veh-km (billion km)	Fuel use by vehicles: Petrol (billion litres)	Fuel use by vehicles: Diesel (billion litres)	Energy use by vehicles (PJ)
1975–76	78.5	101.5	13.0	1.5	562
1984–85	106.6	141.5	15.7	4.0	758
1987–88	118.4	155.6	16.4	4.7	820
1990–91	127.6	163.7	16.5	4.8	844
1994–95	142.9	185.2	17.4	5.7	935

Note: Energy used in petajoules includes gas as well as liquid fuels. One petajoule (PJ) is 10^{15} Joules, with ABARE conversion factors for energy for recent years including 1 litre of petrol = 34.2 MJ (unleaded) and 1 litre of diesel = 38.6 MJ.
Source: Apelbaum Consulting Group (1997, Tables 3.1, 4.2, 4.3).

Table 10.5 Australian urban vehicle usage, selected years, 1975–76 to 1994–95

Year	Passenger veh-km (billion km)	Total veh-km (billion km)	Energy used in urban areas (PJ)	% of all transport energy
1975–76	51.1	63.2	n.a.	n.a.
1984–85	73.5	92±	463	61
1987–88	85.8	107.5	535	65
1990–91	89.7	109.2	534	63
1994–95	102.6	126.2	611	65

n.a. Not available.
Note: Energy used in petajoules includes gas as well as liquid fuels.
Source: Apelbaum Consulting Group (1997, Tables 3.4, 4.3).

Table 10.6 Australian domestic passenger energy efficiency, selected years, 1975–76 to 1994–95

(passenger-km per megajoule)

Year	Cars etc	Buses	Trains	Planes	Ferries
1975–76	0.35	0.96	0.53	0.20	–
1984–85	0.36	0.90	0.65	0.25	0.11
1987–88	0.37	0.92	0.77	0.26	0.26
1990–91	0.37	0.98	0.76	0.28	0.23
1994–95	0.37	0.94	0.76	0.36	0.23

Note: Non-urban cars etc have a higher energy efficiency (0.43 pkm per MJ in 1994–95) than urban cars etc (0.36 pkm per MJ); non-urban buses have a much higher energy efficiency (1.50 pkm per MJ in 1994–95) than urban buses (0.72 pkm per MJ); but urban rail in 1994–95 had a higher energy efficiency (0.83 pkm per MJ) than urban buses. In 1990–91, 1987–88, and 1984–85, non-urban rail was more energy efficiency than urban rail.
Source: Apelbaum Consulting Group (1997, Tables 4.9(b), 4.17, 4.22—air passenger energy efficiencies derived from Table 4.20, which gives energy efficiencies of 0.02 to 0.03 net tonne-km per MJ on the additional assumption that each passenger with luggage has an average weight of 90 kg).

As Table 10.6 shows, cars moving in urban areas are one of the least energy efficient means of travel (when compared with buses and rail); ferries also perform poorly. Of course, load factors are critical for the energy efficiency and comparative performance of each of the modes, and the efficiencies shown are for operational energy use—they do not include 'capital' energy invested in infrastructure and rolling stock and vehicles.

The Australian freight transport task

Table 10.7 shows that road, rail and sea now have roughly equal shares of Australian domestic freight transport if pipelines are excluded. The largest growth has occurred in road freight, making the Australian road freight task one of the largest (in terms of net tonne-kilometres) per capita in the world. Roads' share of interstate non-bulk freight (the main area for competition between road and rail) is forecast to increase from its current level of 57 per cent to 70 per cent by 2020 (Gargett & Perry 1998).

Table 10.7 Australian domestic freight tasks, selected years, 1970–71 to 1994–95

(billion tonne-km)

Year	Road	Govt rail	Private rail	Total rail	Sea
1970–71	27.2	25.2	13.8	39.0	72.0
1975–76	36.7	30.8	26.3	57.1	110.7
1984–85	74.3	45.0	28.4	73.4	95.7
1987–88	81.2	50.1	31.0	81.1	93.6
1990–91	88.2	53.3	35.3	88.6	93.7
1994–95	114.4	61.8	38.1	99.9	109.2

Note: Air freight tasks of about 0.1 btkm in the 1980s, rising to 0.3 btkm in 1994–95 (Apelbaum 1997, Table 4.21).
Source: BTCE (1996); Apelbaum Consulting Group (1997, Tables 3.9, 3.15, 3.22).

Table 10.8 shows strong growth in the role of articulated trucks and light commercial vehicles in the total road freight task, with total road freight tonne-kilometres tripling in the period shown.

Table 10.8 Australian road freight tasks and energy used, selected years, 1975–76 to 1994–95

(billion tonne-km/PJ)

Year	Artic. trucks	Rigid	LCVs	Total	Energy PJ[a]
1975–76	23.0	12.1	1.6	36.7	173
1984–85	52.7	18.6	3.1	74.3	260
1987–88	59.7	21.5	4.3	81.2 ?	279
1990–91	62.9	20.5	4.8	88.2	266
1994–95	85.4[b]	24.2	4.8	114.4[b]	311

a. 'Other trucks' use 2 to 3 PJ of extra energy, but no freight tasks are noted.
b. ABS estimates are about 5 btkm higher for both articulated trucks and all trucks.
Source: Apelbaum Consulting Group (1997, Tables 3.9, 4.3).

Table 10.9 shows the dramatic growth on urban road systems of articulated truck vehicle-kilometres, followed by light commercial vehicle and then rigid truck vehicle-kilometres. (Of course, vehicle carrying capacity, the boundaries between urban and non-urban freight, and the necessary transport of non-urban freight from and through urban centres complicate this picture.)

Table 10.9 Australian urban road freight tasks, selected years, 1970–71 to 1994–95

(billion tonne-km)

Year	Artic. trucks	Rigid	LCVs	Total (% of all road freight)	Energy used PJ[a]
1970–71	3.0	5.4	0.7	9.1 (34)	n.a.
1974–75	5.7	6.4	1.0	13.1 (37)	n.a.
1984–85	13.4	9.9	1.8	25.1 (34)	120
1987–88	15.2	13.1	2.7	28.3 (34)	165
1990–91	14.0	12.2	2.9	29.0 (33)	127
1994–95	19.6[b]	14.5	3.1	37.1 (32)[b]	157

n.a. Not available.
a. Other trucks' use 2 to 3 PJ extra energy, but no freight tasks are noted.
b. ABS estimates are higher.
Note: Lower implied energy efficiencies of urban freight movements; Apelbaum's and ABS data for 1994–95 differ.
Source: BTCE (1996); Apelbaum Consulting Group (1997, Tables 3.9, Table 4.3).

As can be seen from a comparison of the data in Tables 10.7 and 10.10, the difference in operating energy consumed by road, rail and sea to transport comparable tonne-kilometres of freight is considerable; road is substantially more energy intensive. Of course, the advantage of road transport lies in its flexibility and ability to provide intermodal freight connections.

Table 10.10 Energy used in Australian freight tasks, selected years, 1975–76 to 1994–95

(petajoules)

Year	Artic. trucks	Road freight	Rail freight	Sea freight	Domestic aviation: passengers and freight
1975–76	42.1	173	20.9	39.4	48.5
1984–85	80.5	260	28.4	36.7	51.5
1987–88	86.6	279	30.0	37.0	61.2
1990–91	83.6	266	27.6	24.2	61.0
1994–95	102.8	311	27.6	26.2	83.6

Source: Apelbaum Consulting Group (1997, Tables 3.9, 4.3).

Table 10.11 shows that average energy efficiency for road freight is appreciably less than that of most rail and sea freight operations. Note that, on average, articulated trucks are more energy efficient than rigid trucks and light commercial vehicles (with respective average energy efficiencies in 1994–95 of 0.83, 0.34 and 0.04 net tonne-kilometres per megajoule). Like buses, non-urban trucking operations are much more energy efficient than urban trucking operations (with respective average energy efficiencies in 1994–95 of 0.50 and 0.24 net tonne-kilometres per megajoule). Notably, linehaul intercity road freight can now reach 1.00 or more net tonne-kilometres per megajoule. Linehaul intercity rail freight efficiency will vary subject to track condition and alignment.

The high energy efficiency of private rail is because of the preponderance of iron ore haulage in the Pilbara, using the world's most efficient trains—1 litre of diesel will move a little more than 1 tonne of iron ore the 426 kilometres from Mt Newman to Port Hedland in large iron ore trains. Air freight energy efficiency is given by Apelbaum (1997, Table 4.20), who notes energy efficiencies of only 0.02 to 0.03 net tonne-kilometres per megajoule.

Table 10.11 Australian domestic freight energy efficiency, selected years, 1975–76 to 1994–95

(net tonne-km per megajoule)

Year	Road	Govt rail	Private rail	Total rail	Sea
1975–76	0.21	1.60	5.65	2.72	–
1984–85	0.29	1.83	7.06	2.57	2.61
1987–88	0.31	1.93	7.00	2.71	2.56
1990–91	0.33	2.31	7.79	3.21	3.86
1994–95	0.37	2.66	8.77	3.62	4.16

Source: Apelbaum Consulting Group (1997, Table 4.11(b), 4.18, 4.22).

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Attachments

Some future directions in sustainable transport

Attachment A Alternative mobility programs: integrating new forms of public transport

It has been argued that public transport, as we know it, faces a difficult challenge just to maintain its current share of the transport task. Demographic trends (such as our ageing population) and the increasing diversity of 'when and why' we travel—spread across our expanded urban landscape—have changed the nature of what public transport may be required and will be viable. Ambitious targets to increase the role of public transport and to encourage major shifts in modal shares in denser urban areas—for example, such as the Regional Plan for Parramatta, which aims to change the transport mix from the current private:public mix of 60:40 to 30:70 over 20 years—need to be supported by new public transport 'feeder' services in less dense urban areas.

In addition to ensuring that alternatives to the private car are both available and attractive, improved links and more flexible transport services that enable people to use a variety of modes are required. Improved feeder services to public transport may also allow people to plan journeys more confidently, involving a range of modes, while also ensuring better access for people who do not have private vehicular access as a consequence of choice, infirmity or economic circumstances. New economic and cultural arrangements promise to be part of future flexible transport systems, involving new 'shareware' practices and attitudes.

Providing incentives for car pooling and priority transit lanes are steps in this direction, as are the following examples of new arrangements developed by city authorities, consumers and transport authorities to encourage people to opt out of dependence on private cars. Although Australian conditions may vary significantly, these examples might provide useful models for communities, interest groups and local councils to consider when seeking to serve their constituents better and encourage the move away from car dependence.

A.1 Stattauto Berlin and European CarSharing

Stattauto Berlin is the largest car-sharing organisation in Germany. Since its inception in 1988 it has become the centre of the European CarSharing network, which has organisations in Switzerland, Germany, Holland, Austria, Sweden and England. Over 3000 members have access to vehicles in 100 European cities. Stattauto began as a small co-op of concerned students who sought to share the 'expense and guilt' of car ownership and to provide alternative mobility services to members. It encourages the use of sustainable transport modes—public transport, cycling, walking—and provides services to improve links across modes, including access to taxis and private motor vehicles as required. The cost of the service is in line with the policy of encouraging public transport and discouraging dependence on private cars, and the cost of vehicle use is specifically set at more than the cost of mass transit. But the appeal of the scheme also lies in the economic savings it offers members who wish to forego the costs of car ownership and have access to integrated mobility—including taxi and private vehicles when necessary.

Becoming a member of Stattauto requires a refundable investment of \$850 to \$1300, an 'initiation' fee of \$110, and monthly dues of \$7 to \$11. The cost of using vehicles and taxis, based on time and distance, is additional.

One key to Stattauto's success appears to be its commitment to providing an integrated, networked mobility package. Since 1990 it has been operating a Mobilcard identity and billing system, which also provides for multi-modal booking services and security functions. The following are among the features of the Mobilcard system.

- Each member has a Mobilcard identity. The card provides access to car keys at Stattauto depots and monitors the time of collection.
- The Mobilcard includes a field for discounted public transport ticketing and billing. Members can thus use their cards as tickets for most public transport services for the entire area covered by the transport authority.
- The Mobilcard provides discounted access to radio rental cars, for which bills are received at the end of each month as part of the joint bill.
- The Mobilcard enables automated booking and delivery of tickets from German railways.
- Heavy-load bicycles (for small freight tasks) can be booked through Stattauto in much the same way as cars, but use of the bikes costs nothing.
- Bicycle trailers are also made available with Stattauto cars, as required, to enable cycling on reaching one's destination or for the duration of the vehicle share.
- Stattauto participants can use vehicles from any of the European CarSharing scheme organisations, thus enabling integrated multi-modal trip planning and realisation.

Note: Stattauto has published a *Handbook for Carsharers* for others interested in establishing similar programs. Further information is also available from the Stattauto website (http://www.stattauto.de/ECS.html). This information about Stattauto was obtained from the catalogue for *Designing the Environment,* a travelling exhibition of the Goethe Institut, and from http://www.life.ca/nl/44/carshare.html on 31 August 1999.

A.2 Car sharing in Switzerland

The rationale of the car-sharing movement in Switzerland is to use private cars in a public manner via their use as intelligent cars (car sharing) and to integrate with available public transport to maintain individual mobility while gaining energy savings.

The goal is to improve access to and use of public transport by creating a car-share pool, a privately managed form of collective transport that delivers feeder services to the public transport network.

Mobility is provided on call, by dialling a joint cab or a minibus service that draws on the vehicle pool and offers services as required. Schemes are organised collectively by participating community and city authorities, the state and sponsors.

The cab networks are characterised by the following:

- professional drivers (cab driver's licence) or voluntary drivers (normal driver's licence) using car-sharing vehicles;
- overheads covered by the passengers, with the participation of the cities and communities served, the state and sponsors;

- use of five-seat passenger cars or 11-seat minibuses, depending on demand;
- adjustment of offerings to current demand.

Examples are

- Telebus Kriens—local joint cabs serving a specific area in the evening (area-focused operations);
- Telebus Nidwalden—regional, in part route-based joint cabs for night travel (organised in terms of specific routes);
- Telebus Pilatus Market—a local, unlimited joint-cab service offered during shopping hours (area operations).

Attachment B Fuel displacement: hybrid electric vehicles

Toyota has released the world's first mass-produced hybrid electric vehicle onto the market in Japan and plans to make it commercially available in Australia in 2001. The Toyota Prius demonstrated the viability of generating electricity onboard with an internal combustion engine to deliver substantial environmental benefits in a vehicle whose size and performance are comparable to that of a Corolla. It is one of a new generation of vehicles that promise to become available from manufacturers within four to five years, and its appearance is an important advance that is helping to stimulate Australian industry innovation (see Attachment C).

The Toyota Prius offers three important environmental benefits.

- It has twice the fuel economy of an equivalent conventional car (a four-cylinder passenger car with automatic transmission).
- Fuel consumption is halved, which means a halving of greenhouse gas emissions on a typical city drive cycle.
- Its emissions of 'gross pollutants'—carbon monoxide, hydrocarbons and oxides of nitrogen—are around one-tenth of the level permitted under the current Australian Design Rule ADR 37/01 for passenger cars.

B.1 How does it work?

Hybrid systems are automotive power plants that use both petrol engines and electric motors for motive power. Conventionally, there are two kinds of hybrid systems:

- series hybrids, which use a petrol engine to generate electricity for the electric motor (and sometimes batteries) to propel the vehicle;
- parallel hybrids, which use both petrol engines and electric motors for motive power and switch back and forth between them as the situation demands.

The Toyota hybrid system (THS) combines the best aspects of both series and parallel hybrids and offers seamless matching of petrol engine and electric motor power for smooth, low-emission, low–fuel consumption driving. In addition, Toyota has reduced the size and weight of all the components—engine, motor and battery. The THS divides the engine's power along two paths, one to the generator to produce electricity and the other through a mechanical gear system to drive the front wheels. The fuel mix is geared to be about 60 per cent petrol, 40 per cent battery (all onboard generation).

Controlling this power split is one of the secrets to THS efficiency. The primary power source is a specially developed 1.5-litre twin-cam multi-valve Atkinson cycle engine, with a high expansion ratio cycle for maximum extraction of combustion gas expansion energy and low pumping and friction losses. The engine achieves its best fuel consumption per unit of output when operating in the high-torque ranges. Thus, depending on conditions, the THS controls the division of power between engine and electric motor so that the engine always operates in its optimum torque range to maximise fuel economy.

A characteristic of an electric motor is the added benefit for take-off of maximum torque at zero revolutions. The THS therefore offers acceleration that matches or exceeds that of a conventional car with automatic transmission.

When the vehicle decelerates, the motor acts as a generator, converting the vehicle's kinetic energy into electricity and sending it through the inverter to be stored in the battery.

In summary, this is how the THS works.

- When moving off, moving at extremely low speeds or descending long, gentle hills, and in other conditions where the petrol engine would not operate at peak efficiency, the petrol engine is turned off. The electric motor alone propels the car.

- During normal operations, the engine's power is split, with some power being used to propel the car and the remainder being used to generate electricity. The electricity is fed to the electric motor and/or the batteries, to assist in powering the car. The THS computer controls the ratio of power to each path, for maximum efficiency.

- During full-throttle acceleration, additional energy is drawn from the battery to boost the electric motor's output.

- During deceleration or braking the electric motor acts as a generator, transforming kinetic energy from the wheels into electricity. The recovered energy is stored in the battery.

- The battery is regulated to maintain a constant charge. If the battery charge is low, the THS sends more engine power to the generator to generate electricity and recharge the battery.

- The petrol engine shuts down automatically after a pre-determined period once the vehicle is stationary.

B.2 Progress in the market

The Prius production car was launched in November 1997, to coincide with the Kyoto Greenhouse Summit, and went on sale in Japan one month later. Over 10 000 of the cars have now been delivered and production has doubled at the Takaoka plant, to 2000 a month. Toyota has announced it aims to sell 20 000 Prius in the North American and European markets in 2000.

Australian prospects

In late 1998 Toyota brought seven production models of the Prius to Australia for evaluation, display and demonstration to decision makers and the public. Future directions for the THS in Australia will depend on the success of the coming evaluation, an evaluation that has included requests to government to provide financial incentives for demonstration volumes of the technology. If such incentives are forthcoming the Prius may become commercially available in 2001 at a price (inclusive of GST) of about A$36 000, which incorporates a small premium over and above the new purchase price of conventional models of comparable size.

To date, the greatest impediment to the importation and sale of the Prius lies in the Australian Design Rules, which do not yet harmonise with European Design Rules (with which the Prius complies). Initiatives to harmonise ADRs with international design rules are under way.

B.3 Other hybrid developments

Toyota is not alone in developing new-generation low-emission vehicle technology. The development of the THS is itself part of a stepped program that could lead to the introduction of a fuel-cell electric vehicle. DaimlerChrysler has recently unveiled the first practical fuel-cell vehicle by fitting fuel cells to the Mercedes-Benz A-class car; it expects this to be in limited production by 2004. Volvo/Ford (transport) is developing fuel cell–powered vehicles, and companies such as General Motors, Ford, Honda, Volvo, Renault and Fiat are all working on next-generation hybrids. For example, it is anticipated the new Honda EEV (a hybrid oriented to 90 per cent petrol, 10 per cent battery power) will soon be released.

For further information, visit <http://www.toyota.com.au>.

Attachment C Developing and promoting Australian hybrid car capability

Until recently the Australian automotive components industry has not been at the leading edge of the world trend to 'green' vehicles. Australian industry needs to 'get into the game', demonstrate capability in the new technologies, and position itself to produce the new low-emission componentry; failure to do so will mean significant technology imports and potential export market losses.

Internationally, hybrid-electric cars are coming! There is now consensus that generating electricity onboard with a conventional internal combustion engine can produce most of the benefits of fuel cell–powered cars. Hybrid-electric technology is expected to be commercially available within four to five years, while fuel-cell cars are not expected to be affordable for 15 to 20 years.

Australia has fallen behind the United States, Europe and Japan in reducing automotive emissions, in part because the international companies operating in Australia have relied on overseas technology development. In the area of low-emissions technology international companies have spent billions—for example, Toyota is said to have spent $2 billion developing the Prius—and Australia's industry faces the prospect of large-scale importation of the new low-emission technologies. To date, competition in the Australian market has been related to features rather than fuel efficiency or emissions.

C.1 The aXcess Australia hybrid-electric car

Building on the success of the 1998 aXcess Australia showcase car project, which was used to raise international awareness of the Australian automotive components industry, in May 1999 CSIRO launched the development of the aXcess Australia hybrid-electric car to convince international car makers that the Australian components industry can support local manufacture of low-emission technology.

Supported by industry, CSIRO is working on two hybrid cars. The first is being developed in partnership with a leading car corporation and will demonstrate a parallel-hybrid configuration (similar to Prius) full-size car incorporating CSIRO and other local innovations.

The second is a medium-size aXcess Australia low-emission vehicle car to demonstrate exportable componentry and technologies in series-hybrid configuration. The car will look and perform like a conventional car but will feature a hybrid system that delivers twice the fuel efficiency and one-tenth of the pollution of a normal vehicle. The project involves a consortium of more than 80 Australian car component firms and will include several CSIRO technologies, including

- the hybrid petrol–electric power train;
- a surge power unit (or supercapacitor) providing extra boost to the electric motor to enable the car to accelerate swiftly;
- a sophisticated computerised energy-management system for optimum efficiency;
- new electric traction motors using switched-reluctance technology;

- novel lead–acid battery technology.

CSIRO modeling suggests the aXcess Australia hybrid-electric car will halve fuel consumption and contribute up to 90 per cent reductions in emissions of gross pollutants—performance targets designed to parallel the achievements of the Prius, it seems.

The project involves the development, construction and international promotion of the Australian low-emission car and associated Australian capability. It is an important initiative that will encourage Australian industry to 'follow the lead' and provide a stimulus to international car makers to use and draw upon Australian-made hybrid-electric systems in Australia and in export markets. Underscoring the initiative is a concern that if we fail to develop and demonstrate our capability, local assembly of hybrid-electric cars may be unlikely, our automotive industry may lose a competitive opportunity, and our urban environments may miss out on the benefits hybrid-electric technologies offer.

In addition, the aXcess Australia project hopes to contribute to the realisation of exports of $6 billion by 2006; secure a balance between exports and imports within the automotive components sectors; position the Australian automotive industry to be able to supply Australian cars with a high proportion of local components, to satisfy domestic and regional niche markets; and enable Australian-designed and -manufactured components to be used in cars in the United States, Europe and Asia.

A specially selected marketing committee has been appointed through the auspices of the Australian Automotive International Business Group and has been charged with preparing a comprehensive program of international marketing activities for the component manufacturers participating in the program. The committee will develop the theme 'Taking it to the World Together' and promote the message that Australia is 'part of the solution' in relation to environmental concerns.

The aXcess Australia low-emission vehicle is to be launched in the second quarter of 2000.

Note: Information in this attachment was obtained from a CSIRO media release and information pack, *CSIRO Unveils Plan for Hybrid Car* and *CSIRO to Power Australia's 'Ecocar'* (5 May 1999).

Attachment D Alternative fuels—converting to natural gas

Natural gas is considered to be one of the cleanest available transport fuels; its comparative advantages are now under close scrutiny by industry and government. Many groups—among them State transit authorities, local councils, the Australian Greenhouse Office and the Australian Natural Gas Vehicle Council—are working to promote gas-powered vehicles with the aim of improving urban air quality and capturing associated greenhouse gas–emission benefits. Natural gas (and liquid petroleum gas) may also offer substantial fuel cost savings (particularly to large fleet operators).

Diesel fuel has an energy content of 38.7 megajoules per litre; for unleaded petrol the figure is 34.7 megajoules per litre and for LPG it is 24.7 megajoules per litre. Compressed natural gas has an energy content of 38.8 megajoules per cubic metre in New South Wales and the Australian Capital Territory and 41.1 megajoules per cubic metre in Perth. When compressed, 1 cubic metre of natural gas is reduced to 1 litre in volume.

The following provides an overview of the benefits and costs of natural gas vehicles and the options available. LPG is a well-established alternative fuel for which information can quite readily be found, so it is not dealt with in any detail here.

D.1 Environmental benefits

CNG vehicles offer noise reductions of around 50 per cent compared with existing diesel-engine vehicles. The tailpipe emissions from CNG vehicles also offer compelling environmental benefits, as suggested by Table D.1. (Comparative data on the overall environmental benefits of different fuels and fuel systems is an area of continuing research and debate.[9])

A complete picture of the comparative pollutant and greenhouse gas–emission benefits of natural gas, LPG and diesel and petrol vehicle systems requires full fuel–cycle analysis (that is, analysis of energy life-cycle impacts from production, processing, distribution and use of the fuel) and analysis of the energy inputs required to produce the respective ‘hardware’ or material technologies that different fuel systems require. Research into these areas is currently being developed.

Australia is moving to compliance with low-sulphur Euro 2 and 4 diesel standards, which will assist in the reduction of fine particles, soot and smog. It is against the Euro 2 diesel standard that Alternative Fuel Conversion Grant applications will probably be assessed, and further comparative fuel-cycle studies will probably use the standard as a benchmark. It appears that reductions in sulphur content in diesel may be accompanied by a relative increase in the more dangerous ultra-fine (PM2.5) particles. Further study on ultra–fine particle emissions may be required. It is anticipated that natural gas should perform comparatively well in terms of ultra-fine particles in comparison with both high- and low-sulphur diesel.

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[9] For an overview of the debate on the benefits of CNG, LPG and Euro 2 diesel, see Ministry of Transport, Western Australia (1998) and Australian Natural Gas Vehicle Council (1999).

Table D.1 Emissons from CNG vehicles: a comparison

Passenger vehicles	Heavy vehicles	Natural gas vs Euro 2–series diesel engine
Comparative tailpipe emission benefits of CNG passenger vehicles when compared with existing diesel and petrol vehicle options: up to 50% reduction in greenhouse gas emissions 50–80% reduction in carbon monoxide emissions 60–80% reduction in hydrocarbon emissions 60–90% reduction in nitrogen oxides particulate reductions and virtual elimination of lead and sulphur emissions	Indicative average tailpipe emissions benefits of CNG vehicles (approx. 6 tonnes and over) when compared with petroleum-based fuels have been cited as follows: 80% less reactive hydrocarbons 50% less nitrogen oxides 53% less carbon monoxide 20% less carbon dioxide virtually all smoke and soot (particulates) eliminated	Recent tests at the UK Millbrook Proving Ground used real-world operating cycles to compare the performance of two articulated trucks, one using a Perkins TxSi natural gas engine and the other a Euro 2–series diesel engine. Results indicated the following emissions advantages of the CNG vehicle: 80% reduction in hydrocarbons 97% reduction in carbon monoxide 86% reduction in nitrous oxides 94% reduction in particle matter

Source: Australian Greenhouse Office (1999); Australian Gas Association, Australian Natural Gas Vehicles Council and Australian Liquefied Petroleum Gas Association (1999).

D.2 Economic benefits

A survey of recent fleet operators who have trialled conversion to gas indicates that fleet operators can save 40–50 per cent on fuel costs by switching from diesel to natural gas. Projected fuel savings need to be evaluated in relation to the cost of conversion, the number of kilometres travelled annually, and the price of CNG per cubic metre that can be negotiated for fleet purchases. When optimised, CNG systems can also offer savings through lower maintenance costs and longer engine life as a result of reduced wear and tear on the engine.

For all vehicles (private or fleet) there is a threshold of annual ‘kilometres travelled’ at which point the commercial viability of converting to natural gas is assured. On the fuel cost side, the new tax system to be introduced in July 2000 promises to at least maintain pricing parity differences for natural gas and diesel. CNG is sold at between 35 and 42 cents a cubic metre; this compares with a wholesale diesel price of approximately 69 cents a litre, offering possible savings between 27 and 34 cents a litre.

Under the new tax system a grant will be available from the Commonwealth, reducing diesel fuel by 23 cents a litre and CNG by between 11 and 18 cents a cubic metre. The grant, effectively a rebate scheme, will be available to vehicles with a gross vehicle mass of 20 or more tonnes in metropolitan areas and 4.5 tonnes or more in regional areas.

On the capital equipment side, people can choose to adopt natural gas fuelling either by converting existing vehicles or through the purchase of new OEM (original equipment manufacture) vehicles. From July 2000 the Australian Greenhouse Office will offer for vehicles above 3.5 tonnes gross conversion grants of up to 50 per cent of the cost of conversion of existing diesel vehicles or up to 50 per cent of the purchase cost difference between OEM diesel and CNG vehicles.

Regardless of how comparative pricing of diesel, petrol and natural gas works out in the detail of the Alternative Fuel Grant Scheme for vehicles under 20 tonnes in urban areas, the conversion grants promise to provide a very real incentive for fleet operators to consider converting to gas.

As yet, no direct incentives are being provided for conversion of private passenger vehicles, but, even without alternative fuel grants and conversion incentives for light vehicles, the cost of converting a personal vehicle can often be well justified on fuel savings alone providing the vehicle travels an estimated 25 000 kilometres a year or more.

D.3 Making the switch: technology options and their indicative costs

The alternatives to dedicated petrol systems are either dedicated CNG systems or bi-fuel switchable systems (vehicles that can operate on either 100 per cent petrol or 100 per cent natural gas). Diesel engines can be converted either to dedicated or 100 per cent CNG systems or to dual-fuel systems.

Diesel dual-fuel engine technology provides the operator with the ability to run vehicles on a mixture of up to 85 per cent CNG and 15 per cent diesel, or 100 per cent diesel. The technology provides operational flexibility to run vehicles in areas away from CNG refuelling infrastructure: the systems automatically switch to diesel fuelling if the CNG fuel supply runs out. Caterpillar offers dual fuel as an OEM option on some of its larger engine model range, currently in service in Kenworth prime movers.

Any system that uses gas needs CNG fuel storage cylinders, which are usually ‘complete steel’ or ‘steel-lined composite wrapped’. Full composite cylinders provide significant weight savings over lower cost ‘steel’ options. Cylinders represent a large component of the cost of conversion, and it is useful to know that, subject to various conditions, they may be leased or rented as an alternative to purchase when commissioning the conversion of a vehicle or purchasing a CNG vehicle. The following provides a discussion of features and costs of the various CNG systems that can be considered.

Diesel replacement: dedicated CNG systems

- *Advantage*. Dedicated systems (as opposed to dual-fuel systems) enable optimisation of the engine performance to the fuel type.

- *Disadvantage*. There is a limited network of refuelling points in Australia (now being redressed by the Australian Greenhouse Office CNG infrastructure program and the gas industry).

- *New OEMS*. Many major bus and heavy diesel engine manufacturers are now producing dedicated CNG vehicles—for example, MAN, DaimlerChrysler (Mercedes), Volvo, Scania and Renault. Transcom Engine Corporation in Perth has developed leading componentry for heavy vehicle CNG engines, now proven in Renault, RABA (Hungary) and MAN-engined buses.

- *Cost of new OEM vehicles*. New buses—incremental cost range of $23 000–$60 000, with an average premium purchase price over conventional vehicles of $40 000. Heavy trucks—dedicated OEM purchase price premium within the range of $20 000 to $40 000.

- *Conversion of diesel engines to fully dedicated CNG*. Conversion requires engine overhaul and monitoring and the replacement of pistons, cylinder heads and cylinder liners (conversion of compression ignition to spark ignition) plus installation of CNG storage cylinders.

- *Cost of conversion*. Subject to vehicle size, engine conversion costs range from $12 000 to $23 000. Fuel storage cylinder costs can be up to $20 000 (purchase) for multiple 100 per cent composite cylinders. This cost varies significantly between vehicles: a typical 10-tonne truck CNG cylinder costs about $4000. It should be noted that CNG cylinder rental from fuel suppliers removes this cost penalty.

Diesel reduction: dual-fuel systems

- *Technology range*. Current systems generally operate on a mix of up to 85 per cent CNG and 15 per cent diesel (diesel provides pilot ignition for the gas). Systems can run on 100 per cent diesel if required, and generally automatically switch to diesel fuelling should the CNG fuel be depleted. Dual-fuel systems are a practical option for current Australian conditions—given the breadth of our existing fleet and its coverage beyond existing CNG refuelling sites.

- *Advantage*. Mixed-fuel systems enable fleet operators to gain the fuel cost benefits of gas, with additional flexibility and certainty of fuel supply because of the option to run 100 per cent on diesel if necessary. The fuel characteristics of natural gas mean that dual-fuel engines may outperform dedicated diesel engines, particularly in relation to lugging power.

- *Disadvantage*. Relatively few. Some additional tanks are required to store CNG and diesel.

- *Cost of converting diesel to dual-fuel systems*. Dual-fuel conversion systems consist of a bolt-on kit ranging in price from $6500 to $23 000. For a typical 550-horsepower prime mover engine the installed conversion cost is about $13 000 for an electronic system. Converting a diesel truck engine to dual-fuel operation (including installation of cylinders and pipework) takes trained personnel about three man-days for a medium-sized truck. Cylinder costs also need to be added; as noted, these vary but tend, on average, to cost between $4000 and $5000. For example, a 20-tonne Mitsubishi truck with a 600-kilometre CNG range in operation in Canberra required cylinder costs of about $4500 installed.

- *Indicative average engine conversion costs*. For a range of large diesel vehicle engine sizes (estimated installed costs) with warranty provision

  - 4.5-litre engine, $5500;
  - 5.5-litre engine, $8500;
  - 7.5-litre engine, $9000;
  - 8.5-litre engine, $9500;
  - 10- to 16-litre engine, $13 000–$16 000 (some equipment suppliers note conversion costs ranging up to $20 000).

- *Converting light commercial vehicles with spark ignition systems*. These vehicles can be converted to dual-fuel systems via the application of one of many readily available ‘off-the-shelf’ bolt-on systems. Cost of conversion generally range from $2440 plus purchase or rental of CNG cylinders, generally two.

Dedicated CNG systems to replace petrol systems

Dedicated CNG passenger vehicles are not yet on the Australian market, although various manufacturers are producing them internationally and there is an increasing trend toward dedicated single-fuel systems. For example, Toyota sells CNG passenger vehicles in Japan and is trialling CNG Camrys in the United States.

- *Advantage*. CNG systems offer optimal fuel efficiency and prolonged engine life.
- *Disadvantage*. The systems are currently unavailable in Australia and access to refuelling locations is limited.

Petrol systems: bi-fuel switchable systems

Bi-fuel systems can operate on either unleaded petrol or CNG, with the operator opting to switch between fuels.

- *Advantage*. Bi-fuel systems enable use of gas in urban areas and offer the convenience and back-up of switching to petrol for journeys beyond CNG refuelling networks.
- *Disadvantage*. The engine system is tuned and optimised to deliver best average performance for both fuel types, rather than optimal performance of a dedicated system. This may result in reduced fuel efficiency and decreased engine life.
- *Cost of new OEM vehicles*. Volvo recently released the S70 Bi-Fuel, the first factory-built car that can operate on either natural gas or unleaded petrol to be sold in Australia. The extra cost of the Bi-Fuel option, when compared with the standard S70 unleaded petrol vehicle, is about $3000–$4000.
- *Cost of converting petrol cars to bi-fuel systems*. Conversion is a relatively simple process, with readily available 'off-the-shelf' bolt-on systems available for most engine types. The cost of conversion ranges from $2500 to $4000, including engine warranty. For example, any sedan or wagon may be converted for around $2270 plus cylinder rental or purchase (1 cylinder).

Note: Information in this attachment was obtained from *Motoring News* (1999, issue 1, vol. 5), Australian Gas Association, Australian Natural Gas Vehicles Council and Australian Liquefied Petroleum Gas Association (1999) and discussions with various industry participants.

Attachment E Renewable fuels: the biofuels ethanol and methanol

Ethanol is the most widely used alternative fuel in the world, although it is yet to feature significantly in the Australian marketplace. Methanol is still generally produced from natural gas rather than from renewable resources, but it can be produced from biofuels. In Australia, an ethanol pilot plant has been established by Manildra Energy Pty Ltd to demonstrate the commercial feasibility of new production techniques that promise to produce ethanol at a lower price and in greater volume than is possible with conventional production techniques. BHP has an established methanol research program and the only Australian production plant dedicated to demonstrating new technology for converting natural gas to methanol. The objective is to develop the technology so that remote gas reserves can be converted to liquid methanol on site for ready transportation to markets. The information that follows focuses on biofuel feedstocks and production methods.

Although ethanol and methanol are similar, ethanol is considered to be cleaner, less toxic and less corrosive. Both fuels can be mixed with either petrol or diesel, and both can be produced from renewable sources and offer environmental emissions benefits (primarily aromatics reductions and virtual elimination of particulates) and possible disbenefits. For example, biofuels perform well in reducing toxic benzene and 1,3 butiadiene emissions but can result in increased aldehyde emissions, which in turn would need to be regulated if alcohol fuels were more widely used.

As renewable liquid fuels, biofuels have a strategic role to play in the transition away from dependence on traditional liquid fossil fuels. They represent industries in which Australia could expand its capability, particularly in the light of our biomass stocks, sequestration and land-care objectives. Table E.1 outlines the breadth of raw materials that can be drawn upon, processing methods, and the uses of ethanol and methanol.

Table E.1 Ethanol and methanol: sources, processing and use

Source	Processing	Use
Ethanol		
Sugar or starch from dedicated crops; for example, sugar cane, sugar beet, corn, sweet sorghum, cassava, Jerusalem artichoke, and wheat Waste products; for example, from starch production from grains Ligno-cellulose in woody crops, municipal waste, and pulp and paper waste; for example, agricultural waste and herbaceous and woody biomass such as trees	Traditional yeast fermentation and distillation of sugar Starch and cellulose must first be hydrolysed to simple sugars using enzymes and heating with mineral acid Other bacterial fermentation	Octane enhancer for petrol or diesel By-products could be used as feedstocks; for example, dunder from sugar cane fermentation is concentrated 20–30 times and then sold to local cane farmers as potash fertiliser
Methanol		
Ligno-cellulose in woody crops, wastes (including municipal waste) and aquaculture of algae	Produced by gasification and synthesis of cellulose material; converted to methanol using a catalytic reaction	Octane enhancer in petrol (blended) Used at 100% strength as a fuel Fuel for fuel cell in zero-emission vehicles

E.1 How are biofuels used?

To date, biofuels have been used as octane enhancers, for fuel blending to reduce pollutant emissions, and in some countries as a substitute for oil imports. They have been demonstrated to perform better than conventional liquid fuels in terms of both greenhouse and pollutant emissions, although new 'clean' petrol and diesel standards combined with new catalytic converter technology may well change this picture. Internationally there have been numerous trials of the relative advantages and disadvantages of biofuels to investigate different fuel mixes in different vehicle technologies—much of this work is being done in the United States and Europe by companies such as General Motors, Ford, Chrysler and BMW.

Biofuels can be used in the following ways:

- in conventional engine technology—fuel mixing with biofuel content of up to 15 per cent (less for older vehicles);
- new flexible-fuel vehicle (FFV) engine technology, which can operate with varying proportions of biofuels—up to 85 per cent methanol or ethanol (M85 or E85);
- dedicated biofuel engine technologies—systems optimised for high methanol and ethanol concentrations, M85 to M100 and E85 to E100 (for example, direct injection);
- methanol in fuel-cell technologies for hybrid vehicles.

E.2 The outlook for biofuel technologies

Most of the technical barriers to using biofuels have been or are being overcome by extensive research and development programs, particularly in the United States. The most persistent barriers to using biofuels in Australia, as elsewhere, are

- continued low petrol and diesel prices;
- cost-competitive supply and limited distribution arrangements for biofuels;
- relatively high costs of conversion of existing vehicles and the relatively high purchase price of dedicated-technology vehicles;
- the low rate of vehicle turnover in the Australian vehicle market, meaning the rate of uptake is low, with slow flow-on effects to gain economies of scale;
- lack of refinery facilities to blend biofuels with petrol, leading to less efficient blending and possible higher emissions.

Table E.2 summarises some current and prospective developments in biofuel technologies.

The environmental and performance advantages and disadvantages of ethanol and methanol vary according to the fuel mix and vehicle technology and the standard of diesel and petrol with which they are being compared, or indeed mixed. As noted, biofuels may significantly reduce particulate, sulphur and aromatic emissions. Boxes E.1 and E.2 provide a general—albeit incomplete—overview of some of the advantages and disadvantages ethanol and methanol offer as fuels.

Table E.2 Some current and prospective developments in biofuel technologies

Conventional engine technology—fuel mixing	Fuel mixing is well established in countries such as Brazil. Among recent Australian trials are initiatives by ACTION buses, Canberra, in 1994 to trial diesehol (15 per cent ethanol) in some of its fleet and a number of bus fleet operators are exploring biofuel trials and options. Internationally, research is oriented to improving co-solvents and improving catalyst systems to maximise fuel-mix performance and minimise emissions.
New flexible-fuel vehicle engine technology	Anticipated to be commercially available in 2001–06 from numerous vehicle manufacturers—Ford, GM, Chrysler, VW, Mitsubishi and others.
Dedicated biofuel engine technologies	Trials in United States, particularly California, New York City and Wisconsin, Illinois.
Methanol fuel-cell technologies for hybrid vehicles	Fuel-cell technology using methanol is now featured in the General Motors series hybrid Fuel Cell Electric EV1, which has a range of more than 480 kilometres. Fuel-cell vehicles are anticipated to become commercially available within 10–15 years.

Box E.1 Advantages and disadvantages of ethanol as a fuel

Advantages

- Uses proportionally less air than petrol because of the presence of oxygen in the compound, which can lead to lower carbon dioxide emissions and smog precursors, balancing increased evaporative losses.
- Different burning characteristics of ethanol can result in more efficient combustion and overall energy efficiency.
- Ethanol is a renewable fuel that, subject to feedstock, may offer net fuel-cycle greenhouse gas–emission reductions of 34–40 per cent over comparable petrol emissions.
- Exhaust from 10 per cent ethanol blends produces 10–30 per cent less carbon monoxide than conventional petroleum fuels.
- Even low levels of ethanol can lead to substantial reductions in benzene (up to 6.5 times for E85) and E85 performs well in reducing 1,3-butadiene emissions (by 0.6 times) and formaldehyde (by 0.65 times)—both of which are associated with cancer and are emitted from petrol combustion.
- Hydrocarbon emissions may decrease by 1–10 per cent or increase by 15–35 per cent, depending on whether the blended petrol had a lower vapour pressure.
- NO_x emissions are lower than for conventional diesel engines, even without a catalytic convertor, but higher than for methanol.
- Particulate emissions such as sulphur dioxide are very low because ethanol contains no sulphur. The only sulphur associated with ethanol use would come from combustion of sulphur in engine oils.

Disadvantages

- There is potential for driveability problems because of the leaner air–fuel ratio—mainly in the carburetor and poorly tuned vehicles, which experience problems such as stalling, hesitation and power loss that are generally not a problem in newer fuel-injection vehicles.
- Ethanol has two-thirds the energy per unit volume of petrol and so requires greater onboard storage space.
- The increased vapour pressure of ethanol–petrol mixtures leads to increased volatile organic compound emissions and evaporative losses from the fuel system.
- Ethanol is fully miscible with water, so mixtures can separate unless co-solvents or emulsifiers are added to keep the blend evenly mixed.
- Ethanol (E85) combustion can increase exhaust emissions of acetaldehyde—an eye irritant, suspected carcinogen, and smog precursor—by up to 12 times those produced by gasoline vehicles.
- Exhaust emissions of nitrogen oxides can increase by 5–6 per cent over those produced by petrol.

Box E.2 Advantages and disadvantages of methanol as a fuel

Advantages

- The lower heating value of methanol is compensated for by higher pressure of gases after combustion, which increases engine power.
- Methanol is less flammable than gasoline (lower cetane number), accidental flames can be extinguished with water, and fires are less severe when it does ignite.
- Methanol combustion is 10–30 per cent more efficient than petrol combustion, offering commensurate savings in greenhouse emissions.
- Methanol is the fuel of choice for race cars (for example, Indianapolis-type cars) because of its superior performance and fire safety characteristics.
- The high latent heat of vaporisation means there is less tendency for engines to run on after the ignition is turned off.
- Methanol vehicles (M85) can produce up to 30 per cent less volatile organic compounds than petrol and M100 can produce up to 80 per cent less than petrol if the vapour pressure of petrol is adjusted.
- The human body can metabolise and eliminate methanol at low concentrations. Methanol is present in many cooked vegetables and is used as an artificial sweetener in diet soft drinks. It is broken down during digestion.
- Methanol dissolves in water and is biodegradable once the toxicity effect at high concentrations is overcome, so there are fewer problems (such as wildlife and shoreline oil contamination) with spills at sea.
- Methanol has lower ozone-forming potential than gasoline; that is, it is less reactive.
- Emissions of benzene and other aromatic hydrocarbons are minimal; for example, M100 reduces emissions of benzene, toluene and xylene by 25, 16 and 14 times respectively.
- Combustion in methanol-fuelled trucks and buses produces almost no particulates and much less NO_x than for diesel-fuelled trucks and buses.
- Particulate emissions are very low compared with diesel engines.

Disadvantages

- Blends of 15 per cent or less methanol in petrol require the addition of a co-solvent to prevent separation because methanol is highly soluble in water.
- Proportions of methanol above 5 per cent can lead to problems with material such as metals, alloys and elastomers used in fuel and engine systems. Methanol is more corrosive than ethanol.
- Methanol is not as suited as ethanol to blends with diesel because of its low cetane number, poor auto-ignition and poor miscibility (up to 15 per cent can be used with the use of additives).
- The vapour pressure of pure methanol is half that of petrol, leading to potential cold-start problems when using high methanol concentrations.
- Addition of methanol to petrol increases vapour pressure and volatility, leading to potential increase in emissions of volatile organic compounds.
- Methanol is highly toxic, although the toxic effects do not occur until several hours after exposure. Effective antidotes are readily available.
- Pure methanol (M100) combustion can increase the concentration of formaldehyde (up to five times that of gasoline vehicles) and other air toxics such as 1,3-butadiene (up to 10 times) but reduce the amount of acetaldehyde by up to three times and the amount of acrolein by up to 10 times.
- With M85 (85 per cent methanol in petrol) combustion, 1,3-butadiene emissions are about the same, formaldehyde emissions are up to three times higher, acetaldehyde emissions are up to 10 times higher, and acrolein emissions are up to four times higher.

E.3 Future sustainability benefits?

Biofuels are clean, renewable fuels that may play an increased role in the medium to long term, as noted by some petroleum industry participants, who foresee an increased role for biomass in transport energy within 20 to 40 years.

Biofuel production is already occurring in Australia and enhancing regional sustainability. For example, the Manildra ethanol plant at Nowra produces ethanol using local residual carbohydrate from the starch stream, which would otherwise be a waste product. CSR's Sarina plant in Queensland produces ethanol from sugar juice or molasses and is currently the largest Australian ethanol producer. The production of ethanol from ligno-cellulose offers potential synergies for areas undergoing change in their forestry industries, particularly areas adversely affected by policy changes limiting the available forest reserves. It may provide incentives for accelerated reforestation schemes and forms of alternative employment. There are also potential synergies with salinity and soil erosion management plans that call for large-scale tree planting at both State and federal levels, enabling the use of land that is currently marginal, at best, without displacing other agricultural production.

Note: A range of sources were drawn upon for this attachment; they are included in the bibliography. The US Environment Protection Authority's website—http:www.epa.gov (cited August 1999)—is a good starting point and provides links to further explore the area of biofuel innovation.

Attachment F Zero-emission vehicles

At present, the term ‘zero-emission vehicles’, or ‘ZEVs’, means electric vehicles and vehicles with a fuel cell or internal combustion engine using hydrogen, a renewable fuel. Electric vehicles use batteries and the electricity-producing reagents in the onboard battery are regenerated using electricity from an external source or an onboard charging system such as solar panels. Hybrid-electric vehicles with a small internal combustion engine or a fuel cell using petrol or diesel are not classed as ZEVs; instead, they are often known as ‘hypercars’ or ‘supercars’ (see Attachment B).

ZEVs offer urban amenity and local airshed benefits—they generate considerably less noise than conventional engines and are ‘emissions free’ in the airshed in which they operate, in that they reduce the overall emissions of hydrocarbons, carbon monoxide, sulphur oxides, particulates, and smog precursors such as NO_x and volatile organic compounds.

Regulations in California aimed at improving urban air quality have stimulated the development of the ZEV market. According to these regulations, 2, 5 and 10 per cent of new cars sold in 1998, 2001 and 2010 respectively must be ZEVs. As a consequence, the three major car manufacturers in the United States—Ford, General Motors and Chrysler—have been developing vehicles that target the car and light commercial market (pick-up trucks). Other motor vehicle manufacturers—such as BMW, Fiat, Peugeot Citroen, Nissan, Renault, Suzuki, Honda, Toyota, Mazda, Daihatsu and VW—are also involved in electric vehicle research and development. The United States military has been involved in electric vehicle research in California, aiming to strengthen national defence and energy security.

F.1 Environmental benefits

Although these vehicles have no emissions of air pollutants from the tailpipe or from fuel evaporative losses, there are emissions associated with the power generated to supply the electricity required for battery recharging. Because Australia uses coal for most of its power generation, the potential emission reductions are likely to be far less than those for a system that has a greater proportion of renewable energy such as hydro, solar, wind or biomass. The gradual trend in Australia to lowering the emissions intensity of electricity production by such measures as the 2 per cent renewable target and increased levels of co-generation will assist in improving the fuel-cycle benefits of electric vehicles. Efficiency improvements in power generation will also reduce the overall emissions from electric vehicles. Off-peak recharging does have some commercial potential for load levelling, since base load plants (such as Victoria’s brown coal power stations) are difficult to shut down and less efficient at lower capacity factors.

Most power stations are, however, located outside metropolitan airsheds, so do not contribute directly to poor urban air quality. It is easier and more cost effective to implement air pollutant controls on a single large point source than it is to control air emissions from multiple smaller sources.

Alternatively, electric vehicle batteries could be recharged using onboard solar cells or solar panels at the parking station where the car resides during the day. A prototype solar photovoltaic electric vehicle recharging station was built in Sacramento, California, in 1992 with plans for the installation of 70 additional stations.

The range and power output of electric vehicles has been perceived as a major disadvantage. The amount of power that can be stored in batteries at present limits the travel range to 100–250 kilometres, depending on speed, number of passengers, and the type of battery. Substantial research has been done on different battery types—such as sodium–sulphur, nickel–iron, nickel–cadmium, nickel–zinc, nickel–hydrogen, metal–air, zinc–bromide, vanadium–redox, lithium–sulphur, lithium–chlorine and lithium–polymer.

Most cars today can produce five to 10 times more power than is required for 90 per cent of the driving time. The additional power is built in to allow for conditions such as rapid acceleration, load pulling and hill climbing. Electric vehicles are designed to cover the power requirements for the 90 per cent of driving time, so do not at present have the additional capacity for rapid acceleration, load pulling and hill climbing.

To reduce the power requirement, ZEVs often incorporate the advanced design features of 'hypercars' or 'supercars', such as reduced body weight through the use of advanced materials, reduced aerodynamic drag through streamlining, and reduced energy losses through tyre design, reduced rolling resistance and regenerative braking. Lighter vehicles need less power for steering, braking and engine cooling, thus reducing the required supporting structure and fuel and power storage requirements.

The up-front capital cost of ZEVs is higher than that for conventional vehicles because ZEVs are produced in smaller numbers and generally are prototypes, and the lightweight materials used in their construction add significantly to production costs. This is, however, offset by the lower running costs and longer engine life expectancy. The lifespan of the motor in an electric vehicle could be from 25 to 100 per cent longer than that for conventional internal combustion engines.

Batteries need to be replaced approximately every two to four years, but some producers are looking at leasing arrangements to spread the battery replacement cost over the battery life. This would potentially enable efficient management of waste associated with battery use and replacement.

F.2 Optimal usage patterns

ZEVs are most suited to urban environments that have serious air quality problems and whose power generation is located outside the metropolitan airshed. The current trend in Australian cities towards increases in total vehicle numbers and total kilometres travelled by the vehicle fleet may eventually lead to the air quality problems California and other US states have experienced with smog and ozone non-attainment. ZEV technologies, along with continuing efficiency improvements in conventional engine technologies, are among the various technological and cultural options for dealing with potential deterioration in air quality.

Useful references for engineers

There is a rapidly growing literature and body of research relating to ecologically sustainable development and transport. Following is a selection of websites and recent publications that engineers may find useful.

Greenhouse strategies and the international context

See the Australian Greenhouse Office website (http://www.greenhouse.gov.au) for the National Greenhouse Strategy, the latest greenhouse inventory data, Greenhouse Challenge materials for the freight sector, and details of sustainable transport alternative fuel programs.

For reports and publications from the Intergovernmental Panel on Climate Change see the Panel's website (http://www.ipcc.ch/) and for summaries of important international policy documents and agreements (such as Agenda 21 and the Kyoto Protocol) see the Pace University School of Law Energy Project website (http://joshua.law.pace.edu/env/energy/govdocuments.html).

Sustainable transport and sustainable cities: urban form and integrated land-use planning

Two Australian resources that provide guidelines, tools and extensive bibliographies to assist in integrating land-use and transport planning are Hans Westerman's 1998 *Cities for Tomorrow—a guide to better practice* and *Cities for Tomorrow—resource document*, which were produced by Austroads. Austroads's research program has a strong focus on ecologically sustainable development and its website (http://203.35.96.131/austroads/default.html) provides details on forthcoming research proposals and available publications.

Other recent Austroad publications of interest are *Roads in the Community Part 1: are they doing their job?*; *Roads in the Community Part 2: towards better practice*; *Bicycles: Part 14 guide to traffic engineering practice*; and *Australian Cycling: the national strategy 1999–2004*.

Among recent reports from ARRB Transport Research are *Ecologically Sustainable Development: indicators and decision processes* (research report ARR 319); *Integrated Planning and Sustainable Development* (research report ARR 333); and *The Relationship between Urban Form and Travel Behaviour* (research report ARR 335). A report, *State-of-the-art Review—sustainable transport*, is due to be published shortly.

Queensland's Integrated Regional Transport Plan, which clearly articulates sustainability objectives, can be found at http://www.qdot.qld.gov.au/irtp/Shaping.html.

Health and air quality

The Australian Academy of Technological Sciences and Engineering's 1997 *Urban Air Pollution in Australia* provides a comprehensive review of ambient air quality in Australia and of transport's contribution to it (http://www.environment.gov.au/epg/pubs/urban_air_docs.html). Most State environment protection authorities have produced air quality management plans that provide full discussion of the issues and detail action strategies (for example, see the New South Wales Government's *Action for Air*).

Transport-generated Air Pollution—a source document for local government, from ARRB Transport Research, provides a useful discussion of measures that might be adopted to mitigate adverse health effects from transport pollution and contains a useful bibliography.

The Queensland Smogbusters site offers information on local initiatives and provides links to related Australian and overseas sites (http://www.qccqld.org.au/smogbusters/update.htm).

Among international sites of interest are the OECD site on transport, which provides details of the OECD Project on Environmentally Sustainable Transport and links to the major 1997 OECD Vancouver Conference 'Towards Sustainable Transportation' (http://www.oecd.org/env/trans/). Also visit WHO sites (for example, http://www.who.dk/london99/transport.htm).

Technologies for sustainable transport

Numerous websites deal with emerging vehicular technologies and it is often best to visit the websites of respective manufacturers to learn about these technologies. The Western Australian Department of Transport publishes *Trans Scan*, which provides commentary on national and international developments (http://www.transscan.com/html/main.html). A good international site on vehicle technologies is at (http://www.camerawork.net/roads&cars/future.htm#start).

Intelligent transport systems are now a focal area of technological innovation that some say is *the* paradigm shift in the sector as we approach the end of the century. A comprehensive review of these technologies and their systems applications can be found in *Examples of Recent Developments in Specialised Transport Technologies* (ARRB review report 2). Also see ITS Australia's website for progress on the Australian ITS National Strategy (http://www.itsa.uts.edu.au/).

Comparative greenhouse and pollutant emission performance of Euro 2 and Euro 4 liquid fuels and alternative fuels

This is an area where there appears to be little consensus—other than that further research and emissions testing in Australian conditions, with full fuel–cycle analysis, are required. Much of the data currently available in Australia relates to tailpipe emissions (rather than full fuel–cycle emissions) and often comes from overseas testing facilities. For recent studies of the environmental and economic benefits and shortcomings of competitive fuels, see the Australian Greenhouse Office's website; the Western Australian Ministry of Transport (1998) *Euro 2 & Beyond—fuel for Transperth bus fleet: report on the findings of the Expert Reference Group*; and the coming publication *CNG—the natural choice for urban bus fleets*, from the Australian Natural Gas Vehicle Council.

See also the websites of the major oil companies for their clean fuel programs and the conference proceedings from the 'Great Eco-Auto Challenge' conference held in May 1999 by the Society of Automotive Engineers Australasia and Automotive Training Australia.

Useful websites dealing with natural gas vehicles and their emissions performance are

- http://www.arb.ca.gov/research/indoor/in-vehsm.htm
- http://www.natural-gas-vehicles.co.uk/NGV-Web/FAQs/FAQs.html
- http://www.ngvc.org/qa.html#trans
- http://www.iangv.org/sources/qa.html#transemiss

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Abbreviations

AAA	Australian Automobile Association
ABARE	Australian Bureau of Agricultural and Resource Economics
ABS	Australian Bureau of Statistics
ADR	Australian Design Rule
AGA	Australian Gas Association
AGO	Australian Greenhouse Office
AGPS	Australian Government Publishing Service
ALPGA	Australian Liquefied Petroleum Gas Association
ANGVC	Australian Natural Gas Vehicles Council
ARRB	Australian Road Research Board
BTCE	Bureau of Transport and Communications Economics
BTE	Bureau of Transport Economics
CNG	compressed natural gas
DTRS	Department of Transport and Regional Services
ESD	ecologically sustainable development
EST	environmentally sustainable transport
FFV	flexible-fuel vehicle
GDP	gross domestic product
GPS	global positioning system
GVM	gross vehicle mass
GWP	global warming potential
IEAust	Institution of Engineers Australia
ITS	Intelligent Transport Systems
LCV	light commercial vehicle
LEV	low-emission vehicle
LPG	liquid petroleum gas
NCTR	National Committee on Transport, IEAust
NRTC	National Road Transport Commission
OECD	Organisation for Economic Co-operation and Development
OEM	original equipment manufacture
OPEC	Organisation of Petroleum Exporting Countries
RTSA	Railway Technical Society of Australasia
THS	Toyota hybrid system
ZEV	zero-emission vehicle