BTE Publication Summary

Greenhouse Gas Emissions in Australian Transport

Working Paper

The Paper details emissions from various segments of the transport sector, discusses the magnitude of the task involved in reducing transport emissions, and examines the potential for reducing them by alternative means. These include fuel economy improvements, use of alternative fuels, transport system improvements including modal shift, and reductions in discretionary travel.





Bureau of Transport and Communications Economics

WORKING PAPER 1

GREENHOUSE GAS EMISSIONS IN AUSTRALIAN TRANSPORT

SUBMISSION TO THE INDUSTRY COMMISSION INQUIRY INTO THE COSTS AND BENEFITS OF REDUCING GREENHOUSE GAS EMISSIONS Commonwealth of Australia 1991 ISSN 1036-739X ISBN 0 642 16260 3

First published June 1991. Reprinted with amendments July 1991.

This work is copyright. Apart from any use as permitted under the Copyright Act 1968, no part may be reproduced by any process without written permission from the Australian Government Publishing Service. Requests and inquiries concerning reproduction and rights should be addressed to the Manager, AGPS Press, Australian Government Publishing Service, GPO Box 84, Canberra, ACT 2601.

This publication is available free of charge from the Manager, Information Services, Bureau of Transport and Communications Economics, GPO Box 501, Canberra, ACT 2601.

Printed by the Department of Transport and Communications, Canberra.

FOREWORD

On 11 October 1990 the Federal Government decided to adopt, subject to certain conditions, an interim planning target involving stabilisation of greenhouse gas emissions at 1988 levels by 2000, and their reduction by 20 per cent by 2005.

This paper documents the results of the Bureau's research into greenhouse gas emissions from Australian transport, concentrating on domestic transport. The paper had its origins in a Bureau document prepared for the Australian Transport Advisory Council. This initial work was later revised and extended to form the basis of both a Bureau paper for the Transport Working Group on Ecologically Sustainable Development, and a more recent submission to the Industry Commission Inquiry into the costs and benefits of reducing greenhouse gas emissions.

The paper was prepared under the direction of Mike Cronin. Beryl Cuthbertson, Phillip Ironfield, David Cosgrove, Neil Kelso and Steven Wheatstone were involved in various stages of the work. Rebecca Blackburn also assisted.

> M.R. Cronin Research Manager

Bureau of Transport and Communications Economics Canberra May 1991

iii

| CONTENTS | | Page |
|-------------------------------------|--|--|
| | | |
| | | |
| FOREWORD | | iii |
| ABSTRACT | | xi |
| SUMMARY | | xiii |
| | | |
| CHAPTER 1 | GREENHOUSE GAS EMISSIONS IN AUSTRALIA | 1 |
| CHAPTER 2 | THE TRANSPORT TASK AND ENERGY CONSUMPTI | ON 5 |
| | The transport task | 5 |
| | Fuel consumption | 6 |
| CHAPTER 3 | GREENHOUSE GAS EMISSIONS FROM TRANSPORT | 9 |
| | Total emissions | 9 |
| | Trends in transport energy consumption | |
| | and carbon dioxide emissions | 13 |
| | | |
| | | |
| CHAPTER 4 | FUEL ECONOMY | 17 |
| CHAPTER 4 | FUEL ECONOMY The fuel economy of cars | 17 17 |
| CHAPTER 4 | FUEL ECONOMY The fuel economy of cars Potential fuel economy improvements: | 17 17 |
| CHAPTER 4 | FUEL ECONOMY The fuel economy of cars Potential fuel economy improvements: ships and aircraft | 17 17 24 |
| CHAPTER 4 CHAPTER 5 | FUEL ECONOMY The fuel economy of cars Potential fuel economy improvements: ships and aircraft ALTERNATIVE TRANSPORT FUELS | 17 17 24 27 |
| CHAPTER 4 CHAPTER 5 | FUEL ECONOMY The fuel economy of cars Potential fuel economy improvements: ships and aircraft ALTERNATIVE TRANSPORT FUELS Liquified petroleum gas | 17 17 24 27 28 |
| CHAPTER 4 CHAPTER 5 | <pre>FUEL ECONOMY The fuel economy of cars Potential fuel economy improvements: ships and aircraft ALTERNATIVE TRANSPORT FUELS Liquified petroleum gas Methanol</pre> | 17 17 24 27 28 28 |
| CHAPTER 4 CHAPTER 5 | <pre>FUEL ECONOMY The fuel economy of cars Potential fuel economy improvements: ships and aircraft ALTERNATIVE TRANSPORT FUELS Liquified petroleum gas Methanol Natural gas</pre> | 17 17 24 27 28 28 28 29 |
| CHAPTER 4 CHAPTER 5 | <pre>FUEL ECONOMY The fuel economy of cars Potential fuel economy improvements: ships and aircraft ALTERNATIVE TRANSPORT FUELS Liquified petroleum gas Methanol Natural gas Biomass fuels: ethanol</pre> | 17 17 24 27 28 28 29 30 |
| CHAPTER 4 CHAPTER 5 | <pre>FUEL ECONOMY The fuel economy of cars Potential fuel economy improvements: ships and aircraft ALTERNATIVE TRANSPORT FUELS Liquified petroleum gas Methanol Natural gas Biomass fuels: ethanol Electricity and hydrogen</pre> | 17 17 24 27 28 28 29 30 32 |
| CHAPTER 4 CHAPTER 5 | <pre>FUEL ECONOMY The fuel economy of cars Potential fuel economy improvements: ships and aircraft ALTERNATIVE TRANSPORT FUELS Liquified petroleum gas Methanol Natural gas Biomass fuels: ethanol Electricity and hydrogen Diesel</pre> | 17 17 24 27 28 28 29 30 32 33 |
| CHAPTER 5 CHAPTER 5 | <pre>FUEL ECONOMY The fuel economy of cars Potential fuel economy improvements: ships and aircraft ALTERNATIVE TRANSPORT FUELS Liquified petroleum gas Methanol Natural gas Biomass fuels: ethanol Electricity and hydrogen Diesel TRANSPORT SYSTEM IMPROVEMENTS</pre> | 17 17 24 27 28 28 29 30 32 33 35 |
| CHAPTER 4 CHAPTER 5 CHAPTER 6 | <pre>FUEL ECONOMY The fuel economy of cars Potential fuel economy improvements: ships and aircraft ALTERNATIVE TRANSPORT FUELS Liquified petroleum gas Methanol Natural gas Biomass fuels: ethanol Electricity and hydrogen Diesel TRANSPORT SYSTEM IMPROVEMENTS Urban passenger transport</pre> | 17 17 24 27 28 28 29 30 32 33 33 35 35 |
| CHAPTER 5 CHAPTER 6 | <pre>FUEL ECONOMY The fuel economy of cars Potential fuel economy improvements: ships and aircraft ALTERNATIVE TRANSPORT FUELS Liquified petroleum gas Methanol Natural gas Biomass fuels: ethanol Electricity and hydrogen Diesel TRANSPORT SYSTEM IMPROVEMENTS Urban passenger transport Non-urban passenger transport</pre> | 17 17 24 27 28 28 29 30 32 33 35 35 35 39 |
| CHAPTER 5 CHAPTER 6 | <pre>FUEL ECONOMY The fuel economy of cars Potential fuel economy improvements: ships and aircraft ALTERNATIVE TRANSPORT FUELS Liquified petroleum gas Methanol Natural gas Biomass fuels: ethanol Electricity and hydrogen Diesel TRANSPORT SYSTEM IMPROVEMENTS Urban passenger transport Non-urban passenger transport Non-urban freight</pre> | 17 17 24 27 28 28 29 30 32 33 35 35 35 39 41 |

.

v

| | F | age | | |
|---------------------------------|--|-----|--|--|
| CHAPTER 7 | SPATIAL EFFICIENCY | 47 | | |
| | | | | |
| CHAPTER 8 | THE EFFECT OF FUEL PRICES ON DEMAND FOR | | | |
| I | TRANSPORT FUELS | 49 | | |
| | | | | |
| CHAPTER 9 | FACTORS BEARING ON THE COST OF | | | |
| | GREENHOUSE MITIGATION IN TRANSPORT | 51 | | |
| | Existing estimates of costs and benefits | 51 | | |
| | Automobile fuel economy and utilisation | 53 | | |
| | Alternative transport fuels | 54 | | |
| | Transport system developments | 55 | | |
| | Transport and Australian industries | 56 | | |
| | Modelling impacts on national economic | | | |
| | welfare | 58 | | |
| | | | | |
| APPENDIX I | CONVERSION OF FUEL CONSUMPTION DATA | | | |
| | TO GREENHOUSE GAS EMISSIONS | 61 | | |
| APPENDIX II | DATA SOURCES | 67 | | |
| | Road transport | 67 | | |
| | Rail | 68 | | |
| | Sea | 69 | | |
| | Air | 69 | | |
| | | | | |
| APPENDIX III | INTERNATIONAL TRANSPORT | 71 | | |
| | Energy consumption by international | | | |
| | transport | 71 | | |
| | International passenger and freight | | | |
| | tasks | 72 | | |
| | | | | |
| REFERENCES | | 75 | | |
| | | | | |
| ABBREVIATIONS AND DEFINITIONS 8 | | | | |

vi

FIGURES

, **"**.

1 ...

~

, . , .

 \sim

| | | Page |
|-----|---|------|
| 3.1 | Australian carbon dioxide emissions by sector, 1987-88 | 11 |
| 3.2 | Australian carbon dioxide emissions from domestic transport by vehicle type, 1987-88 | 11 |
| 3.3 | Australian consumption of major transport fuels | 15 |
| 4.1 | Car fuel economy | 19 |
| 4.2 | Relative characteristics of US cars for model years 1978 to 1989 | 22 |
| 4.3 | Possible improvements in new car fuel efficiencies | 22 |
| 7.1 | Urban density versus gasoline use | 48 |

vii

TABLES

~

 \frown .

 \mathcal{C}

1--

 \sim

<u>`</u>.

1

 \sim

 $\tilde{\mathbf{x}}$

 \sim

<u>____</u>___

| | | Page |
|-------|---|------|
| 2.1 | Estimated energy consumption in Australian domestic transport (full fuel cycle), 1987-88 | 7 |
| 3.1 | Carbon dioxide emissions from Australian domestic transport | 10 |
| 3.2 | Major greenhouse gas emissions from domestic transport by mode, 1987-88. | 13 |
| 4.1 | New car fuel economy | 18 |
| 4.2 | Car fleet fuel economy | 21 |
| 5.1 | Greenhouse gas emissions and fuel costs of alternative transport fuels | . 27 |
| 6.1 | Urban passenger transport, Australia | 36 |
| 6.2 | Non-urban passenger transport, Australia | 40 |
| 6.3 | Non-urban freight transport, Australia | 42 |
| 6.4 | Urban freight transport, Australia | 45 |
| I.1 | Energy content of fuels | 61 |
| I.2 | Conversion efficiency of electrical power sources | 62 |
| I.3 | Carbon dioxide emissions (full combustion) by vehicle type | 63 |
| III.1 | Estimated primary energy consumption in Australia's international transport task, 1987-88 | 72 |

ix

ABSTRACT

This paper documents the results of the Bureau's research into greenhouse gas emissions from Australian domestic transport. Brief attention is also given to the emissions from Australia's international transport.

The paper details emissions from various segments of the transport sector, discusses the magnitude of the task involved in reducing transport emissions, and examines the potential for reducing them by alternative means. These include fuel economy improvements, use of alternative fuels, transport system improvements including modal shift, and reductions in discretionary travel.

Some comment is made about the effects on particular industries of greenhouse mitigation strategies in the transport sector, and about the difficulties involved in assessing the costs and benefits of such strategies to the economy.

The dominant role of the private car in generating emissions is highlighted, and the paper concludes that if a substantial and rapid reduction in transport sector emissions is required, it may be impossible to avoid reduction in motor car usage. It is emphasised that a less demanding target for the transport sector would be appropriate if the marginal costs of reducing emissions proved to be greater in transport than in other sectors of the economy.

SUMMARY

On 11 October 1990 the Federal Government decided to adopt, subject to certain conditions, an interim planning target involving the stabilisation of greenhouse gas emissions at 1988 levels by 2000, and their reduction by 20 per cent by 2005.

This paper documents the results of the Bureau's research into greenhouse gas emissions from Australian transport, concentrating on domestic transport. The paper details emissions from various segments of the transport sector, discusses the magnitude of the task involved in reducing transport emissions, and examines the potential for reducing them by alternative means. These include fuel economy improvements, use of alternative fuels, transport system improvements including modal shift, and reductions in discretionary travel. Attention is given to the effects on particular industries of greenhouse mitigation in strategies transport sector, the and to the difficulties involved in assessing the costs and benefits of such strategies to the economy.

The main greenhouse gases emitted directly from transport are carbon dioxide, by far the most important, carbon monoxide, and minor amounts of methane, nitrous oxide, and chlorofluorocarbons. Domestic transport appears to have contributed an estimated 26 per cent of 1987-88 Australian carbon dioxide emissions; close to 70 megatonnes on a 'full fuel cycle' basis. It is estimated that transport accounted for about 14 per cent of total Australian greenhouse gas emissions, in terms of radiative forcing.

The paper emphasises the magnitude of the task involved should the transport sector be required to reduce its emissions by 20 per cent. Projected rates of growth in transport sector emissions, even allowing for some improvement in fuel economy, indicate that under a 'business as usual' scenario, reductions of some 30 to 50 per cent from the expected 2005 levels would be required. Should the marginal cost of reducing emissions prove to be greater in transport than in other sectors of the economy, then a less demanding target could be envisaged.

The main source of transport emissions is the private car, being responsible for around 54 per cent of total carbon dioxide emissions from domestic transport. The usage of cars in urban areas currently accounts for around 39 per cent of total transport carbon dioxide emissions. In terms of the primary transport tasks, urban passenger transport accounted for 45 per cent of 1987-88 carbon dioxide emissions; non-urban passenger transport, 24 per cent; non-urban freight, 19 per cent; and urban freight, 12 per cent.

Fuel economy improvements in cars could clearly have a major impact on transport emissions. However the scope for, and the manufacturing costs of, improvements in the energy efficiency of automobile design are disputed among engineers. Moreover, the target date of 2005 may be too close for large changes in vehicle technology and/or vehicle size and power to penetrate the car fleet. The paper suggests therefore that if a substantial and rapid reduction of emissions is required from the transport sector, it may be impossible to avoid reduction in motor car usage.

The urban use of the motor car can be influenced by a variety of measures. Many of these would involve little capital outlay and would confer positive non-greenhouse external benefits. The potential for such benefits reflects the frequent existence of market failure in urban traffic and road systems. Congested urban roads are not usually priced to users. Parking access is frequently underpriced. Developers of both residential and commercial buildings are frequently undercharged for the

xiv

extra demands which their developments place on the urban road and public transport infrastructures.

There appears to be limited scope for greenhouse emission reduction from more use of rail and urban public transport, and greenhouse implications are unlikely to dominate decisions on substantial new investments in these There may however be other environmental benefits areas. a non-greenhouse nature associated with such modal of shift, and the greenhouse implications could be recognised in cost-benefit analysis of particular projects, along with these others.

Alternative transport fuels offering lower greenhouse emissions have been discussed, but they appear to be either limited in range of application or to be high-cost pending some significant technological breakthrough.

Many of the greenhouse strategies discussed in the paper would have negligible effects on domestic freight costs to Australian industries and any such impact would be greatly reduced by the achievement of international reciprocity. In contrast, any international measures tending to restrict or raise the costs of international shipping would have significant implications for industries exporting low-value bulk commodities over long distances. They would give some additional incentive towards further processing of such commodities before export.

The motor car industry could be favourably affected by measures such as early scrappage (at the expense of other parts of the economy). On the other hand its international competitiveness would be adversely affected should major retooling be required, even using overseas design for vehicles with improved fuel economy.

The Bureau's paper stresses the difficulties in quantifying costs and benefits of emission reduction strategies. These arise from the many gaps in our present knowledge of the outlook for vehicle engineering and production economics, the behavioural response of

xv

consumers and firms, and the implications of other externalities and distortions within the transport economy.

.

CHAPTER 1 GREENHOUSE GAS EMISSIONS IN AUSTRALIA

The Federal Government decided on 11 October 1990 to adopt an interim planning target for emissions of greenhouse gases not controlled by the Montreal Protocol on Ozone Depleting Substances. The target required emissions of these gases to be stabilised at 1988 levels by 2000, and to be reduced by 20 per cent by 2005. The decision carried the proviso that the adoption of response measures should not result in adverse effects on the economy in the absence of similar action by major greenhouse producing countries.

The Cabinet proviso reflected the earlier recommendations of the Prime Minister's Working Group on greenhouse gas emissions, and the sentiments expressed in the Federal Discussion Paper on *Ecologically Sustainable Development* (Department of Prime Minister and Cabinet 1990). These indicated that response strategies should be cost-<u>effective</u>, and preferably be justifiable on broad grounds of <u>efficiency</u>, or offer other economic or environmental benefits besides greenhouse gas reduction.

The Ecologically Sustainable Development Discussion Paper (Department of Prime Minister and Cabinet 1990) noted that:

Many of the reforms that could lead to higher levels of efficiency in the transport sector could also result in considerably lowered levels of pollution in terms of global warming, local air pollution and noise.

The Australian Minerals and Energy Council (AMEC 1990) has discussed the difficulties involved in securing

substantial reductions in emissions. AMEC had previously concluded that:

Achieving the full potential of energy response measures which are technically and economically feasible will reduce Australia's forecast growth in emissions from 37 per cent from 1989/90 to 2004/05, to a growth of 13 per cent. Even this level of reduction may require government intervention and change to Australia's lifestyle.

The 13 per cent growth in emissions to 2005 was to be achieved with a transport sector emissions growth of 27 per cent, 7 per cent growth in the industrial sector, and an absolute reduction of 19 per cent in the residential sector. This compares with AMEC's base-line forecast (based on ABARE 1989) of 37 per cent emissions growth, with 47 per cent in transport, 20 per cent in the industrial sector, 39 per cent in the residential sector, and 69 per cent emissions growth in the commercial sector. (Australian Bureau of Agricultural and Resource ABARE Economics) revised its forecasts in January 1991, with a somewhat lower forecast average annual growth rate of transport sector energy consumption, although the forecast average annual growth rates of overall energy consumption have been increased marginally (see chapter 3).

A report prepared by Deni Greene Consulting Services and the National Institute of Economic and Industry Research (NIEIR 1990) for the Australian and New Zealand Environment Council, was much more sanguine regarding Australia's ability to meet a target of a 20 per cent reduction on the 1988 level of greenhouse gas emissions by 2005. While assuming Federal and State Governments would need to undertake a range of programs to reduce greenhouse emissions, the report considered that a reduction of 20 per cent on 1988 levels could be achieved by efficiency improvements in the supply and use of energy, fuel substitution and some energy conservation. These measures were forecast to lead to annual savings in the cost of energy supply of over \$6 billion per year in 2005.

The report used a reference forecast of 394.4 megatonnes of carbon dioxide in 2005, an increase of about 42 per cent over 1988 levels, with transport sector fuel demand increasing by just over 33 per cent by 2005. The 20 per reduction scenario involved transport emissions cent falling 18 per cent from 1988 levels, residential emissions 61 per cent, commercial sector emissions 47 per cent, and emissions from the industrial sector 4 per cent.

The report considered that the reduction in transport emissions (18 per cent) under the 20 per cent overall reduction scenario could be achieved with various combinations of programs. For example, a medium intensity program of vehicle efficiency improvements could reduce transport fuel intensity by about 35 per cent from 1988 levels; a program of medium intensity fuel substitution and conservation programs involving commuter modal shift from car to bus and a reduction in discretionary car travel could together reduce fuel use by about 20 per cent.

An earlier Deni Greene report to the Department of Arts, Sport, Environment, Tourism and Territories (Greene 1990) contained, *inter alia* an 'efficient use' scenario, for a 20 per cent emissions reduction from 1988 levels, which involved a reduction in transport sector emissions of only about 1 per cent from 1988 levels. By contrast, the emissions from the residential sector needed to fall almost 50 per cent, emissions from manufacturing by 27 per cent, and for the commercial sector, a reduction of almost 20 per cent from 1988 levels would have been required.

CHAPTER 2 THE TRANSPORT TASK AND ENERGY CONSUMPTION

THE TRANSPORT TASK

In this paper the emphasis is on domestic transport. Fuel used in international transport to and from Australia might be roughly half as large as domestic transport fuel consumption appendix (see III). However, the responsibility for emissions generated from these services is clearly shared among importing, exporting and carrier countries, and cannot readily be assigned to any particular trading nation. Domestic transport is defined in this paper to exclude off-road mobile equipment used in agriculture and mining, and off-shore uses such as fishing and pleasure boating.

In 1987-88, the domestic transport task amounted to around 242 billion passenger kilometres, and around 260 billion tonne kilometres of freight.

Domestic passenger transport was dominated by car travel, with cars and light commercial vehicles accounting for around 82 per cent of all passenger kilometres. Bus, rail and air travel were small by comparison, moving approximately 7, 4, and 6 percent of total passenger kilometres respectively. Air travel accounted for around per cent of the non-urban passenger task. 15 Rail accounted for around 4 per cent of the urban, and 3 per cent of the non-urban passenger task; bus travel for 3 per cent of the urban, and 13 per cent of the non-urban passenger task.

The domestic freight task, in terms of aggregate tonne kilometres, was fairly evenly split between road (30 percent), rail (30 per cent) and sea (40 per cent). The share of road transport has been steadily increasing over

time. Heavy semi-trailers (6 or more axles) performed some 55 per cent of the road freight task in 1987-88.

FUEL CONSUMPTION

Estimates of the transport sector share of total Australian fuel consumption vary according to the treatment given to purchases of fuel for international transport, to fuel for off-road use, to fuel used in offshore uses, and to which point in the fuel (or energy) cycle the estimates relate.

The Bureau of Transport and Communications Economics (BTCE) estimates of aggregate energy consumption for Australian transport are shown in table 2.1^1 . In 1987-88, Australian domestic transport consumed an estimated 963 petajoules² of energy on a 'full fuel cycle'³ basis. This figure excludes transport fuel purchases in Australia used in the international movement of goods and people. (The BTCE estimates that for all transport servicing Australian international trade, less than 10 per cent of the fuel used by sea freight and less than 40 per cent of fuel used in air transport was purchased in Australia).

The estimated domestic transport share of total Australian energy consumption is 27.3 per cent; road transport accounting for 23.6 per cent, rail 1.3 per cent, air 1.8 per cent, and sea 0.7 per cent.

Generally, there are substantial energy losses in the generation and supply of electricity (produced primarily by coal-fired power stations). The heavy dependence of the residential and industrial sectors on electricity

- The basis for converting data on fuel volumes to estimates of energy consumption is explained in Appendix I.
- 2. A petajoule equals 10¹⁵ joules.
- 3. Full fuel cycle includes energy used in extraction, transport of feedstock, refining and power generation, and distribution/transmission, as well as end-use.

therefore inflates their shares of total primary energy consumption compared with their shares of secondary (or end-use) energy consumption. Transport's share is correspondingly reduced. Australian domestic transport accounted for around 25 per cent of total primary energy consumption in 1987-88, as opposed to its 37 per cent share of end-use energy consumption.

|] | DOMESTIC TRANSPOR | r (FULL | FUEL | CYCLE), | 1987-88 |
|--------------------|-------------------|---------|------|---------|--|
| Mode | | | | | Full fuel cycle [*] (Petajoules) |
| Road ^b | | | | | 834 |
| Rail | | | | | 45 |
| Air | | | | | 63 |
| Sea° | | | | | 23 |
| Total ^d | | | | | 963 |
| Per cent of tot | al Australian | | | | |
| energy consumpt | ion | | | | 27 |

| TABLE 2.1 | ESTIMATED | ENERGY CO | ONSUMPTION | IN AUSTRA | ALIAN |
|-----------|------------|-----------|------------|-----------|---------|
| | DOMESTIC S | TRANSPORT | (FULL FUEL | CYCLE), | 1987-88 |

a. Full fuel cycle energy consumption refers to the amount of (predominantly fossil) fuel combusted to deliver energy for enduse. It includes the generation and transmission losses for electricity, and energy used in fuel extraction, refining and distribution. In the case of liquid fuels used in transport, adjustment to a full fuel cycle basis is estimated to add around 10 per cent to end-use energy consumption.

b. Excludes fuel for off-road purposes in farming and mining.

c. Excludes fishery and pleasure craft.

d. Total has been adjusted to avoid double-counting energy used in the domestic transport of fuel.

Sources BTCE estimates, ABARE (1989), ABS (1990).

CHAPTER 3 GREENHOUSE GAS EMISSIONS FROM TRANSPORT

The main greenhouse gases emitted directly from transport dioxide, methane, are carbon nitrous oxide, and chlorofluorocarbons. Carbon monoxide should also be regarded as a greenhouse gas since, even though it is not radiatively active, it largely oxidises to carbon dioxide and it reacts so as to reduce methane and ozone absorption. The method used in this paper for calculating carbon dioxide emissions is based on the total carbon content of the fuel, where it is assumed that there is complete combustion of the fuel's carbon to carbon dioxide. Carbon monoxide is not then treated separately. evidence, however, Some recent suggests that this procedure could underestimate the indirect contribution to the greenhouse effect of carbon monoxide (Zillman 1990).

Methane and nitrous oxide make relatively minor contributions to total transport emissions and chlorofluorocarbons are to be phased out. Current policy will result in controls over losses of chlorofluorocarbons during servicing of air conditioners, and they are to be phased out in new air conditioners by 1997. The further development of policies on greenhouse gas emissions need not therefore take chlorofluorocarbons into account.

TOTAL EMISSIONS

The World Resources Institute (WRI 1990) has ranked Australia 19th in its list of countries contributing to greenhouse gas emissions, accounting for 1.1 per cent of global net emissions. WRI based this ranking on estimates of annual increases in the atmospheric concentrations of the primary greenhouse gases (that is, net emissions; which equal total emissions minus the absorption into sinks, such as oceans and forests). Lead.

For 1987, the WRI estimated net increase in greenhouse concentrations for Australia had, as its main component, an emission of around 240 megatonnes of carbon dioxide. This estimate is somewhat lower than the 269 megatonnes estimated by the BTCE for 1987-88 (based on ABARE energy consumption figures). NIEIR estimates (in Deni Greene Consulting Services and the NIEIR 1990), of 276.1 megatonnes, are of the same order of magnitude as those of the BTCE.

Domestic transport (as defined in chapter 2), and including only fuel used domestically, appears to have contributed an estimated 26 per cent of 1987-88 Australian carbon dioxide emissions (see figure 3.1); close to 70 megatonnes on a 'full fuel cycle' basis. Total emissions of carbon dioxide from Australian transport are shown in table 3.1.

| TABLE 3.1 | CARBON | DIOXIDE | EMISSIONS | FROM | AUSTRALIAN |
|-----------|--------|-----------|-----------|------|------------|
| | DOMEST | IC TRANSI | PORT | | |

| | 1984-85 | 1987-88 |
|---|---------|---------|
| Carbon dioxide emissions in megatonnes | 64 | 69 |
| Per cent of total emissions of Australian carbon dioxide | 25 | 26 |

Notes 1. It is assumed all carbon in fuels is combusted to carbon dioxide.

2. Emissions are on a full fuel cycle basis.

Source BTCE estimates.



Figure 3.1 Australian carbon dioxide emissions by sector, 1987-88

It is estimated that transport accounted for about 14 per cent¹ of total Australian greenhouse gas emissions, in terms of <u>radiative forcing</u> (or overall contribution to the greenhouse effect). A large proportion of the strongly radiative greenhouse gases, such as methane and nitrous oxide, were emitted from other sectors.

While these figures exclude emissions from ships and aircraft carrying freight and passengers into and out of Australia, the extent of these emissions is not a minor issue. The Australian economy is significantly dependent on the export of low-value bulk commodities over long distances. This task consumes a lot of fuel, most of it is purchased overseas and used in foreign flag vessels.

The relative importance of the different greenhouse emissions from transport can be seen from the actual domestic emissions of the major greenhouse gases from burning transport fuel. For 1987-88 these were (on the basis of the full fuel cycle):

69.4 megatonnes of carbon dioxide (including 6.5 megatonnes generated indirectly as carbon monoxide emissions);

0.02 megatonnes of methane (0.3 megatonnes of carbon dioxide equivalent); and

. 0.004 megatonnes of nitrous oxide (1.4 megatonnes carbon dioxide equivalent).

Table 3.2 shows, by mode, these 1987-88 transport emissions, and the equivalent tonnage of carbon dioxide which would produce the same total warming effect as the greenhouse emissions mix. Carbon dioxide and carbon monoxide accounted for 98 per cent of all Australian

^{4.} The contribution was probably between 14 and 16 per cent, depending on the extent to which transport is responsible for the national level of chlorofluorocarbon release.

transport greenhouse gas emissions, in terms of carbon dioxide equivalents.

The main source of <u>transport emissions</u> is the private car, being responsible for around 54 per cent of total carbon dioxide emissions from domestic transport (figure 3.2). The usage of cars in urban areas currently accounts for around 39 per cent of total transport carbon dioxide emissions. In terms of the primary transport tasks: urban passenger transport accounted for 45 per cent of 1987-88 carbon dioxide emissions; non-urban passenger transport, 24 per cent; non-urban freight, 19 per cent; and urban freight, 12 per cent.

| Arisful | L . | Gas emitted [®] (kilotonnes) | | | 5) |
|---------|-----------------|---------------------------------------|------|------------------|--------------------------------------|
| Mode | CO ₂ | со | CH, | N ₂ O | Total CO2 equivalent ^e |
| Road | 53 670 | 4 000 | 17.7 | 1.7 | 60 840 |
| Rail | 3 470 | 18 | 0.4 | 1.2 | 3 930 |
| Air | 4 230 | 106 | 0.4 | 1.1 | 4 790 |
| Sea | 1 590 | 7 | 0.4 | | 1 620 |
| Total | 62 960 | 4 131 | 18.9 | 4.0 | 71 180 |

| TABLE 3.2 | MAJOR GRE | ENHOUSE | GAS EMISSIONS ^a | FROM DOMESTIC |
|-----------|-----------|---------|----------------------------|---------------|
| | TRANSPORT | BY MODE | , 1987-88 | |

a. Based on the full fuel cycle.

b. Gases are - carbon dioxide (CO_2), carbon monoxide (CO), methane (CH_4) and nitrous oxide (N_2O).

c. Total in radiative forcing equivalent of carbon dioxide.

Source BTCE estimates based on OECD (1989).

TRENDS IN TRANSPORT ENERGY CONSUMPTION AND CARBON DIOXIDE EMISSIONS

Over the twelve years to 1988, the consumption of transport fuels (and presumably the level of annual carbon dioxide emissions) increased by about 60 per cent, an

annual growth rate of about 4 per cent. There was a particularly rapid growth in diesel consumption; about 170 per cent over the same period, largely reflecting the expansion of the road freight industry.

Forecasts by ABARE and NIEIR are based on expected rates of increase in fuel demand which are significantly lower than in the past.

ABARE, in its 1991 published forecasts of energy demand and supply, projected transport fuel consumption growth of about 2.2 per cent per year, to a level nearly 44 per cent higher than that of 1987-88 by the year 2004-5 (ABARE 1991). The ABARE projections are fairly closely aligned with those of NIEIR (1990a), which projected transport sector fuel consumption growth rates of just under 2 per cent per year, cumulating to nearly 30 per cent total growth between 1988 and 2000 (figure 3.3).

Applying rates of growth of 1, 2 and 3 per cent to transport emissions would yield projections of emissions growing by about 18, 40 and 55 per cent respectively from 1987-88 levels by 2005. Effecting an absolute reduction of 20 per cent from the 1988 level of emissions under any of these scenarios would clearly be a challenging task, requiring reductions of some 30 to 50 per cent from the likely emission levels in 2005.

The magnitude of this challenge becomes evident when it is considered that autonomous technical change built in to most forecasts implies a trend to improved fuel economy. For instance, the ABARE forecast appears to imply a 15 per cent average improvement in fuel economy in Australian transport in the 17 years to 2005. Were it not for such improvement, ABARE forecasts would suggest an approximate 66 per cent, rather than a 44 per cent, increase in transport energy use by 2004-05.

Even if it is inferred from the AMEC (1990) and Greene (1990) view (see chapter 1), that Australian transport's share of reductions in emissions would not have to be as large as that in other sectors of the economy, there is still likely to be considerable difficulty in achieving

the required cuts in transport sector emissions. An 'across the board' cut in transport sector emissions will not be the most efficient route if different sectors and modes provide different scope for cost-effective emission reductions. It will always be most efficient to make the greatest cuts in emissions in those areas which can abate emissions at the lowest cost.

of reducing transport emissions include Possible ways improved vehicle fuel economy, use of alternative fuels, improvements in urban transport systems, and encouraging shifts of passengers and freight to more fuel efficient Improved urban design could also assist transport modes. reducing the growth in emissions, since continued in growth in low density residential developments would put upward pressure on energy demand. More generally, the pursuit of a rapid reduction in carbon dioxide emissions could require reducing the projected from transport transport task, eg. through less travel of a discretionary nature.





CHAPTER 4 FUEL ECONOMY

THE FUEL ECONOMY OF CARS

Improving the fuel economy of cars will be a key factor in reducing greenhouse gas emissions, since some 54 per cent of Australian transport emissions of carbon dioxide come from the car. Cars are purchased for a variety of reasons, such as comfort, carrying capacity, safety, power or prestige, with fuel economy often a minor criterion.

New cars

In 1979 the average fuel economy rating of new cars was 10.9 litres per 100km in Australia and about 11.6 in the United States (see table 4.1).

By 1988 the new car average in Australia had fallen to 9.1 litres per 100km. This was a slower rate of improvement than occurred in the United States, where by 1988 the new car average was 8.2 litres per 100km (see figure 4.1). has attributed Falvey et al. (1986) some of this improvement in fuel economy to the substitution of diesel engines for petrol engines in large US cars. It also seems that the operation of the Corporate Average Fuel Economy scheme in the USA induced some consumer shift away from cars subject to mandatory targets towards other vehicle types. Canada's rate of improvement was also much higher than Australia's. Several other countries which had better new car fuel economy in 1979 than did Australia, also had rates of improvement somewhat better than Australia's.

| | | Average consumption (litres/100km) | | | Per cent total change |
|-----------------|------|---------------------------------------|------|------|-----------------------------|
| | 1979 | 1983 | 1986 | 1988 | period |
| Australia | 10.9 | 9.2 | 9.3 | 9.1 | -16.5 |
| Canada | 11.4 | 8.5 | 8.4 | 8.1 | -28.9 |
| West Germany | 9.6 | 8.1 | 7.5 | 7.9 | -17.7 |
| Italy | 8.3 | 7.3 | 6.8 | 6.8 | -18.1 |
| Japan | 8.6 | 7.8 | 8.3 | 8.6 | 0 |
| Sweden | 9.2 | 8.6 | 8.4 | 8.2 | -10.9 |
| UK | 9.0 | 7.9 | 7.5 | 7.4 | -17.8 |
| USA | 11.6 | 8.9 | 8.4 | 8.2 | -29.2 |

TABLE 4.1 NEW CAR FUEL ECONOMY

Note The US use of a harmonic mean to calculate its published average fuel economy rates (in miles per gallon) is consistent with the use of weighted arithmetic means to calculate average fuel intensities (in litres per 100km). Figures for Australia prior to 1986 (obtained under AS 2077) have been adjusted to be comparable with those obtained under AS 2877.

Sources

DPIE (personal communication), IEA (unpublished), US Energy Information Administration (1990).





Variation among countries in average fuel economy per vehicle will reflect different standards for emissions (eg nitrogen oxides and particulates), as well as differences in social geography and infrastructures which underlie travel demand.

Some caution must be exercised in using these figures, as they are based on various test driving cycles, and not on real road conditions in the various countries. These tests may differ in content, may change over time, and the

relative weights given to urban and non-urban driving¹ may also differ. In 1986, for example, Australia changed from test standard AS2077 to standard AS2877, which introduced a 2.75 per cent discrepancy between 'as measured' figures before and after this date. Figures in table 4.1 for Australia prior to 1986 have been corrected for this factor: under the old standard AS2077, the figure for 1988 would have been 9.35 litres per 100km.

A recent American study (Difiglio et al. 1989) argued that the US fuel economy improvements had been obtained without any loss of key vehicle characteristics, such as interior space and power (see figure 4.2).

Car fleet average fuel economy

These improvements in new car fuel economy were, of course, reflected imperfectly and sluggishly in the estimated on-road performance of the total car fleet (see table 4.2). In Australia, the fleet average fell from 12.7 litres per 100km in 1979 to about 11.8 in 1988, while in the United States, average fuel consumption per car fell from about 16.3 litres per 100km in 1979 to 11.8 in 1988.

This comparative slowness of the improvement in the fleet average in Australia would have been influenced by the ageing of the car fleet. In 1971 some 29 per cent of Australian cars were 3 years old or less: in 1988 only 13 per cent. In 1971 around one-quarter of Australian cars were ten years or more old; in 1988 almost half. Not only has the ageing of the fleet slowed down the introduction of more fuel efficient new cars, but the fuel consumption of any given car tends to increase with age.

Low scrappage rates have been due to many factors, such as an increase in design life, increases in the real prices of new cars, and higher interest rates. Hopefully there

1. Frequently referred to as city and highway cycle.

will be a more rapid improvement of the fleet average in coming years, as these older vehicles reach the end of their design lives.

| | 1979 — | Average consumption (litre/100km) | | | Per cent total change over period |
|----------------------|--------|--------------------------------------|-------|---------|---|
| | | | | | |
| Australia | 12.7 | 12.5ª | 12.0° | 11.8 | -7.1 |
| Canada | 15.7 | 13.8 | 12.4 | na | -24.6° |
| West | | | | | |
| Germany ^d | 10.8 | 10.9 | 10.9 | 10.7 | -0.9 |
| Italy | 9.1 | 8.0 | 7.8 | 7.6 | -16.5 |
| Japan | 11.8 | 11.0 | 10.7 | na | -9.3 |
| Sweden | 10.9 | 10.8 | 10.5 | 10.3 | -5.5 |
| UK | na | na | na | - na | na |
| USA | 16.3 | 13.7 | 12.9 | 11.8 | -27.6 |

TABLE 4.2 CAR FLEET FUEL ECONOMY

a. 1982 figure.

b. 1985 figure.

c. Based on 1987 estimate of 11.84 litres per 100km.

d. Possibly based on erroneous data, according to IEA.

na not available.

Sources DPIE (personal communication), IEA 1990 (unpublished), US Energy Information Administration (1990).

The potential for future fuel economy improvements in cars

Difiglio et al. (1989) explored the potential for further improvements in new car fuel economy in the United States. They concluded that "using technology already included in





manufacturers' production plans and based on consumers' willingness to pay for fuel economy" a new car fuel consumption of 6.9 litres per 100km could be reached by the year 2000. A further improvement to 6.5 litres per 100km would be cost-effective based on fuel cost savings over the vehicle life, and could be achieved without significantly reducing average vehicle size and performance. The Difiglio study went on to argue that downsizing the mix of cars, by influencing consumer choice through subsidies and taxes on vehicles, could bring the average fuel consumption of new cars down to 5 litres per 100km (see figure 4.3).

Other overseas studies (e.g. Mellde et al. 1989, Brosthaus in OECD/IEA 1990a) lend support to the Difiglio views. An Organisation for Economic Co-operation and Development gave qualified support, concluding (OECD) expert panel significant improvements fuel that in economy and emissions could be achieved for vehicles entering the market in the near term, but that the extent of actual improvements was difficult fuel economy to quantify (OECD/IEA 1990b). While agreed some experts that reductions in standards and performance would not result, others thought that vigorous government action aimed at downsizing vehicles and reducing engine capacity would be This question is of some importance, as there necessary. are some fears that 'downsizing' of the fleet could result in an increase in road trauma, through both an increase in number of motor vehicle fatalities the and in the seriousness of injuries.

There appears to be controversy in the US about the scope for improvements in automobile technology to affect fuel economy. A Chrysler Corporation paper (Bussman 1989), concluded from a sample study of the on-road performance of 1988 and 1989 model cars, that the potential gains in fuel economy available from currently available technology would be much less than indicated by Difiglio. Bussman asserted that many fuel saving technologies when combined on one vehicle involved a negative synergy: the combined fuel saving being less than the sum of fuel consumption

3

savings each technology was able to achieve when used in isolation. The Vice-President Technical Affairs of Ford USA (McTague 1990) estimated fuel economy improvements at 0.8 per cent per year for the next 10 to 15 years. This would lead to 7.5 litres per 100km by 2000, and 7 litres per 100km by 2005, a cumulative improvement of about 8 and 12 per cent respectively from current US new car levels.

The Australian motor industry has now proposed fuel economy targets of 8.2 litres per 100km in the year 2000 and 8.0 litres by 2005, roughly equal to the current US average for new cars (Federal Chamber of Automotive Industries 1990). Some of the improvements in car technology could be more costly, particularly in Australia, than is anticipated in, for example, the Difiglio study. The economies of scale in production available overseas are frequently not available with the level of Australian production.

Obviously it would take a considerable time before the existing stock of cars could be replaced with new technology vehicles. A larger question is to what extent improved fuel economy per vehicle results in lower total consumption of fuel.

Some trend improvement in fuel economy was built into the demand forecasts discussed earlier ----ABARE (1991)suggested its fuel consumption forecasts were consistent with an improvement in fleet average fuel economy from 11.8 to 10.9 litres per 100km by 2004-05 (about 0.4 per cent per year). This would have to be allowed for in considering the potential for reducing greenhouse emissions below forecast levels.

POTENTIAL FUEL ECONOMY IMPROVEMENTS: SHIPS AND AIRCRAFT

Ships

There appears to be the potential to realise steady incremental fuel economy gains for the Australian flag fleet over the next 15 years, from replacement of existing

Australian vessels and from ongoing technical progress in engine, hull, hull appendage and propeller design.

Diesel engines, for which only gradual improvements in consumption are foreseen by industry publications, will remain the dominant prime mover for merchant ships in the foreseeable future. However, ship fuel efficiencies can apparently be further increased by improved hydrodynamics (Geisler 1989).

Australian National Maritime Association data on the fuel economy of Australian flag vessels wholly or partly engaged in the coastal trade, show a 20 per cent reduction in average tonnes of fuel per 1000 deadweight tonnage per day for general cargo vessels, a 50 per cent reduction for dry bulkers and a 40 per cent reduction for tankers from 1975 to 1987. Australian National Maritime Association attributed this improvement to increasing ship size, lower design speeds, more energy efficient engine technologies, improved hull designs and improved surface finishes.

The extent to which these improvements in fuel economy per day translate into fuel economy improvements per tonne kilometre is not precisely known. It appears that some reduction in the average speed of ships has occurred, which would result in an overall fuel economy improvement for the shipping task less than implied by the per day figures.

Expected replacement vessels for the current Australian flag (major trading) fleet could be some 15 to 25 per cent more fuel efficient (on a per day basis) than those they replace. By the time many existing Australian flag vessels do come to be replaced, efficiency gains of another 10 to 20 per cent could be available.

It is foreseeable that the average efficiency of the Australian flag fleet could rise by some 15 to 25 per cent (on a fuel consumption per 1000 deadweight tonnage per hour basis) by 2005.

Aircraft

Gains in the average fuel economy of the Australian air fleet over the next 15 years will mainly flow from the replacement of existing so-called Chapter 2 aircraft with Chapter 3 aircraft by 2002. Chapter 3 aircraft, besides being quieter, are typically 30 to 40 per cent more fuel efficient than their Chapter 2 equivalents.

However, this margin might only apply to some 25 to 30 per cent of the current fleet, giving average savings of 7.5 to 12 per cent on the current fleet average fuel economy. Another 1 or 2 per cent might be available from replacing the 10 to 15 per cent of aircraft in the fleet which are only marginally in the Chapter 2 category.

Some additional gains might also be expected from ongoing technical progress in the design of existing high-bypass engine types fitted to replacement aircraft in the period to 2005. Refined versions of existing big-fan engines, including high-efficiency compressors, wide-chord fan blades and fully electronic controls, offer useful improvements in fuel economy, and will be standard on most engines by the 1990s. But major changes, such as the prop-fan engine currently still in development, would be needed to repeat the consumption gains made with the initial introduction of the high-bypass engine. Gains may be made from replacing engines on existing Chapter 3 aircraft with later engines.

Overall average savings of 10 to 15 per cent in the fleet average fuel economy by 2005 would not seem unreasonable. The ABARE (1991) projections are based on econometric models which appear to incorporate an efficiency growth of some 18 per cent for domestic aviation over the period to 2004-05 (BTCE estimate).
CHAPTER 5 ALTERNATIVE TRANSPORT FUELS

subject Alternatives to petroleum have been а of discussion and research since the early seventies. The greenhouse implications of alternative fuels have recently examined by DeLuchi et (1988) been al. and the International Energy Agency (1990), and in the Australian context by Le Cornu (1990), Walker (1990) and the NSW Department of Minerals and Energy (1990) (see table 5.1).

TABLE 5.1 GREENHOUSE EMISSIONS AND FUEL COSTS OF ALTERNATIVE TRANSPORT FUELS

| di | Per cent change in greenhouse emissions, carbon ioxide equivalent ^a | Overall fuel costs, 1987 \$US per barrel gasoline equivalent ^b |
|------------------------------------|---|---|
| Conventional gasoline | | . 27 |
| Synthetic gasoline (from gas) | 0 to +30° | 43-61 |
| Synthetic diesel (from gas) | 0 to +30° | 69 |
| Compressed natural gas | -19 ^d | 20-46 |
| Methanol from gas | -3ª | 30-67 |
| Methanol from coal | +51 | 63-109 |
| Methanol, ethanol from biomass | -100 | 64-126 |
| Electric, hydrogen from non-fossil | -100 | 81-135° |
| Electric, from coal | +26° | na |
| Electric, from natural gas | -18° | na |

a. DeLuchi et al (1988)

b. IEA (1990)

c. Le Cornu (1990). Le Cornu has nuclear-based electric and hydrogen as 3 to 5 times the cost of gasoline.

d. Le Cornu (personal communication, 1990) notes that DeLuchi's figures appear to assume natural gas is pure methane. Some Australian natural gas contains significant amounts of other hydrocarbons and naturally occurring carbon dioxide.

- e. DeLuchi et al (1989)
- na not available.

The most *economically* viable alternatives appear to be liquified petroleum gas, compressed natural gas and methanol from gas. Some substitution of diesel for petrol engines may also be viable.

LIQUIFIED PETROLEUM GAS

The penetration of liquified petroleum gas into Australian transport markets is expected to be limited by supply considerations to low levels, probably not more than 5 per cent of gasoline use (ABARE 1991). Le Cornu (1990) adds that liquid petroleum gas offers only small reductions of carbon dioxide emissions when compared with petrol.

BTCE estimates based on figures published by the National Roads and Motorists Association (NRMA 1989) comparing fuel consumption for several similar liquid petroleum gas and petrol fuelled vehicles, indicate emissions were some 10 to 14 per cent lower from these liquid petroleum gas fuelled vehicles. The NRMA (1990) notes that the limited under-bonnet space in some front wheel drive cars prevents the fitting of the necessary liquid petroleum gas components.

METHANOL

Methanol from natural gas, even if pure methane, does not offer significant carbon dioxide advantage а over A NSW Department of Minerals and conventional fuels. Energy study concluded that the production of methanol from natural gas was not commercially attractive at prevailing (August 1990) methanol prices. However, the study noted that its preferred methanol fuel for light duty vehicles, an M85 blend of 85 per cent methanol and 15 per cent unleaded petrol, would have a cost only about 15 per cent higher than that for petrol. Ecogen (1991 personal communication) has indicated that this comparison refers to production costs net of all excise taxes. Technology to run diesel engines on M100 (i.e. straight

methanol) is still being evolved. The initial use of methanol may be in the form of 15 per cent methyl tertiary butyl ether (a methanol derivative) added to petrol as an octane enhancer (NSW Department of Minerals and Energy 1990).

Methanol from coal would involve substantially more carbon dioxide emissions than gasoline, as well as an additional cost penalty (Walker 1990). There is also some concern over the health and safety aspects of methanol use, such as its high toxicity. The NSW study notes that attention will need to be paid to education, labelling and the prevention of non-vehicle methanol use.

NATURAL GAS

Compressed natural gas is already entering commercial short-haul transport uses for buses and trucks in Australia. It has been estimated (Walker 1990) that compressed natural gas might substitute for almost 10 per cent of diesel fuel in road transport by 2005. Walker suggested this increased penetration of compressed natural gas into the truck fleet could reduce carbon dioxide emissions from all trucking by about 2.5 per cent.

While fugitive losses of methane from compressed natural gas distribution systems of around 3 per cent could offset these gains, Walker (1990) has argued that such losses are unlikely. Le Cornu (1990) considers that any losses would be confined to old reticulation systems but points out that the natural carbon dioxide content at wellhead of natural gas from some sources, unless extracted and reinjected, could affect its greenhouse advantages.

More significant penetration of the market by compressed natural gas would appear possible, but would depend on improvements to the distribution system, to make compressed natural gas more readily accessible for long distance transport, and on the level of excise levied. Development Corporation The Energy Research and is currently funding a project, managed by Australian Gas

Light Sydney Limited, which will investigate the economics of a natural gas distribution system for the non-urban road transport industry between Brisbane and Perth. The Victorian Gas and Fuel Corporation also has been reported as planning a chain of compressed natural gas refuelling stations from Brisbane to Perth, to service heavy trucks (De Fraga 1991). The report added that the trucks would be powered by spark-ignition compressed natural gas engines, developed from existing diesel engines by the Victorian Gas and Fuel Corporation in collaboration with Bosch.

The NRMA (1991) considers that liquified natural gas would be the preferred option for heavy trucks, because a liquified natural gas vehicle's range would be similar to that of a diesel or petrol vehicle, although refrigerated tanks would be required. Compressed natural gas, on the other hand, contains only about one sixth of the energy per unit of volume as petrol.

BIOMASS FUELS: ETHANOL

The present feedstocks for commercial production of ethanol are grains (as in the United States) and sugar cane (as in Brazil). The IEA (1990) observed that only in special economic circumstances will corn or sugarcane be available for commercial conversion to ethanol. The NSW Department of Minerals and Energy (1990) study concluded that the potential use of ethanol from NSW sugar cane was limited, to only about one per cent of NSW petrol consumption, by supply considerations regarding suitable land and alternative use (crystal sugar). In any case, it was considered uneconomic using conventional technology.

The IEA (1990) stated also that if alcohol from biomass is to become a major alternative fuel, it must broaden its resource base to process cellulosic feedstocks. Though we do not yet have commercial large-scale technology to do this, extensive research is currently being conducted in this area.

Estimates of the net carbon dioxide emissions from use of ethanol from biomass vary widely. Rogers (1990) argued that net emissions would be nearly zero because the atmospheric carbon dioxide consumed in photosynthesis would offset that released in burning the fuel. However this would be the case only if the feedstock crops did not displace other crops or natural vegetation, and if no carbon-based energy were consumed in fertilising, harvesting and processing the crops, which appears somewhat unlikely. Walker (1990) and Le Cornu (1990) suggested that net emissions would be low, while a net carbon dioxide penalty compared with gasoline was claimed by the Amoco oil company (1989 study cited in NSW Department of Minerals and Energy 1990). The NSW Department of Minerals and Energy (1990) study concluded that ethanol produced from sugar cane could generate emissions of 34 to 40 per cent of those of gasoline, since bagasse would provide additional energy to be used in the conversion process.

At this time, ethanol does not appear to offer a low-cost strategy for reducing carbon dioxide emissions (Walker 1990, IEA 1990). A CSR report (cited in Rogers 1990) found the cost of ethanol produced from molasses in Australia to be 50 to 60 cents per litre. Le Cornu has pointed out a bias in some cost comparisons between fuels. For instance, commonly excise is included in the gasoline cost, but not in the ethanol cost. (Excise is a cost to the individual user but not to society). In the US, the ethanol industry is supported by large subsidies and concessional treatment of ethanol and ethanol blends.

The IEA (1990) and the NSW Department of Minerals and Energy (1990) pointed to possibilities for significant reductions in ethanol production costs over the next 10 years. This would come mainly from the development of technologies for conversion of cellulosic materials such as sugar cane bagasse and high cellulose crops. The study considered the most likely form of use would be a 10 per cent blend of anhydrous ethanol with unleaded petrol. In the longer term, ethyl tertiary butyl ether (an ethanol derivative) might be used in this blend.

ELECTRICITY AND HYDROGEN

The development of electric-powered or hydrogen-powered road vehicles faces difficult engineering problems, but such vehicles would produce virtually no greenhouse emissions in use. However, in both cases there would be the heavy greenhouse gas emissions where electricity was generated from fossil fuels.

DeLuchi et al. (1989) considered that for electric vehicles powered by the 1985 US mix of electric power sources there would be only 1 per cent less emissions than from petrol powered cars, while electric vehicles powered by natural gas fuelled electricity generation would show a moderate (18 per cent) decrease in emissions (see table 5.1).

Some recent Australian research (Gosden 1990) suggests that, in the case of electric vehicles, carbon dioxide emissions may be only 80 per cent of those of their new petroleum fuelled counterparts. Gosden (personal communication 1991) considered that previous studies of electric vehicle emissions may have been adversely affected by the inefficiency of battery recharging after short test cycles.

The sodium sulphur battery, likely to be introduced during the 1990s, has the potential to improve electric vehicle range dramatically. This battery has an energy density of 70 to 80 watt hours per kilogram, compared to the current lead acid battery (about 35 watt hours per kilogram). There are, however, some safety questions to be addressed because of the potential hazards of reactive compounds at elevated temperatures (Gosden 1991 personal communication).

DeLuchi et al. (1989) suggested that by 2000, electric vehicles could be viable as second cars in multi-vehicle

households and in other limited markets, with greater potential if an economical form of rapid recharging could Life cycle costs could be lower than be developed. internal combustion comparable engine vehicles if optimistic goals are achieved for battery life, cost and performance; if not, life cycle costs could be significantly higher (DeLuchi et al. 1989).

It has been suggested (for example, Mellde 1989) that photovoltaic cells ultimately hydrogen from would effectively deal with the present qlobal problems associated with automobiles. But the technology is not at hand and it will be at least 20 years before it could begin to make a quantitative impact.

DIESEL

The trend towards increased penetration of diesel engines in road transport will have some effect in reducing greenhouse gas emissions, though the magnitude of the improvements is in doubt. likely Le Cornu (1990)indicated improvements of the order of 20 per cent in vehicular emissions could be expected compared with petrol, but stressed the cost penalty associated with the more expensive diesel engines and pointed out the local air quality effects of particulate emissions. He also noted constraints on the availability of diesel in the refinery output mix (Le Cornu 1990 personal communication).

Available figures for comparable new cars also indicate carbon dioxide emission reductions of a similar magnitude (DPIE 1990). The IEA is conducting further research on the emissions implications (on a full fuel cycle basis) of increased use of diesel over gasoline.

CHAPTER 6 TRANSPORT SYSTEM IMPROVEMENTS

The potential for reducing greenhouse gas emissions through various strategies designed to increase the efficiency of transport operations, including possible modal shift, is discussed below in sections covering urban¹ and non-urban passenger transport, and urban and non-urban While freight. there exists scope for efficiency improvements within each mode, overall there appears to be limited prospect for reduction in emissions from modal shift.

The estimates of emissions per unit transport task from each mode (given in the tables below) reflect performance, rather than technical capability. Increases in load factors, for example, or improved operating conditions or lower speeds, could change the achieved levels of emissions substantially.

URBAN PASSENGER TRANSPORT.

Some quite approximate estimates of modal shares and associated emission levels are shown in table 6.1. Further research would be desirable to permit а √distinction in emission levels by time of day (especially between peak and off-peak) and by routing (for example, between radial and lateral movements). The availability of suitable data for this purpose has constrained the analysis presented at this stage.

Urban passenger transport accounts for the highest level of carbon dioxide emissions of any of the transport tasks, constituting 45 per cent of the total. Within this

^{1.} In this paper, urban areas include all cities with populations above 40,000.

category, cars are by far the biggest single contributor, being responsible for around 88 per cent of urban transport carbon dioxide emissions in 1987-88.

| | , | | 1987-88 | | | | | | |
|------------------|---------------------------------------|---------|---------|--------------------|---|------------------------|--|--|--|
| : | Passenger kilometres (billions) | | Energy | Energy use (MJ/ | Rate of CO ₂ emissions (grams/ | Total CO, emissions | | | |
| Mode | 1984-85 | 1987-88 | (PJ) | pass km) | pass km) | tonnes) | | | |
| Road | | | | | | | | | |
| Car | 114.9 | 131.3 | 384 | 2.9 | 210 | 27.3 | | | |
| LCV ^a | 6.4 | 6.8 | 26 | 3.8 | 270 | 1.8 | | | |
| Bus | 4.2 | 4.5 | 7 | 1.6 | 120 | 0.5 | | | |
| Rail | 6.0 | 7.0 | 11 | 1.6 | 150 | 1.0 | | | |
| Total | 133.6 | 151.5 | 433 | •• | •• | 31.1 | | | |

TABLE 6.1 URBAN PASSENGER TRANSPORT, AUSTRALIA

a. Light commercial vehicles

b. Totals may not add, since they include all transport vehicle types, for example, ferries. These make very small contributions to total emissions.

.. not applicable. LCV Light commercial vehicle.

PJ Petajoule.

Note Energy and emission figures relate to the full fuel cycle.

Sources BTCE estimates based on: ABS (1987, 1990), BTCE Transport Indicators database, ABARE (1989), RIC (unpublished data), Adena & Montesin (1988), and personal communication with S. Eriksson (1991).

When used for journeys to work, the car will usually have a much worse energy intensity and carbon dioxide emission rate per passenger kilometre than when used for other private purposes. This follows from the especially low

average occupancy rate (about 1.2 per vehicle, compared with around 2.0 when used for private purposes) and from the poor energy efficiency resulting from driving in congested conditions. However, journeys to work account for only about 35 per cent of urban automobile kilometres. In other uses, the energy intensity of automobiles may not be very different from that of public transport, and its advantages in utility are usually considerable.

Electrified rail, in purely greenhouse terms, does not score as favourably as it might if energy security and urban pollution were at issue. This is because greenhouse gas emissions depend on the amount of primary fuel used in power generation. In Sydney, with black coal as the major primary fuel, the ratio of primary to end-use energy is about 3 to 1; in Melbourne, with lignite as the primary energy source, this ratio is about 3.8 to 1.

Recent information from the Electricity Commission of NSW suggests that modern alternating current traction systems (as opposed to the existing old direct current NSW State Rail Authority traction network) could reduce energy consumption by electric rail by some 40 per cent. It also appears that the new trains in use by the NSW State Rail Authority are much more fuel efficient than their predecessors.

railways would have significantly Commuter greater efficiencies during peak periods than the average efficiencies given in table 6.1. The high (one-way) loadings of trains at these times will give rail a substantial advantage in terms of greenhouse emissions for radial commuting to and from central business districts, and possibly other nodes of high employment density. (In peak-hours, emission intensity per passenger kilometre might average roughly a quarter of the corresponding for cars with the average journey-to-work figure However, public transport already commands a occupancy). large share of such journeys in Sydney and some other cities.

Buses also achieve high loading factors in peak hours and will therefore average substantially lower emissions per passenger kilometre at these times than cars with average occupancies.

During off-peak periods, low occupancy often implies high energy intensities per passenger kilometre for public transport. For the bus fleet, the major part of energy use (and consequently, the major part of carbon dioxide emission) occurs during off-peak periods.

The dominance of the private car in urban passenger transport can be seen from the following example. If patronage of the public transport system during peak periods (assumed to account for 60 per cent of the public transport task) were doubled, by drawing commuters away from private car use, total carbon dioxide emissions would be reduced by no more than could be achieved by an increase in the average fuel economy of the Australian car fleet of between 2 and 4 per cent.

While this is not to say that such a contribution from increased public transport patronage would not be useful in pursuing simultaneously, greenhouse, road congestion, and urban pollution objectives, it may be that only a small part of the urban passenger transport market is in fact contestable as between public transport and the car. A Melbourne survey (cited in Ministry of Transport 1986) found that only 8 per cent of car drivers (and 10 per cent of passengers) thought they had а car convenient alternative, while only 18 per cent of public transport users had a car available. Also, only a small percentage of urban passenger kilometres are car journeys to work to central areas, perhaps around 6 per cent, and this would be one area where public transport might offer an alternative.

Because of the high emission intensity of car use for journey to work, greenhouse objectives would be fostered by State Government initiatives focused on this area. Although across-the-board expansion of public transport

investment may be deterred by the magnitude of operating deficits, less costly measures could include:

- improving energy efficiency through traffic control (e.g. the Sydney Coordinated Adaptive Traffic System);
- promoting higher car occupancy through parking strategies and priority traffic lanes;
- encouraging rail travel through improved rail-bus interchange and secure park-and-ride facilities;
- improving bus transit times through priority traffic
 lanes; and
- restricting central business district car use through area entry, parking or road pricing strategies.

NON-URBAN PASSENGER TRANSPORT.

The private car is estimated to have been responsible for around 63 per cent of the 1987-88 non-urban passenger task carbon dioxide emissions (see table 6.2).

The least greenhouse emission-intensive mode is the bus. No doubt this reflects high load factors and better traffic conditions in comparison with the urban bus average. The non-urban bus task has increased substantially over the period from 1984-85 to 1987-88. At the same time passenger numbers on non-urban rail services have declined slightly.

Air transport is the most energy intensive mode. However, the long distances between major cities in Australia suggest limited scope for substitution between airlines on the one hand and the less emission-intensive modes, bus or rail, on the other. It appears that most inter-city passengers may be constrained by income or time towards one mode or the other. About 70 per cent of air travel between Sydney and Melbourne is for business purposes. There may be some potential for substituting teleconferencing for some inter-urban business travel, although studies have shown that face-to-face meetings remain preferable for negotiating and bargaining (Wilgand 1986).

| | | | 1987-88 | | | | | | |
|--------------------|---------------------------------------|---------|---------------|--------------------|--------------------------------------|------------------------|--|--|--|
| | Passenger kilometres (billions) | | Energy use | Energy use (MI/ | Rate of CO ₂ emissions | Total CO2 emissions | | | |
| Task | 1984-85 | 1987-88 | (PJ) | pass km) | pass km) | tonnes) | | | |
| Road | | | | | | | | | |
| Car | 57.7 | 55.9 | 143 | 2.6 | 180 | 10.2 | | | |
| LCVª | 6.1 | 5.2 | 19 | 3.6 | 250 | 1.3 | | | |
| Bus | 9.0 | 11.8 | 9 | 0.8 | 60 | 0.7 | | | |
| Rail | 2.4 | 2.3 | 4 | 1.6 | 120 | 0.3 | | | |
| Airline | 10.5 | 13.3 | 50 | 3.8 | 260 | 3.5 | | | |
| Total ^b | 87.7 | 90.3 | 232 | | •• | 16.5 | | | |

TABLE 6.2 NON-URBAN PASSENGER TRANSPORT, AUSTRALIA

a. Light commercial vehicles.

b. Totals may not add since they include all vehicle types, even light aircraft.

.. not applicable.

LCV Light commercial vehicle.

PJ Petajoule

Note Figures relate to the full fuel cycle.

Sources BTCE estimates based on: ABS (1987 & 1990), BTCE Transport Indicators database, ABARE (1989), RIC (1990), Adena, M.A. & Montesin, H.J. (1988).

For travel other than between major cities, there may also be limited substitution possibilities, for similar reasons. The flexibility of the private car is likely to be more important for rural and inter-provincial town travel.

Reducing non-urban speed limits for cars below 100 kilometres per hour in the interests of fuel economy is perhaps unlikely to gain favour in Australia.

Fuel economy from improved vehicle and aircraft design may be the only significant source of greenhouse gas emission abatement in the non-urban passenger area. There has in fact been considerable improvement, partially attributable to the purchase of newer, more fuel efficient aircraft. This trend will continue with the introduction of aircraft designed to meet noise regulations, which are also more energy efficient.

NON-URBAN FREIGHT.

Non-urban freight accounts for around 19 per cent of total transport emissions. The low emission intensity of Australia's bulk task is evident from table 6.3. Bulk rail is essentially specialised in moving minerals (iron ore and coal) and grains from inland to ports. Bulk shipping is concentrated on the long-haul movement of minerals and petroleum around the coast to processing and refining centres. Hence while sea transport of bulk commodities is the most energy and carbon dioxide emission efficient of all modes, substitution possibilities between coastal bulk shipping and bulk rail are limited by the origin and destination of the different bulk tasks.

The highest carbon dioxide emissions per tonne kilometre occur in air freight, which carries a specialised segment of the task. Non-bulk sea transport is comparable to nonbulk rail, and considerably better than trucks, in terms of emission efficiency. Much of the current non-bulk sea transport task involves Bass Strait crossings. Shipping may provide some scope for intermodal substitution in the case of cargo moving from Tasmania to, for example, Brisbane. Non-bulk freight carried on government railways compares favourably with road transport in energy intensities and carbon dioxide emission rates. Emission levels per tonne kilometre are around 58 per cent of those for freight carried on articulated trucks. The non-bulk

task is however carried predominantly by road vehicles, which account for over 70 per cent of tonne kilometres in this category.

| | | | 1987-88 | | | | | |
|----------|-----------------------------------|---------|--|-----------|-----------|---------|--|--|
| | Tonne kilometres (billions) | | Rate of CO ₂ Tota Energy Energy emissions emis | | | | | |
| | , | , | use | use (MJ/ | (grams/ | (mega | | |
| Mode 1 | 984-85 | 1987-88 | (PJ) | tonne km) | tonne km) | tonnes) | | |
| Bulk | | 1 | | | | | | |
| Rail | | | | | | | | |
| Govt | 30.6 | 37.1 | 15 | 0.4 | 29 | 1.1 | | |
| Private | 28.4 | 31.0 | 4 | 0.1 | 10 | 0.3 | | |
| Sea | 92.5 | 89.2 | 16 | 0.2 | 13 | 1.2 | | |
| Non-bulk | | | | | | | | |
| Rail | 14.3 | 13.1 | 11 | 0.8 | 60 | 0.8 | | |
| Sea | 5.1 | 4.9 | 3 | 0.7 | 51 | 0.3 | | |
| Air | 0.2 | 0.2 | 9 | 44.5 | 3 050 | 0.6 | | |
| | | | | | | | | |
| Road | | | | | | | | |
| LCV | 1.3 | 1.6 | . 32 | 20.2 | 1 443 | 2.3 | | |
| Rigid | 8.7 | 8.4 | 27 | 3.3 | 237 | 2.0 | | |
| Artic | 40.9 | 44.5 | 63 | 1.4 | 104 | 4.6 | | |
| Total | 222.0 | 230.0 | 181 | | •• | 13.3 | | |

TABLE 6.3 NON-URBAN FREIGHT TRANSPORT, AUSTRALIA

Not applicable.
LCV Light commercial vehicle.
Rigid Rigid truck.
PJ Petajoule.
Artic Articulated truck.
Govt Government operated.

Note Energy and emission figures relate to the full fuel cycle.

Sources ABS (1987 & 1990), ABARE (1989), RIC (1990), BTCE estimates.

The amount of freight transported by road has increased rapidly, approximately doubling within the last decade. This has prompted proposals to shift more long-haul rail for energy conservation (given the freight by differences in emission rates between trains and trucks), environmental and safety reasons (for example, Laird 1990). To the extent that there is contestability between modes in non-urban freight transport, it is probably largely limited to the inter-state segment of the non-bulk task, where there is some scope for rail to increase its Laird (1990) gives the level of inter-state share. freight on transport corridors as 13 billion tonnekilometres for road and as 6.6 billion tonne-kilometres for rail, for 1987-88. Competition between the two modes is likely to result in rail's increasing its share of a growing total inter-state task, rather than in anv decrease in the existing road task. The remaining 40 billion tonne-kilometres of the non-urban road freight task is unlikely to be contested by rail.

Major structural changes are required in rail if it is to offer the quality of service, transit times and rates necessary to win a larger share of the market. This will and in labour productivity improvements in require proposed National Rail Freight organisation. The Corporation, now under consideration by Federal and State Governments, would be a key element in this respect. Laird (1990) has argued that further fuel economy would be obtained in the rail network of south-eastern Australia if it is upgraded in terms of ruling grades, curvature and clearances.

The road system is a major public investment and there are sources of inefficiency in the way it is funded and managed, and in the way heavy vehicles are charged for using it. The Inter-State Commission (1990) proposal for a restructuring of charges, including a levy for the external costs of road use, and the recent Special Premier's Conference decision on uniform regulation will affect road use to some extent.

If the various reforms now under consideration slow down the expansion of road freight in favour of rail freight (and possibly encourage some revival in coastal liner shipping), there would be some abatement in the growth of greenhouse emissions. Equally there is scope for improved fuel economy within each mode. In the case of road freight the Federal Government is considering legislation extend the operating zones of B-Doubles. This to is expected to reduce fuel consumption per tonne kilometre on these routes, though the extent of the effect is the subject of controversy. Available estimates indicate increases in fuel economy ranging between 9 and 23 per cent. The Government is also, mainly for safety reasons, to require heavy vehicles to be fitted with speed limiters set at 100 kilometres per hour, and this should have a favourable effect on fuel economy.

URBAN FREIGHT.

Given the variation in the type of freight carried in the urban areas, from small high value products (including document carriage) to common bulk commodities, such as fuel, it appears unlikely that the task could be efficiently performed with a very different vehicle mix. Even if some substitution of articulated for rigid trucks were possible, this would have only a marginal impact on total transport emissions given the relatively small level of emissions from urban freight (see table 6.4)

| | | | | | 1987-88 | | |
|-------|-----------------------------------|---------|---------------|--------------------|---|-----|---|
| | Tonne kilometres (billions) | | Energy use | Energy use (MJ/ | Rate of CO ₂ emissions (grams/ | | Total CO ₂ emissions (mega |
| Mode | 1984-85 | 1987-88 | (PJ) | tonne km) | tonne | km) | tonnes) |
| Road | | | | | | | |
| LCV | 1.8 | 2.7 | 44 | 16.4 | 1 | 168 | 3.1 |
| Truck | | | | | | | |
| Rigid | 9.9 | 13.1 | 52 | 4.0 | | 290 | 3.8 |
| Artic | 11.8 | 15.2 | 24 | 1.6 | | 118 | 1.8 |
| Total | 23.4 | 31.0 | 120 | | | | 8.7 |

TABLE 6.4 URBAN FREIGHT TRANSPORT, AUSTRALIA

LCV Light commercial vehicles. PJ Petajoule.

. ~

5

~

٢.

:C,

~

,~~**`**

 $\widehat{}$

Artic Articulated vehicle. Not applicable.

..

Note Figures relate to the full fuel cycle.

Sources ABS (1987 & 1990), ABARE (1989), RIC (1990), BTCE estimates.

CHAPTER 7 SPATIAL EFFICIENCY

The long distances separating Australia's major cities, and the remoteness of natural resources from markets influence the transport intensity of the Australian economy. In urban areas, it is open to planners and land use authorities to incorporate energy and spatial efficiency considerations into future developments.

Though there are clearly many factors influencing car use, some recent research (Newman and Kenworthy 1989) has focused on the effect of low residential density (rather than central city job density) as the most important element underlying extensive use of private cars and high gasoline consumption. Collins and Taylor (1991), who also note a link between low residential density and heavy dependence on the private car, believe that low density suburbs are incompatible with good public transport.

In terms of residential density the major Australian cities are closer to North American cities than to European cities (see figure 7.1). Concentrating urban development upon corridors most readily served by public transport, and directing land use strategies towards intensifying residential densities may therefore tend to reduce growth in automobile-kilometres. However, Young (1991,153) considers that p for Melbourne, urban consolidation could 'realistically only cater for a small proportion of future metropolitan population increase.'



48

 $\widehat{}$

CHAPTER 8 THE EFFECT OF FUEL PRICES ON DEMAND FOR TRANSPORT FUELS

This paper does not attempt to review the many alternative policy instruments which Federal and State governments might use to influence greenhouse gas emissions from the transport sector. One instrument, sometimes discussed in the international debate, is a greenhouse tax on fuel consumption. The impact of such a tax would depend on the price elasticity of demand for transport fuel.

In 1990, Professor David Hensher of the Transport Research Centre at Macquarie University, was commissioned to produce a report (Hensher 1991) which examined, *inter alia*, long-term fuel price elasticities of demand, including the nature of the relationship between fuel price and overall demand.

Though there is some controversy over the magnitude of the long-term elasticity, the Hensher results appear to be the most plausible. Hensher applied a structural equation model to Sydney panel data to estimate a five year elasticity of demand for petrol in passenger cars of -0.66. This estimate comprises three elements: the change in the fleet size with respect to a change in fuel price (around -0.31); the change in vehicle kilometres travelled per vehicle with respect to changes in the fuel price (around -0.26); and the change in the average fleet fuel efficiency with respect to change in the fuel price (around -0.09). The elasticity is likely to be even larger over the longer term. It is possible the own-price elasticity demand for automotive gasoline could be as high as -1, in the very long term, when induced technology changes are taken into account.

Estimates of long-term price elasticities of demand for fuel (which Hensher derived using a reduced form model directly on ABARE data on national fuel consumption) were considerably lower, at around -0.25. Another study (Caddy 1989 cited in Hensher 1991) concluded that the own-price elasticity of demand for petrol was similar to that implied from the reduced form approach on the ABARE data. However, a problem in the dependent variable lag structures used may have caused the low elasticity estimate. When Hensher ran a structural equation model based on vehicle use, fleet size and fleet fuel efficiency on the ABARE data over the period 1976 to 1988, the estimated five-year elasticity was -0.641, of similar magnitude to the result he derived from the Sydney panel data.

Estimates of the short-run elasticity of demand for petrol with respect to a change in fuel price are somewhat lower, since over the short term fleet size and fleet fuel efficiency are largely fixed. Short-run elasticities reflect primarily any changes in vehicle utilisation that occur in response to a change in fuel price. For Australia, estimates of the short-run elasticity range from -0.11 to -0.38.

Hensher also examined the demand for automotive diesel oil, predominantly used as a fuel for trucks and off-road uses. Hensher's estimate of the five year elasticity was -0.55, slightly less than the elasticity for petrol. An assessment for aviation turbine fuel, carried out as part of the same study, concluded that the one year own-price elasticity of demand for domestic aviation fuel was around -0.12. A similar elasticity for international aviation was estimated at around -0.18.

CHAPTER 9 FACTORS BEARING ON THE COST OF GREENHOUSE MITIGATION IN TRANSPORT

EXISTING ESTIMATES OF COSTS AND BENEFITS

At least four Australian studies have attempted а quantitative analysis of this subject. They do not differ significantly in defining the size of the problem: transport energy consumption and carbon dioxide emissions are likely to grow by about 40 per cent over the 17 years to 2005 under a policy-free scenario, so that achieving an actual reduction of 20 per cent by that year is а demanding target. (Of course, if the marginal cost of reducing emissions proved to be greater in transport than in other sectors of the economy, then a less demanding target could be envisaged, but the relative marginal costs remain unknown).

Marks et al. (1989) assessed the cost of a 20 per cent reduction in carbon dioxide emissions from road transport. One of their options included a mix of two policies: a progressive improvement in automobile fuel economy which would ultimately raise average vehicle production costs by 25 per cent, and a progressive increase in fuel taxation, raising fuel prices by between 62 and 123 per cent by 2005. They concluded this would reduce Australia's gross domestic product growth rate by 0.029 percentage points per year, and that the present value of the foregone gross domestic product over 17 years would be about \$10 billion (at a 5 per cent discount rate).

Greene (1990) concluded that a 1 per cent reduction in transport greenhouse emissions from 1988 levels could be achieved by 2005 through a combination of strategies (including improved vehicle fuel economy, better road cost recovery and switches towards rail freight and public transport). These measures were projected to yield annual savings to the economy of \$4.1 billion by 2005.

Deni Greene Consulting Services and NIEIR (1990) estimated that transport greenhouse emissions could be reduced by 18 per cent by 2005, involving additionally the introduction of alternative fuels and the downsizing of the average car. This was expected to result in annual savings of \$1.6 billion by 2005.

NIEIR (1990b) suggested that a hypothetical target of reducing transport carbon dioxide emissions by 20 per cent approached through combinations of could be improved vehicle fuel economy, downsizing of cars, use of compressed natural gas and ethanol as transport fuels and/or some modal shift in favour of rail freight and urban public transport. The Institute argued that the full target would be achievable at rising marginal costs. It estimated that, not discounted, savings would exceed costs over the 17 years up to 2005; costs (mainly investment outlays) would precede savings and put stress on the macro-economy. The present value (discounted at 8 per cent) of the impact on private consumption over the whole 17 years was likely to be a net loss of between \$0.4 and \$0.7 billion, but on more favourable assumptions could be positive.

It is possible to point to various errors in these studies and, more frequently, to inadequately supported assertions and neglected complications. The Bureau's position is that all of these results should be regarded as premature. There are too many gaps in our present knowledge of the outlook for vehicle engineering and production economics, the behavioural response of consumers and firms, and the implications of other externalities and distortions within the transport economy. However, it will hopefully be useful to review some of these outstanding issues.

AUTOMOBILE FUEL ECONOMY AND UTILISATION

Both the scope for, and the manufacturing costs of, improvements in the energy efficiency of automobile design are disputed among engineers (see chapter 4). The potential for such changes in Australia is the subject of a consultancy study by Nelson English, Loxton and Andrews (NELA), sponsored by the Federal and Victorian Governments.

The dynamics through which improvements in new vehicle technology would influence the average fuel economy of the car fleet have been examined by the Federal Office of Road Safety (1991) and are also to be examined in the NELA study. The choice and setting of alternative policy instruments -new vehicle design regulation, sales taxes, fuel tax, re-registration requirements - would influence the speed and the cost and the equity of change.

Measures to advance the scrappage of existing cars through re-registration regulations and charges involve greater capital costs to the economy than those that influence the mix of new vehicles and rely on 'natural wastage' to change the fleet characteristics.

Measures which raise the price of transport fuels would in time influence technology choice by new car suppliers and new car purchasers (primarily companies and higher income groups). They would more immediately reduce car utilisation (kilometres driven) by lower income groups, whose foregone travel must be counted as an economic cost and whose choice of technology is limited.

Measures which lead on average to a 'downsizing' of the automobile mix might seem low-cost options to noneconomists, by virtue of reducing consumer outlays on both vehicles and fuel while permitting the quantity of travel to be maintained. To economists, downsizing would imply that previously revealed wants for power and interior space become undersatisfied. The social cost of such a shift could be examined in the context of hedonic market

share models - reviewed by Greene and Liu (1988) - and applied in the analysis by Difiglio et al.

However, Greene and Liu admit their approach could be biased towards showing too great a loss of consumer surplus if consumer preferences were to adapt to new circumstances. (If there were an element of irrational machismo in the previously expressed wants, this seems a likely outcome). Moreover, there is possibly a sizeable element of market failure underlying the pre-existing mix of new car purchases, in that the Fringe Benefits Tax has not induced any appreciable cashing out of company cars. The possibility of increased road trauma associated with smaller vehicles is another factor to be considered.

If a substantial (and rapid) reduction of carbon dioxide emissions is in fact required by 2005 from the transport sector, it may be impossible to avoid reduction in motor car utilisation. This is the dominating transport mode, and the target date of 2005 is too close for large changes in vehicle technology and/or vehicle size and power to penetrate throughout the car fleet. Motor car utilisation aggregate could, in of course, be reduced through increased fuel taxes. However, there are other (nongreenhouse) reasons for targeting constraints on motor car use towards particular urban problems through urban traffic management or road pricing innovations.

 $\hat{()}$

ALTERNATIVE TRANSPORT FUELS

Although many alternative transport fuels offering lower greenhouse emissions have been discussed (see chapter 5), they appear to be either limited in range of application or to be high-cost pending some significant technological breakthrough.

The substitution of diesel fuel for petrol in new cars would involve a direct cost penalty associated with the more expensive diesel engine. There would also be a negative externality from particulate emissions. There is increasing medical evidence about the adverse effects of such emissions from conventional diesel fuel.

The substitution of compressed natural gas or liquid natural gas for diesel fuel in commercial road transport (trucks and buses) appears to be low-cost in dedicated short-haul operations, and also delivers a positive external benefit in the context of urban air pollution.

Wider penetration of natural gas may not be a viable prospect. If it is to be advanced it would require significant capital outlays in providing an infrastructure of gas distribution and compression on long-distance routes. This issue is being examined under an Energy Research and Development Corporation research grant.

TRANSPORT SYSTEM DEVELOPMENTS

Ì

The area of significant intermodal contestability in freight would seem to be the inter-city segment of the non-bulk task (see chapter 6). In the next decade a greater part of the growth in this market can be expected to go to rail in response to the proposal to develop the National Rail Freight Corporation and the introduction of full road cost recovery for heavy road vehicles. The National Rail Freight Corporation would involve capital outlays, but these are predicated to generate sufficient return profitability in and in other positive externalities (for example safety road and road construction expenditures) to justify themselves without reference to the favourable side-effect on greenhouse (The BTCE has estimated the benefit cost ratio for gases. the National Rail Freight Corporation at 2.4, including quantified externalities but excluding consumer surplus). Similarly, the measures proposed for charging and regulating road transport would appear to be justified by improved allocative efficiency and/or positive externalities other than greenhouse effects.

The urban use of the motor car, a dominating source of carbon dioxide emissions, can be influenced by a variety

of measures (see chapter 6). Many of these measures would involve little capital outlay and would confer positive non-greenhouse external benefits. The potential for such benefits reflects the frequent existence of market failure in urban traffic and road systems. Congested urban roads are not usually priced to users. Parking access is frequently underpriced. Developers of both residential and commercial properties are frequently undercharged for the extra demands which their developments place on the urban road and public transport infrastructures.

Substantial new investments in urban public transport raise questions which necessarily have to be would analysed on a case-by-case basis. Greenhouse implications per se are very unlikely to dominate such decisions. As an interim approach, the greenhouse issue could be brought into cost-benefit analysis of urban public transport projects by shadow-pricing the energy consumption impact the basis of its contribution to achieving the on Government's emission reduction target. (Ideally, it might be more efficient if eventually all externalities, including greenhouse, were incorporated into direct measures, but urban transport systems, pricing in Australia and overseas, are a long way from such an ideal.)

ر مر

TRANSPORT AND AUSTRALIAN INDUSTRIES

Consumption of fossil fuels by international carriers moving cargoes and passengers to and from Australia is very large. Any international measures tending to restrict or raise the costs of international shipping would have significant implications for some industries, such as those exporting low-value bulk commodities over long distances (eg iron ore, mineral sands, alumina and coal). At the same time such developments per se would give some additional incentive towards further processing of such commodities before export.

Measures which raised costs in international aviation would have an impact on the development of inward tourism

as well as on the welfare of Australians wishing to travel overseas.

Many of the greenhouse strategies discussed previously would have negligible effects on domestic freight costs to Australian industries. In so far as the pursuit of a demanding greenhouse mitigation target in the transport sector did raise domestic freight costs, the implications parallel those of increased energy costs to industry. In principle the international competitiveness of industries which are both trade-exposed and relatively transportintensive would be adversely affected. However, any such impact would be greatly reduced by the achievement of international reciprocity. That is, it is desirable that similar measures should be taken by other countries with competing industries. There are some major industries where freight hauls for some domestic high-bulk industrial raw materials are considerably longer than in competing countries (eg steel making and aluminium smelters) and it could be argued that reciprocity would not fully redress However, these industries tend to use the balance here. is coastal bulk which (i) shipping a relatively "greenhouse-friendly" transport mode and (ii) is somewhat anomalously subject to excise on bunkers, the removal of which might offset any impact of greenhouse strategies on freight costs.

Greenhouse strategies may have significant impacts on the Australian motor industry, either favourable or Measures which advanced the car scrappage unfavourable. rate would apparently benefit suppliers of new cars (at some cost to the rest of the economy). Measures which required an increase in retooling outlays by the motor industry might tend to reduce its international competitiveness, since such outlays would have to be amortised over relatively short production runs.

The impact of regulatory measures on motor industry competitiveness would be more severe if it were not matched by parallel developments affecting vehicle design in the major automobile manufacturing countries.

MODELLING IMPACTS ON NATIONAL ECONOMIC WELFARE

Attempts at quantitative modelling of the welfare costs or benefits of a strategy for reducing transport carbon dioxide emissions encounter a number of analytical difficulties.

First, the substitution of capital for fossil energy will have a fairly central role. Capital outlays will be followed by energy use savings. Consequently a careful intertemporal analysis is needed. Also, in a context where the capital intensity of the economy is changed, impacts on national welfare cannot be inferred from projected changes in 'gross domestic product'.

Second, where the strategy examined seeks to reduce the consumption of energy by households and motorists, which will affect the utility derived from comfort and travel, it seems inappropriate to use the national accounting concept of private consumption as a measure of household welfare. Such welfare should be related to the quantity and quality of travel, rather than to the consumption of fuel in situations where consumption efficiency would shift.

Third, examination of the impact of transport policies on economic welfare needs to take account of market and intervention failure (or externalities) in the transport system, especially those concerned with urban congestion, urban pollution and undercharging for public infrastructure provision.

Fourth, the use of fossil energy in the production of vehicles and infrastructures needs to be taken into account. More generally, energy inputs need to be tracked through a capital matrix, as well as through intermediate product flows.

Fifth, there is a serious econometric problem. Estimates of the behavioural parameters, required to simulate policy

shifts in the transport sector (and elsewhere) are in some cases lacking, while in other cases there is a superabundance of conflicting results. Error margins on parameter values are large, and typically, in large economic models, interact with one another to imply proportionately larger errors around the model's predictions.

APPENDIX I CONVERSION OF FUEL CONSUMPTION DATA TO GREENHOUSE GAS EMISSIONS

Liquid fuel consumption can be converted to its energy equivalent in petajoules, using the conversion factors indicated in table I.1.

| Fuel type | Megajoules/litre | | |
|-------------------------------|------------------|--|--|
| Liquid petroleum gas (mixture |) 25.7 | | |
| Aviation Gasoline | 33.0 | | |
| Automotive gasoline | 34.2 | | |
| Aviation Turbine | 36.8 | | |
| Automotive diesel | 38.6 | | |
| Industrial diesel fuel | 39.6 | | |
| Fuel oil (low sulphur) | 39.7 | | |

TABLE I.1 ENERGY CONTENT OF FUELS

Source ABARE (1989).

For electricity, the total energy consumed to produce a unit of electric power needs to be derived. Losses due to generation and transmission are taken into account by the conversion efficiencies in table I.2.

| | Conversi (joules joule | Conversion factor (joules input per joule output) | | | |
|-------|------------------------------|---|--|--|--|
| State | 1984-85 | 1987-88 | | | |
| NSW | 2.885 | 2.868 | | | |
| Vic | 4.068 | 3.865 | | | |
| Qld | 3.245 | 2.999 | | | |
| SA | 3.307 | 3.119 | | | |

TABLE I.2 CONVERSION EFFICIENCY OF ELECTRICAL POWER SOURCES^a

a. Weighted average for coal, oil and natural gas used to produce electricity.

Note 1 kilowatt hour = 3.6 megajoules.

Source ABARE (1989).

Technical data indicating the carbon dioxide emissions per petajoule of each fuel, for each vehicle type, (see table I.3) then allow the calculation of carbon emissions from transport vehicles.

Calculations of emissions from transport fuels depend on:

the type of fuel and the nature of the vehicle;

the carbon content of the fuel, and the level of combustion of the carbon when the fuel is used in a vehicle engine;

whether the full fuel cycle is included;

treatment given to carbon monoxide, methane, nitrous oxide, chlorofluorocarbons, ozone and other trace gases; and

the time period being considered - given variation in the active lives of different emissions.

62

| Vehicle type | | | | | | | | | |
|-----------------|--------|--------|-------------------|----------|------|------|-------|-------|-------------|
| | Petrol | Diesel | LPG | Electric | IDF | Coal | Avgas | Avtur | Fuel oil |
| | | | | | | | | | |
| Road | 71.2 | 73.8 | 65.0 | •• | •• | •• | •• | •• | |
| Rail | | | | | | | | | |
| Australia | | 73.8 | • • | •• | 70.0 | 94.2 | • • | | |
| NSW | •• | | | 265 | | | | | |
| Vic | | | | 414 | | | | | |
| Qld | | | • • | 287 | | | | | |
| SA | | | •• | 253 | | | •• | ••• | |
| Air | | | | • | | | 71.2 | 70.8 | |
| Sea | | 73.8 | 64.0 ^b | | 70.0 | 94.2 | | | 78.0 |

`)

>

)

-- - --

)

·)

TABLE I.3 CARBON DIOXIDE EMISSIONS (FULL COMBUSTION) BY VEHICLE TYPE (kilotonnes of carbon dioxide per petajoule)

ı.

Ŷ

a. Fuel types are automotive gasoline (petrol), automotive diesel (diesel), liquid petroleum gas (LPG), electricity, industrial diesel fuel (IDF), coal, aviation gasoline (avgas), aviation turbine fuel (avtur) and fuel oil.

b. Natural gas.

.. not applicable.

)

)

)

•)

Source Deluchi et al. (1988), OECD (1989).

The factors in table I.3 assume all the carbon in the fuel is totally combusted to carbon dioxide. They give only direct emissions from the vehicle (that is, they do not include the full fuel cycle). However, in the case of electricity, the emission rate relates to the coal burned to produce the electric traction.

Also, the factors in the table are based on crude oil with a carbon content more characteristic of overseas (rather than the lighter Australian) oils. They may therefore slightly overstate current Australian transport emissions (by around 3 per cent). However Australia-specific conversion factors cannot be stated with certainty due to the variation in carbon content of refinery feedstocks from different sources.

When comparing delivered energy forms (such as alternative fuels in vehicles) the full fuel cycle should be considered. Emissions from the full fuel cycle include those generated in extraction, transport and refining of the primary fuel, and distribution of the end product. The emission estimates derived from table I.3 were adjusted by adding 10 per cent (on average) for liquid fuels and 1 per cent for coal.

Chlorofluorocarbons are not included in the estimates in this paper, since there are no reliable estimates of chlorofluorocarbon release from automobile airconditioning refrigerated and transport. Chlorofluorocarbons could contribute as much as 15 per cent of Australian greenhouse gas emissions (in carbon dioxide equivalent terms). Australia has adopted the restrictions of the Montreal Protocol (1987) to limit production of most of these gases during the 1990s (Ozone Protection Act 1989).

Tropospheric ozone also is not included, since while ozone is a greenhouse gas of concern to the northern hemisphere, southern hemisphere emissions are considered negligible at present (Pearman 1989). For this reason, carbon monoxide emissions were not dealt with separately from their

potential conversion to carbon dioxide, even though the presence of carbon monoxide contributes to ozone pollution.

For road vehicles, liquid petroleum gas generates less carbon dioxide emissions (per unit of energy) than petrol and diesel fuel. However there is little scope for substitution of liquid petroleum gas for other fuels given its limited availability. For the transport sector petrol and aviation gasoline are the major producers of carbon monoxide and liquid petroleum gas is the major source of methane.

In the case of rail, carbon dioxide emissions due to electric trains are high (per unit of energy end-use) since the electricity generated to power the trains is primarily coal based and there are substantial losses during transmission. In Victoria, where brown coal is used for electricity generation, emissions per unit of electrical energy are particularly high.

Emissions may be considered in more detail by deriving carbon monoxide, methane, and nitrous oxide emissions due to vehicles and subtracting the uncombusted carbon from the total combustion estimates. This actual emission spectrum for the transport sector is illustrated in table 3 for the year 1987-88.

An approximate measure of the total greenhouse gas impact can then be obtained by converting other greenhouse gases to equivalent carbon dioxide emissions by applying conversion factors reflecting the radiative warming effect of each gas. The conversion factors used to estimate the carbon dioxide equivalents presented in this paper were based on molecular relationships given by Pearman (1989). By weight, these are:

for carbon monoxide - grams of CO x 1.57, for methane - grams of CH_4 x 16.5, and for nitrous oxide - grams of N_2O x 350.
In considering the importance of emissions of greenhouse gases in causing global warming, it is necessary to consider the lifetime of the gas in the atmosphere. A gas that reacts immediately it is released to degrade or remove itself from the atmosphere is far less important than a gas that has a long residence in the atmosphere (Pearman 1989). Pearman's estimates are based on the relative contribution to global warming that each gas would make in the long term (more than 100 years).

Methane has an atmospheric life of around 10 years while emissions of carbon dioxide, chlorofluorocarbon and nitrous oxide reside in the atmosphere for more than 60 years. Carbon dioxide is emitted in the greatest quantities and is by far the most significant greenhouse gas.

The analysis in this paper concentrates on carbon dioxide emissions and adopts emission estimates based on the assumption of complete combustion of carbon to carbon dioxide, rather than to a mix of carbon gases, principally carbon monoxide and carbon dioxide. Emissions of other greenhouse gases, principally methane and nitrous oxide, contribute very little to total transport greenhouse gas emissions. Calculating greenhouse gas emissions on this basis (ie as carbon dioxide emissions only) results in a figure only 3 per cent less than would be obtained by summing the individual contribution to radiative forcing of all the gases produced by combustion.

The figure of three per cent depends on the current pattern of fuel use in the transport sector, which relies on petroleum-based fuels. Where alternative fuels are being considered on a full fuel cycle basis, the other gases (methane and nitrous oxide) may be more prominent (for example, fugitive losses of methane during distribution of compressed natural gas).

APPENDIX II DATA SOURCES

The figures in both the tables and the text of the paper should be regarded as approximate since the data used to construct these tables have been estimated from varying sources, some of which were incomplete. The tables do not include separate entries for all transport vehicle types; with motorcycles, urban ferries and general aviation, for example, only appearing in totals. These make very small contributions (collectively less than 2 per cent) to total transport emissions.

The data on which the analysis is based were derived from many sources. These include the 1987 and 1990 ABS SMVU and other ABS publications, annual reports of transport authorities, government departments and research bureaux, the BTCE Transport Indicators database, NELA (1988), Adena and Montesin (1988) and personal communication with S. Eriksson (1991).

For analysis of greenhouse gas emissions from the transport sector, fuel consumption data were converted to estimates of greenhouse emissions, using conversion factors mainly from OECD (1989).

Greenhouse gas emissions were based on the emission rates of the different greenhouse gases per unit of fuel, for different major transport vehicle types.

ROAD TRANSPORT

Data for cars, motorcycles, utilities, rigid trucks and articulated trucks were based on the ABS SMVU (1987, 1990), which provides a detailed breakdown of vehicles by vehicle type, size, fuel used, and area of operation. Calculations of passenger kilometres for cars were based on kilometres travelled (from the ABS SMVU), multiplied by average vehicle occupancies reported in Adena and Montesin (1988), and supplied by S. Eriksson (1991) in personal communication.

In determining passenger kilometres for utilities (and trucks) the SMVU (ABS 1987) was used. It was assumed that vehicles involved in business journeys should not be considered, since here freight movement (and not passenger movement) was likely to be the prime function of the journey.

RAIL

Task totals for rail have been largely estimated from the RIC report (RIC 1990).

Tonne kilometres were derived from 1986-87 RIC data (RIC 1990), and rail authority tonnage and tonne kilometre data provided in annual reports.

Passenger kilometre data were derived from RIC (1990) and rail authority data on passenger numbers and train kilometres for 1986-87.

Information on fuel consumption was based on data provided in railway authorities annual reports, Electricity Supply Association of Australia annual reports, and House of Standing Committee On Representatives Transport, Communications And Infrastructure paper (1989). The methodology is similar to that used in both Nelson English et al. (1988) and BTE(1980a) in that data are disaggregated using the ratio of train kilometres performed for each task to total train kilometres, adjusted for different average energy requirements for passenger and freight trains. One variation was that the proportion of diesel to non-diesel trains in urban passenger transport was calculated separately for each state.

The division of energy requirements for bulk and non-bulk freight was based on engineering rolling resistance formulae.

Where data for train kilometres in electrified areas were unavailable, the estimates in Nelson English et al. (1988) were used.

SEA

Coastal tonne kilometres were based on information provided in the annual publications of Coastal Freight Australia for 1987-88 and 1984-85 (DoTC 1986 and 1989). These data were subdivided by vessel type and deadweight size based on information about each particular ship in Australian Shipping for 1985 and 1988 (DoTC 1985 and 1988).

Fuel consumption for coastal vessels (except urban ferries) was based on estimates of daily fuel consumption for individual ships. Estimates of fuel consumption for each vessel type were made using regression equations derived from a sample of vessel fuel consumption data provided in Lloyd's Register of Ships 1991.

AIR

The analyses of domestic air transport were based on the data and methodology provided in BTE (1980a) and Nelson English et al (1988), updated using the BTCE Transport Indicators database. Additional work was done to partition freight and passenger tasks.

APPENDIX III INTERNATIONAL TRANSPORT

In this paper the emphasis has been on domestic transport. Since benefits from international transport services accrue to many countries, emissions generated from these services are clearly a shared responsibility and cannot readily be assigned to any particular trading nation.

However, because of its remoteness and dependence on commodity exports, the Australian economy is likely to be particularly sensitive to any measures which might raise the cost of sea freight. Equally, rising international aviation costs would be a matter of concern to Australian households and the tourism industry. Some assessment should therefore be made of Australia's international task and its greenhouse impact.

ENERGY CONSUMPTION BY INTERNATIONAL TRANSPORT

Estimates of aggregate energy consumption for all international transport servicing Australian trade and overseas travel are shown in table III.1. In 1987-88, when domestic transport directly Australian consumed an estimated 880 petajoules energy¹, of international transport services to and from Australia consumed something of the order of 470 petajoules of energy; that is, just over half as large as the domestic consumption.

For transport to and from Australia, over 90 per cent of the fuel used by international sea freight and over 60 per cent of fuel used by international airlines was purchased outside Australia.

1. Primary energy consumption, and not full fuel cycle.

TABLE III.1 ESTIMATED PRIMARY ENERGY CONSUMPTION IN AUSTRALIA'S INTERNATIONAL TRANSPORT TASK, 1987-88

| Mode | | | | | | Fuel consumption (petajoules) | | | |
|------------|-------------------|-----|-----|----|---|----------------------------------|------|------------|--|
| Air Sea | | | | | | | | 130 340 | |
| Total | | | | | x | | | 470 | |
| Note | Figures basis. | are | not | on | a | full | fuel | cycle | |

Source BTCE estimates.

INTERNATIONAL PASSENGER AND FREIGHT TASKS

Emission levels for the international passenger and freight tasks are hard to estimate because of the difficulty in determining the amount of fuel consumed for the international task. Both aircraft and ships will frequently refuel at international points en route to Australia, although with aircraft the choice of refuelling points is somewhat restricted by the loss in payload imposed by the carriage of excess fuel. There has been no apportionment of the energy consumed between source and destination countries.

For 1987-88, the international maritime task involving Australia has been estimated (by the BTCE) as 3540 billion tonne kilometres and 320 million passenger kilometres (largely holiday cruises). International shipping tonne kilometres were calculated using the methodology given in BTE Occasional Paper 37 (BTE 1980a), where the tonnages imported and exported by trade areas (ABS 1988) are multiplied by the distances to the relevant trade areas (Caney 1981).

The fuel requirement for this extensive maritime task is substantial, and has been estimated (by the BTCE) at

roughly 340 petajoules for 1987-88. Less than ten per cent of this fuel requirement was purchased in Australia.

Maritime energy consumption was calculated by estimating the fuel efficiency of the international shipping fleet. For 1987, the average fuel consumption of the Australian flag fleet is given by the Australian National Maritime Association, (in tonnes of fuel oil per day per thousand tonnes deadweight) as 2.97 for general cargo ships, 0.75 for tankers and 0.52 for dry bulk ships. Total fuel used may be estimated from these consumption rates by making assumptions regarding average ship speeds and load factors.

The international air passenger task involving Australia has been estimated (by the BTCE) to be around 47.4 billion passenger kilometres for 1987-88. There were approximately 130 petajoules of energy consumed during 1987-88 in accomplishing Australia's total international air task (which included around 2.1 billion tonne kilometres of air freight). Over 60 per cent of the fuel used was uplifted by aircraft while overseas.

Estimates of passenger kilometres for international air transport (and similarly for air freight) were derived by multiplying passenger flows by route distances for representative locations provided by DoTC. Fuel consumption was estimated by relating fuel consumed by Qantas (per passenger kilometre) to the transport task performed by all international operators to and from Australia.

Australia's international freight task greatly exceeds the domestic freight task (as measured in tonne kilometres), due to the very long routes and large bulk tonnages involved with Australian trade. The preceding fuel consumption estimate for 1987-88 implies emission levels of about 9 megatonnes of carbon dioxide for international air transport and about 26 megatonnes of carbon dioxide for international shipping.

REFERENCES

Abbreviations

| ABARE | Australian Bureau of Agricultural Resource | | | | | | | | |
|-------|--|--|--|--|--|--|--|--|--|
| | Economics | | | | | | | | |
| ABS | Australian Bureau of Statistics | | | | | | | | |
| AMEC | Australian Mineral and Energy Council | | | | | | | | |
| BTCE | Bureau of Transport and Communications Economics | | | | | | | | |
| BTE | Bureau of Transport Economics | | | | | | | | |
| Dotc | Department of Transport and Communications | | | | | | | | |
| | Economics | | | | | | | | |
| DPIE | Department of Primary Industry and Energy | | | | | | | | |
| IEA | International Energy Agency | | | | | | | | |
| NELA | Nelson English, Loxton and Andrews | | | | | | | | |
| NIEIR | National Institute of Economics and Industry | | | | | | | | |
| | Research | | | | | | | | |
| NRMA | National Roads and Motorists Association | | | | | | | | |
| OECD | Organisation for Economic Cooperation and | | | | | | | | |
| | Development | | | | | | | | |
| RIC | Railway Industry Council | | | | | | | | |
| SMVU | Survey of Motor Vehicle Use | | | | | | | | |
| WRI | World Resources Institute | | | | | | | | |

ABARE 1989, Projections of Energy Demand and Supply Australia 1989-90 to 1999-2000, ABARE, Canberra.

- 1991, Projections of Energy Demand and Supply Australia 1990-91 to 2004-2005, AGPS, Canberra.

ABS 1987, Survey of Motor Vehicle Use Australia 30 September 1985, Cat No. 9208.0, ABS Canberra.

ABS 1988, Shipping and Cargo Australia 1987-88, Cat No. 9206.0, ABS 1988.

ABS 1990, Survey of Motor Vehicle Use Australia 30 September 1988, Cat No. 9208.0, ABS Canberra.

Adena, M.A. & Montesin, H.J. 1988, Day-to-day Travel in Australia 1985-86, Report CR 69, Federal Office of Road Safety, Canberra.

AMEC 1990, Energy and the Greenhouse Effect, Department of Primary Industries and Energy, Canberra.

BTE 1980a, Consumption of Transport Energy in Australia 1975-76, OP 37, AGPS, Canberra.

BTE 1980b, Regression Analysis of Ship Characteristics, OP 38, AGPS, Canberra.

Bussman W.V. 1989, Potential Gains in Fuel Economy, A Statistical Analysis of Technologies Embodied in Model Year 1988 and 1989 cars, Roneo.

Caney, R.W. & Reynolds, J.E. 1981, Reeds Marine Distance Tables, Thomas Reed Publications Ltd., London.

Collins, A.G. & Taylor W.J. 1991, Transport Strategies for Melbourne's Growth Corridors, The Institution of Engineers 1991 National Transport Conference, National Conference Publication No. 91/4, The Institution of Engineers, Canberra.

De Fraga, C. 1991,'Natural Gas May Power Road and Public Transport in Future', Age, 15 Jan., pp. 85.

DeLuchi, M.A., Johnston, R.A. & Sperling, D. 1988, 'Transportation Fuels and the Greenhouse Effect'. Transportation Research Record, 1175, pp. 33-44.

DeLuchi, M.A., Wang, Q. & Sperling, D. 1989, 'Electric Vehicles: Performance, Life-cycle Costs, Emissions, and Recharging Requirements', *Transportation Research A*, vol. 23A, no. 3, pp. 255-278. Deni Greene Consulting Services and NIEIR 1990, Reducing greenhouse gases, Options for Australia, a report prepared for Australian and New Zealand Environment Council, Australian and New Zealand Environment Council, Canberra.

DPIE 1990, 1990 Australian Fuel Consumption Guide for New Car Buyers - A Comparison of New Car Fuel Consumption, Canberra.

Department of Prime Minister and Cabinet 1990, Ecologically Sustainable Development, A Commonwealth Discussion Paper, AGPS, Canberra.

DoTC 1985, Australian Shipping 1985, AGPS, Canberra.

DoTC 1986, Sea Transport Statistics, Trade and Cargo Review, 1984-85, DoTC, Canberra.

DoTC 1988, Australian Shipping 1988, AGPS, Canberra.

DoTC 1989, Sea Transport Statistics, Trade and Cargo Review, 1987-88, DoTC, Canberra.

Difiglio, C., Duleep, K.G. & Greene D.L. 1989, 'Cost Effectiveness of Future Fuel Economy Developments', The Energy Journal, January (revised August 1989).

Falvey R.E., Frank J., Fried H.O. & Babunovic M. 1986 'Fuel Economy Standards and Automobile Prices', *Journal of Transport Economics and Policy*, January 1986, pp. 31-45.

Federal Chamber of Automotive Industries 1990, An Automotive Policy for an Improved Environment, paper presented to the 1990 Invitation Symposium of the Australian Academy of Technological Sciences and Engineering, Melbourne.

Federal Office of Road Safety 1991, A Model for the Prediction of Carbon Dioxide Emissions due to Cars and Stationwagons, DoTC, Canberra.

Geisler, O.J., 1989, Marine Propulsion Systems - Research for Efficiency, Marine Engineering Now and in the Future, Marine Management (Holdings).

Gosden, D.F. 1990, Electric Vehicles and the Greenhouse Effect, SUEE/EVRF 020990, University of Sydney.

Greene D.L. & Liu, J. 1988, 'Automotive Fuel Economy Improvements and Consumers' Surplus', Transportation Research A, vol. 22A, no. 3, pp. 203-218.

Greene, D. 1990, A Greenhouse Energy Strategy, Sustainable Energy Development for Australia, a report prepared for the Department of the Arts, Sport, the Environment, Tourism and Territories, Canberra.

Hensher 1991, Demand Forecasts and Demand Elasticities for Australian Transport Fuel, Occasional Paper 103, BTCE, Canberra.

House of Representatives Standing Committee on Transport, Communications and Infrastructure 1989, Rail: Five Systems - One Solution, The Efficiency of Australian National's East - West Operations, AGPS, Canberra.

IEA 1990, Substitute Fuels for Road Transport, OECD, Paris.

Inter-State Commission 1990, Road User Charges and Vehicle Registration: a National Scheme, AGPS, Canberra.

Laird, P.G. 1990, 'The Potential for Liquid Fuel Savings in Australian Land Freight Transport', in Swaine, D.J. (ed) *Greenhouse and Energy*, CSIRO, Australia.

Le Cornu, J.K. 1990, 'Greenhouse Gas Emissions from the Production and Use of Alternative Transport Fuels' in Swaine. D.J (ed) *Greenhouse and Energy*, CSIRO, Australia. Lloyd's Register of Ships 1991, Lloyd's of London press, Colchester.

Marks, Swan, Dixon, Johnson, McLennan, Schedde 1989, The Feasibility and Implications for Australia of the Adoption of the Toronto Proposal for Carbon Dioxide Emissions, CRA Ltd, Melbourne.

McTague, J.P. 1990, The Customer, the Environment and the Gasoline Powered Vehicle, paper presented to the 1990 Invitation Symposium of the Australian Academy of Technological Sciences and Engineering, Melbourne.

Mellde, R.W., Maasing I.M. & Johansson T.B. 1989, 'Advanced Automobile Engines for Fuel Economy, Low Emissions and Multi Fuel Capability', Annual Review of Energy, vol. 14, pp. 425-44.

Ministry of Transport 1986, Strategy Development Final Report, Metropolitan Arterial Road Access Study, Ministry of Transport, Melbourne.

NIEIR 1990a, The Energy Working Party: Part Two, NIEIR, Melbourne.

NIEIR 1990b, Implications of Adopting Carbon Dioxide Emission Reduction Targets in the Transport Sector, Report to the Department of Transport and Communications, Canberra.

NELA 1988, Consumption of Transport Energy in Australia 1984-85, National Energy Research, Development and Demonstration Program, Consultancy Report No 24, Canberra.

Newman, P. and Kenworthy, J. 1989, Cities and Automobile Dependence: an International Sourcebook, Gower, Aldershot UK.

NRMA 1989, 'The Latest on Liquid Petroleum Gas', The Open Road, June, Sydney.

NRMA 1990, 'The Gas Option', The Open Road, December, Sydney.

NRMA 1991, 'Natural Power', The Open Road, February, Sydney.

NSW Department of Minerals and Energy 1990, Investigation into Ethanol and Alternative Transport Fuels in New South Wales, Department of Minerals and Energy, Sydney.

OECD 1989 1st draft, Global Climate Change - The Energy Dimension, Part 3: Greenhouse Gas Emissions and Emission Factors, Environment Directorate, Paris.

OECD/IEA 1990a, Informal Expert Panel on "Low consumption/low emission automobile", Dipl - Ing. Josef Brosthaus, Institute for Energy Technology and Environmental Protection, Cologne, Rome.

OECD/IEA 1990b, Follow-up to the Informal Expert Panel on "Low Consumption/ Low Emission Automobile", Paris.

Pearman, G. 1989, The Greenhouse Effect, Global & Australian Perspectives, Energy and the Greenhouse Effect, Australian Institute of Energy, Melbourne.

RIC 1990, Rail into the 21st Century, AGPS, Canberra.

Rogers, P.L. 1990 'Ethanol as a Transport Fuel', Vehicles: Energy and Environmental Impact, Energy Research Development and Information Centre, University of New South Wales, Sydney.

US Energy Information Administration 1990, Monthly Energy Review, August 1990,19, Washington DC.

An Historic View of the Urban W. 1991, Young, Development/Transport Interaction in Melbourne, The of Engineers 1991 National Transport Institution Conference, National Conference Publication No. 91/4, The Institution of Engineers, Canberra.

Walker, I.J. 1990, 'Potential to Reduce Emissions of Greenhouse Gases in the Energy Sector', Energy Programs Division Discussion Paper No. 1, Department of Primary Industries and Energy, Canberra.

Wilgand, R.T. 1986, Global Mobility, Substituting Communications for Transportation, Centre for Advanced Research in Transportation, Arizona State University, Tempe, Arizona.

WRI 1990, World Resources 1990-91, Oxford University Press, New York.

Zillman J.W. 1990, Transport and the Global Greenhouse, paper presented to the 1990 Invitation Symposium of the Australian Academy of Technological Sciences and Engineering, Melbourne.

ABBREVIATIONS

Ĵ

~

3

, 5

.

 $\tilde{}$

 $\hat{\sim}$

Ä

-

1

.

 \sim

| ABARE | Australian Bureau of Agricultural and Resource | | | | | | |
|------------------|---|--|--|--|--|--|--|
| | Economics | | | | | | |
| ABS | Australian Bureau of Statistics | | | | | | |
| AMEC | Australian Minerals and Energy Council | | | | | | |
| Avgas | Aviation gasoline | | | | | | |
| Avtur | Aviation turbine fuel | | | | | | |
| BTCE | Bureau of Transport and Communications Economics | | | | | | |
| BTE | Bureau of Transport Economics | | | | | | |
| CH₄ | Methane | | | | | | |
| со | Carbon monoxide | | | | | | |
| CO2 | Carbon dioxide | | | | | | |
| Dotc | Department of Transport and Communications | | | | | | |
| DPIE | Department of Primary Industry and Energy | | | | | | |
| IDF | Industrial diesel fuel | | | | | | |
| IEA | International Energy Agency | | | | | | |
| LCV | Light commercial vehicle (utilities and panel vans) | | | | | | |
| LPG | Liquified petroleum gas | | | | | | |
| MJ | Megajoule (million joules) | | | | | | |
| NELA | Nelson English, Loxton and Andrews | | | | | | |
| NIEIR | National Institute of Economic and Industry | | | | | | |
| | Research | | | | | | |
| NRMA | National Roads and Motorists Association | | | | | | |
| N ₂ O | Nitrous oxide | | | | | | |
| OECD | Organisation for Economic Co-operation and | | | | | | |
| | Development | | | | | | |
| PJ | Petajoule (10 ¹⁵ joules) | | | | | | |
| RIC | Railway Industry Council | | | | | | |
| SMVU | Survey of Motor Vehicle Use | | | | | | |
| WRI | World Resources Institute | | | | | | |