Transport and Energy in Australia Part 2 - Consumption by Categories

Occasional Paper

This report investigates the current level of energy consumption by various categories of Australian transport. It examines the present Australian transport task and the associated levels of energy consumption. The efficiency of each major mode of transport is assessed in terms of energy consumption - both direct and indirect.

BUREAU OF TRANSPORT ECONOMICS

ENERGY CONSUMPTION BY CATEGORIES OF AUSTRALIAN TRANSPORT

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FOREWORD

This report investigates the current level of energy consumption by various categories of Australian transport. It examines the present Australian transport task and the associated levels of energy consumption. The efficiency of each major mode of transport is assessed in terms of energy consumption - both direct and indirect.

The report is a development of work done in a previous related report entitled: "Transport and Energy in Australia: Phase 1 - Review", which reviewed recent Australian and overseas literature on the subject.

This report has been prepared by Nicholas Clark and Associates. The BTE does not necessarily agree with the findings of the consultant's report.

J.H.E. Taplin
Director

Bureau of Transport Economics
Canberra, A.C.T.
August 1975

NICHOLAS CLARK AND ASSOCIATES

P.O. Box 524
SOUTH MELBOURNE

20th Feb, 1975

Dr. J. H. E. Taplin,
Director,
Bureau of Transport Economics,
P.O. Box 367,
CANBERRA CITY, A.C.T. 2601

Dear Dr. Taplin,

I have pleasure in forwarding to you our report on Energy Consumption by Categories of Australian Transport.

The report details Australia's transport task, measured in terms of passenger-kilometres and tonne-kilometres of movement, and examines the direct energy consumption of each of its constituent categories. These are drawn together in an assessment of the efficiency with which each transport mode utilises its input of primary energy in performing its task.

A brief analysis, based mainly on the results of overseas studies, is also made of the indirect energy consumption by transport, i.e. the energy consumed in manufacturing and infrastructure services associated with the transport sector, and an assessment carried out of the contribution of international transport movements to Australia's energy budget.

The most significant findings of our study are as follows:

- Road transport uses fully 79 percent of all domestic transport energy, and as much as 55 percent of the total is attributable to personal travel by the private car;
- Australia's international shipping uses about as much primary energy as is used for travel by private car in Australia;
- Indirect energy consumption by cars is equal to over 60 percent of their direct consumption;

.../

Offices: 145 Cecil Street, South Melbourne, 3205. *Telephone:* (03) 69 7159
6 Scarborough Street, Red Hill, Canberra 2603 *Telephone:* (062) 95 8612
Postal Address: Box 591, Manuka, ACT 2603

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- The domestic transport modes which use the greatest amounts of energy (principally the road modes) are also those which are the most energy-intensive, are powered by petroleum-based fuels, and show the most rapid rate of growth of demand.

In the light of these results, we suggest that studies be carried out to assess the effects of alternative policies aimed at achieving a redistribution of energy usage within the transport sector. In particular an examination should be made of the price elasticity of energy consumption for travel by private car, utilising if necessary the results of studies of the effect on travel demand of recent rapid rises in the cost of petroleum fuels in European countries.

Yours sincerely,

J A Lee

John A. Lee
Senior Associate
for NICHOLAS CLARK & ASSOCIATES

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CHAPTER 1 PREAMBLE

1.1 INTRODUCTION

The importance of the transport sector in Australia is well-documented: it contributes approximately nine per cent of the gross national product and is attributed a 12 per cent share of gross national expenditure. It is also a major consumer of primary energy.

This report presents the findings of a study aimed at estimating the amount of primary energy consumed by the various categories of Australian transport, and relating this to the task performed by each.

Information published by the then Department of National Development in 1972[1] suggests that in 1970-71, of the total national consumption of energy of about 2200 x 10^{12} kJ, transport uses 26.4 per cent, electricity generation 28.9 per cent, agriculture 1.9 per cent, remaining primary and secondary industry 38.3 per cent, and the domestic and commercial sectors 4.5 per cent. This report examines in detail, not only the 26.4 per cent used by transport, but also the amount of energy consumed in the industrial and commercial sectors in activities directly associated with transport (known as indirect energy consumption) and the consumption of energy for international transport movements attributable to Australia.

1.2 SOURCES OF INFORMATION

Data on the traffic task performed by the various transport categories are mainly derived from annual reports of the respective operating authorities, from information collected by the Australian Bureau of Statistics (formerly the Commonwealth Bureau of Census and Statistics) and, in the case of road transport, from

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(1) Australia's Natural Resources, Ministerial Statement and Review, September 1972.

the CBCS surveys of motor vehicle and bus usage. Where assumptions are made to develop estimates (particularly in relation to international traffic), these are clearly stated in the text.

Information concerning the use of energy has been derived from publications of the Department of Minerals and Energy (which incorporates much of the Department of National Development within its structure), and from reports of the various organisations concerned with the production and distribution of transport fuels and energy sources. In all cases, energy is expressed in terms of the energy content of the primary fuel source used to derive the energy eventually utilised for transport purposes. Thus, the energy consumption of electric trains, for example, is defined to equal the energy content of the coal used to develop the electrical power for traction.

In some cases, information concerning indirect energy consumption and the specific consumption rates of certain vehicles were not available for Australian conditions, and proxy values taken from the results of overseas studies had to be used in lieu. Where this is the case, the validity of so doing is discussed in the text.

1.3 CHOICE OF BASE YEAR

Road transport has a major influence on the patterns of energy consumption for transport and on the transport task itself. And yet information on its contribution is, to all intents and purposes, unavailable for all but the year 1970-71, to which the recent CBCS Survey of Motor Vehicle Usage refers. For this reason, and because little reliable information for more recent years is available for other modes, 1970-71 was chosen as the study year. Contributing to the argument was the fact that recent US studies have been published which apply to 1970-71 and which were of particular use where Australian data are lacking.

1.4 ACCURACY OF ESTIMATES

The estimates of direct energy use by modes of road transport are critically dependent on the data base provided by the 1971 CBCS Survey of Motor Vehicle Usage. Whilst the standard sampling errors associated with most of the CBCS estimates are not excessive, the size and effect of non-sampling errors is unknown. The analysis of Chapter 3 (Section 3.3.6) indicates, however, that errors in the estimation of direct energy use by road transport are probably of the order of 20 per cent. As far as other domestic transport modes are concerned, errors in estimates of total energy use are likely to be within about 20 per cent, but these modes are much less significant in the total pattern of energy consumption than are the road modes. It is difficult, however, to gauge the likely magnitude of error associated with the sub-divisions of each mode's energy consumption.

The estimates of energy usage by international transport movements attributable to Australia could be as much as 30-50 per cent in error, such is the difficulty of accurately estimating both task and specific energy consumption rates. This point is made at the appropriate place in the text.

Within all tables, except where otherwise stated, discrepancies between totals and the appropriate sums of individual entries may be attributed to rounding errors. The symbol '--' means that the entry is zero, negligible or not applicable. The symbol 'n.a.' means that the entry is not available.

1.5 CITING OF REFERENCES

In this report, use is made of publications produced by authorities which have since been changed in name, disbanded or whose functions have been incorporated within the structure of a new authority. For example, the former Commonwealth Bureau of Census and Statistics is now known as the Australian Bureau of Statistics; the former Department of Shipping and Transport has been incorporated within the Department of Transport.

When a reference is cited, the name of the publishing authority which is given is that which was applicable at the time of publishing.

A final point concerns the attribution of data which derives from the 1971-73 CBCS Survey of Motor Vehicle Usage. Some of this source data which is unpublished has been obtained by enquiry from Australian Bureau of Statistics and where required an appropriate note to this effect is made. The only published data so far appears in the CBCS Survey of Motor Vehicle Usage 12 Months Ended 30th September 1971 (Preliminary), Canberra, September 1973.

CHAPTER 2 THE AUSTRALIAN TRANSPORT TASK

The task performed by Australian transport can be measured in terms of the number of passenger-kilometres and tonne-kilometres performed by individual categories of operation. In this Chapter an evaluation of this task has been made keeping in mind the later aim of:

(i) providing an indication of the efficiency with which each mode utilises its consumption of energy; and,

(ii) for any particular mode, providing the basis for calculating the division of energy consumption between the various sub-categories of that mode's transport operations.

Estimates of the transport task for each mode are derived from published information, and in some cases sub-divisions are made according to assumptions clearly stated in the text. The contributions of each mode, and certain sub-categories of each mode, to the total task, passenger and freight, are summarised in Tables 2.17 and 2.19 at the end of the Chapter.

2.1 ROAD TRANSPORT

2.1.1 Cars and Station Wagons

The only reliable source of information relating to the overall number of occupant-kilometres travelled in Australia by road vehicles (excluding buses) is the CBCS Survey of Motor Vehicle Usage for the year ending 30 September 1971. Table 2.1 is taken from the preliminary report of the survey. It shows that the car, station wagon and motor cycle task comprises some 85 per cent of the total.

TABLE 2.1 - TOTAL ANNUAL OCCUPANT-KILOMETRES BY ROAD TRANSPORT (EXCLUDING BUSES), 1970-71

Type of vehicle	Occupant-kilometres ('000 million)	Per cent of total
Cars and station wagons	125.7	84.5
Light commercial vehicles	11.8	7.9
Trucks	10.1	6.8
Motor cycles	1.1	0.7
Totals	148.7	100.0

Source: CBCS Survey of Motor Vehicle Usage, 12 Months Ended 30th September 1971 (Preliminary). Canberra, September, 1973.

In the analysis of this Chapter to follow, it is assumed that the remaining 15 per cent of the passenger transport task (attributable to light commercial vehicles and trucks) is performed incidentally to the carriage of goods. That is, commercial vehicles and trucks perform no passenger task per se, but achieve a small level of occupant-kilometres in performing their road freight task. The likely error due to this assumption can be gauged using the proportion of the distance travelled by commercial vehicles and trucks for solely private purposes; this is approximately 22 per cent for light commercial vehicles and three per cent for trucks. These imply a likely error in the estimate of the occupant task (on the assumption that it is essentially performed by cars and station wagons) of only about two per cent.

In the preliminary report of the Survey of Motor Vehicle Usage, there is no sub-division of the number of occupant-kilometres by particular purposes and by detailed area of operation. Estimates from the Survey are available, however, of the numbers of vehicle-kilometres travelled by cars and station wagons in categories resulting from such a subdivision. These are shown in Table 2.2. The interstate column in the Table refers only to vehicle-kilometres travelled in other States by vehicles registered in the home-State. To obtain a true interstate value, therefore, the column has to be adjusted to include vehicle-kilometres travelled in the home-State on interstate journeys. With the available information, the only way this may be done is to assume that home-State use of out-of-State roads is approximately equal to home-State use of home-State roads for interstate travel, an assumption likely to underestimate interstate vehicle-kilometres for Queensland, Victoria (to a small extent) and South Australia and to overestimate the task for Western Australia and New South Wales. On balance, however, the assumed total interstate task may be close to the actual value. Note that the 'rest-of-State' values have to be reduced to account for the vehicle-kilometres of home-State interstate traffic. Again, the assumed rest-of-State task is probably sufficiently accurate. The adjusted distribution of vehicle-kilometres is shown in Table 2.3.

Cars and station wagons travelled 63.8×10^9 kilometres in 1970-71, which corresponded to 125.7×10^9 occupant-kilometres. This represents an average number of occupants per car of 1.97[(1)].

It is unlikely that the derived occupancy rate applies for all types of trip. Comprehensive transport studies undertaken for most urban areas in Australia, for example, suggest that for the journey to work, a rate of 1.3 is more appropriate. Further evidence from these same studies was used to develop appropriate rates for other trip categories.

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(1) Throughout the subsequent text a rounded figure of 2.0 is used.

TABLE 2.2 - DISTANCES TRAVELLED BY CARS AND STATION WAGONS, BY PURPOSE AND AREA OF OPERATION, 1970-71

(10^6 kilometres)

Purpose	Area of Operation				Total
	Capital City and Environs	Provin-cial Urban	Rest of State	Inter-state (1)	
Business	7,255.8	904.9	4,434.4	356.4	12,951.6
Paid to and from work	2,187.5	226.7	592.4	45.0	3,051.7
Unpaid to and from work	8,944.6	1,185.1	2,469.4	196.0	12,795.1
Private	17,077.6	3,011.5	12,957.4	1,956.1	35,003.0
Total	35,465.9	5,328.2	20,453.6	2,553.5	63,801.9

(1) Refer text for interpretation of 'interstate' column.

Source: Unpublished information from CBCS Survey of Motor Vehicle Usage, 1971-1973.

TABLE 2.3 - ADJUSTED DISTANCES TRAVELLED BY CARS AND STATION WAGONS, BY PURPOSE AND AREA OF OPERATION, 1970-71

(10^6 kilometres)

Purpose	Area of Operation				Total
	Capital City and Environs	Provin-cial Urban	Rest of State	Inter-state	
Business	7,255.8	904.9	4,078.0	712.8	12,951.6
Paid to and from work	2,187.5	226.7	547.4	90.0	3,051.7
Unpaid to and from work	8,944.6	1,185.1	2,273.4	392.0	12,795.1
Private	17,077.6	3,011.5	11,001.3	3,912.2	35,003.0
Total	35,465.9	5,328.2	17,900.1	5,107.0	63,801.9

Source: Refer to text.

The rates developed are shown in Table 2.4, together with the relevant sources of evidence, and provide the bases for calculating the occupant-kilometres, by category, shown in Table 2.5.

As far as possible, care was taken to ensure that car occupancy rates were assigned to categories in a way which was consistent with the rates which were known. A weighted averaging technique, according to vehicle-kilometres attributable to each category, was used to achieve this balancing process.

The private/rest-of-State and private/inter-state vehicle occupancy rates seem excessive in comparison with the other occupancy figures. In the absence of better information, however, these must be accepted as correct. Any difference between the actual and assumed value of vehicle occupancy for any one category would, of course, result in a change in at least two of the elements in the matrix of Table 2.5. The accuracy of Table 2.4 is, therefore, critical to that of some of the findings of the remainder of the study. Further research could well concern itself with obtaining better estimates for all categories of vehicle occupancy figures.

2.1.2 Motor Cycles

The results of the CBCS Survey of Motor Vehicle Usage show that, in 1970-71, motor cycles travelled an estimated 1.014×10^9 kilometres[1] associated with approximately 1.1×10^9 occupant-kilometres. This implies an average number of occupants per vehicle of 1.1. It is not known how the motor cycle occupancy rate may vary by area or by purpose, but a figure of 1.1 is probably representative of all categories.

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(1) Unpublished information from CBCS Survey of Motor Vehicle Usage, 1971-73, subsequent to preliminary figure.

TABLE 2.4 - ASSUMED VEHICLE OCCUPANCY FOR CARS AND STATION WAGONS BY PURPOSE AND AREA OF OPERATION

(persons per vehicle)

Purpose	Area of Operation				
	Capital City and Environs	Provincial Urban	Rest of State	Interstate	All Areas
Business	1.2	(1) 1.1	1.1	1.1	1.2
Paid to and from work	(1) 1.3	(3) 1.3	1.1	1.1	1.3
Unpaid to and from work	(2) 1.3	(3) 1.3	1.1	1.1	1.3
Private	1.8	1.7	4.0	3.4	2.7
All purposes	(4) 1.5	(5) 1.5	2.9	2.9	2.0

Purpose	City or Town	Occupancy
(1) Business trips:	Bendigo (1971)	1.06
	Rockhampton (1971)	1.01
	Launceston (1967)	1.08
(2) Work trips:	Melbourne (1964)	1.37
	Brisbane (1960)	1.33
	Sydney (1971)	1.22
	Hobart (1964)	1.46
	Adelaide (1968)	1.27
(3) Work trips:	Bendigo (1971)	1.24
	Rockhampton (1971)	1.22
	Ipswich (1966)	1.38
	Launceston (1967)	1.30
	Townsville (1966)	1.33
(4) All purposes:	Brisbane (1960)	1.58
	Sydney (1971)	1.41
	Hobart (1964)	1.41
	Adelaide (1968)	1.64
(5) All purposes:	Bendigo (1971)	1.47
	Rockhampton (1971)	1.43
	Ipswich (1966)	1.50
	Launceston (1967)	1.48
	Townsville (1966)	1.44

Source: See text for details. The estimates of the Table were derived in part from the above transportation study results.

TABLE 2.5 - ESTIMATED OCCUPANT-TASK BY CARS AND STATION WAGONS, BY PURPOSE AND AREA OF OPERATION, 1970-71

(10^9 occupant-km)

Purpose	Area of Operation				Total
	Capital City and Environs	Provincial Urban	Rest of State	Interstate	
Business	8.7	1.0	4.5	0.8	15.0
Paid to and from work	2.8	0.3	0.6	0.1	3.8
Unpaid to and from work	11.6	1.5	2.5	0.4	16.1
Private	30.7	5.1	44.0	13.3	93.1
Total	53.2	8.0	51.6	14.8	127.6(1)

Notes: Totals differ from row and column totals because occupancy figures of Table 2.4 are rounded to 1st decimal place.

(1) This figure differs from that shown in Table 2.1 due to rounding of the average occupant number from 1.97 to 2.0 (see footnote, page 9).

Source: Refer to text.

From the CBCS survey[1], estimates of the number of vehicle-kilometres by each category have been made (see Table 2.6) and these have been used, together with an average occupancy of 1.1, to develop estimates of the person-kilometres by area of operation and purpose, shown in Table 2.7.

TABLE 2.6 - ESTIMATED DISTANCE TRAVELLED BY MOTOR CYCLE BY PURPOSE AND AREA OF OPERATION, 1970-71

(10^6 kilometres)

Purpose	Area of Operation				Total
	Capital City and Environs	Provincial Urban	Rest of State	Inter-state	
Business	31.6	2.4	50.7	0.2	85.0
Paid to and from work	35.7	4.4	17.2	0.5	57.8
Unpaid to and from work	233.7	47.2	63.5	6.2	350.7
Private	271.7	49.4	168.7	30.5	520.3
Total	572.8	103.4	300.1	37.4	1,013.7

Source: Unpublished information from CBCS Survey of Motor Vehicle Usage, 1971-73, subsequent to Preliminary Report.

(1) Unpublished information from CBCS Survey of Motor Vehicle Usage, 1971-73.

TABLE 2.7 - ESTIMATED PERSON-TRAVEL BY MOTOR CYCLES, BY PURPOSE AND AREA OF OPERATION, 1970-71

(10^6 person-km)

Purpose	Area of Operation				Total
	Capital City and Environs	Provincial Urban	Rest of State	Interstate	
Business	34.8	2.6	55.8	0.2	93.5
Paid to and from work	39.3	4.8	18.9	0.6	63.5
Unpaid to and from work	257.1	51.9	69.9	6.8	385.7
Private	298.9	54.3	185.6	33.5	572.3
Total	630.0	113.7	330.1	41.2	1,115.0

Source: Developed from Table 2.6 by assuming an average occupancy of 1.1 persons per motor cycle.

2.1.3 Commercial Vehicles

The CBCS Survey of Motor Vehicle Usage reports the total task of road freight vehicles in 1970-71 as 27,182 M tonne-kilometres. In the survey, vehicle owners were asked, among other things, to provide data which enabled estimates to be made of the number of tonne-kilometres performed by vehicles registered in each State in metropolitan, provincial, urban, rural and out-of-State areas. These data are brought together in Table 2.8. Before they can be used as an estimate of movement within each State or Territory, it is necessary to adjust the out-of-State movements column, in order to obtain a true interstate estimate. The same problem arose above in establishing the interstate task by cars and station wagons (see pages 6-7).

TABLE 2.8 - INITIAL ESTIMATE OF ROAD FREIGHT TRANSPORT TASK BY STATE OF VEHICLE REGISTRATION AND AREA OF OPERATION, 1970-71

(million tonne-km)

State of Vehicle Registration	Area of Operation				Total
	Capital City and Environs	Provincial Urban	Rest of State	Interstate	
NSW	2,886	909	4,233	1,460	9,488
VIC	2,114	307	2,935	1,442	6,798
QLD	677	244	1,563	476	2,959
SA	729	-	1,625	934	3,286
WA	852	-	2,307	36	3,196
TAS	124	54	499	8	683
NT	44	-	492	41	577
ACT	195	-	-	-	195
Total	7,619	1,512	13,654	4,395	27,182

Source: Unpublished information from CBCS Survey of Motor Vehicle Usage, 1971-73, subsequent to Preliminary Report.

If it may be assumed, as it was on a previous page for cars and station wagons, that home-State use of out-of-State roads is approximately equal to home-State use of home-State roads for interstate trips, then the task is seen to be broken down by area of operation in the manner shown in Table 2.9.

A limited check of the accuracy of Table 2.9 is possible with the use of the findings of a survey of interstate freight movements for the year 1970-71, undertaken by the ABS. Results have not yet been published, but preliminary information has been made available for the purpose of this study. Coverage is limited to those freight forwarders and/or road transport operators who were engaged in the interstate movement of freight for hire and reward between Sydney, Newcastle, Wollongong, Melbourne, Brisbane, Adelaide, Perth, Darwin and Canberra, and who moved a total of at least 2,540 tonnes during the quarter ended 30th September, 1971. Thus, interstate movements to other urban centres or from rural regions would not necessarily be included.

TABLE 2.9 - REVISED ESTIMATE OF ROAD FREIGHT TASK, BY AREA OF OPERATION, 1970-71

(million tonne-km)

Area of Operation	Task
Capital City and Environs	7,619
Provincial Urban	1,512
Rest of State	9,259
Interstate	8,790
Total	27,182

Source: Refer to text. The interstate task has been adjusted to allow for home state travel on interstate trips.

The ABS gave totals for tonnes moved between centres and, by multiplication by the road distance, estimates of tonne-kilometres of interstate road freight can be produced. These are given in Table 2.10. They are far from comprehensive, but indicate that just over 3,000 million tonne-kilometres were performed in 1971-72 by major operators in the inter-city interstate road freight task. A comparison with Table 2.9, however, shows a discrepancy of 5,620 million tonne-kilometres between the two estimates of the interstate task(1). Whether the

(1) Which represents 64 per cent of the estimate of Table 2.9

TABLE 2.10 - INTERCITY FREIGHT MOVEMENTS BY ROAD: ESTIMATED TONNE-KILOMETRES PERFORMED 1970-71

(million tonne-km)

From: \ To:	Sydney	New-castle	Woll-ongong	Melbourne	Brisbane	Adelaide	Perth	Darwin	Canberra	Total
Sydney	-	-	-	477.5	306.8	220.6	89.0	16.6	9.0	1,119.6
Newcastle	-	-	-	33.3	14.3	13.6	9.0	-	-	70.2
Wollongong	-	-	-	11.4	2.2	3.2	--	-	-	16.8
Melbourne	453.1	9.4	3.5	-	260.1	186.4	87.8	6.4	11.0	1,027.6
Brisbane	181.2	4.6	0.8	138.8	-	39.7	14.0	44.4	-	423.4
Adelaide	171.3	3.7	1.5	136.2	78.9	-	17.5	11.7	2.9	423.6
Perth	24.2	-	-	30.8	6.1	20.6	-	-	-	81.7
Darwin	-	-	-	-	5.8	-	-	-	-	5.8
Canberra	1.3	-	-	-	-	-	-	-	-	1.3
Total	831.2	27.6	5.8	828.0	674.1	484.1	217.2	79.1	23.0	3,170.0

Source: See text.

freight task of unsurveyed interstate movements is sufficiently large to explain this discrepancy is hard to say. Included in the figure of 5,620 million tonne-kilometres would be interstate haulage of primary produce and interstate movements by ancillary[1] transport.

The CBCS Survey of Motor Vehicle Usage also provides estimates of the road freight task by category of vehicle usage. These are given in Table 2.11, and illustrate the importance of ancillary road transport in the total task. 34 per cent of the total tonne-kilometres were performed by ancillary vehicles. Hire and reward operations, the most significant category, were responsible for 65 per cent of the total.

TABLE 2.11 - ESTIMATED ROAD FREIGHT TASK, BY CATEGORY OF VEHICLE USAGE, 1970-71

(million tonne-km)

Vehicle Usage	Freight Task	Per cent of Total
Hire and reward		
1 client	5,267	19.4
>1 client	12,361	45.5
Ancillary	9,322	34.3
Other	67	0.2
Not Stated	166	0.6
Total	27,182	100.0

Source: CBCS Survey of Motor Vehicle Usage, 12 months ended 30th September, 1971 (Preliminary). Canberra, September 1973.

(1) An ancillary function is one which is performed incidentally to the main task at hand. Thus an example of ancillary transport of goods is provided by the operations of a large department store, whose main business is to sell consumer goods, but part of whose service involves the delivery, or road freighting, of goods to purchasers.

2.1.4 Buses

The Commonwealth Bureau of Roads' estimates the passenger task performed by buses as being 8.87×10^9 passenger-kilometres. The accuracy of this figure is not given. Nor is a break-down of the task according to area of operation available.

The ABS Bus Fleet Operations Survey for the twelve months ended 30th June 1971 does, however, give estimates of vehicle-kilometres by area of operation, and Table 2.12 gives the resulting task if it may be assumed that total passenger-kilometres may be allocated to metropolitan and other areas according to the proportion of vehicle-kilometres travelled in each area. This simplified assumption may not be entirely accurate; it implies that vehicle occupancies for each area are similar. It is possible, however, that urban services operate with a slightly greater average number of persons per vehicle than do non-urban and provincial services. On the other hand, both charter and scheduled inter-city operations usually run with greater passenger loads, and this may be sufficient to justify the previous assumption.

2.1.5 Trams

The only readily available estimate of the passenger task performed by the tram services of Australia is one provided by the Commonwealth Bureau of Roads(1). This is 0.53×10^9 passenger-kilometres, although, again, the accuracy of the figure cannot be determined.

Nonetheless, trams carry out only a very small portion of the total passenger task, so an error of the order of even 20 per cent in the estimation of their

(1) Commonwealth Bureau of Roads, Report on Roads in Australia, 1973

TABLE 2.12 - ESTIMATED PASSENGER TASK BY BUS, BY AREA OF OPERATION, 1970-71

(10^9 passenger-km)

Area of Operation	Passenger Task
Capital Cities	4.67
Rest of States	4.20
Total	8.87

Source: Refer to test

contribution is not significant to the findings of this Chapter, although it is significant to the calculations of energy intensiveness in Chapter 5.

2.1.6 Total Road Transport

The results of the above analyses, for cars and station wagons, motor cycles, commercial vehicles, buses and trams, are summarised in Table 2.13, which shows the estimated traffic task performed by road transport.

By far the greatest part of the passenger task (96 per cent) is performed by the private car, with only 3 per cent of the task carried out by road public transport vehicles.

2.2 RAIL TRANSPORT

2.2.1 Urban Rail Services

Only the operators of the government rail services in Melbourne, Adelaide and Hobart publish, in their annual reports, estimates of the numbers of passenger-kilometres performed by their operations. No information is available to enable accurate estimation of the value for other urban rail services, but the order of magnitude of the total

TABLE 2.13 - SUMMARY OF ESTIMATED TASK PERFORMED BY ROAD TRANSPORT, 1970-71

(10^9 person-km)

Mode	Urban Areas	Non-Urban Areas	Total
(A) PASSENGER TASK, BY AREA OF OPERATION			
Cars and Station Wagons (1)	61.2	66.4	127.6
Motor Cycles (2)	0.7	0.4	1.1
Buses	4.7	4.2	8.9
Trams	0.5	-	0.5
Total	67.1	71.0	138.1

(B) FREIGHT TASK, BY AREA OF OPERATION			
Commercial Vehicles (3)	9.13	18.05	27.18

(1) Derived from Table 2.5

(2) Derived from Table 2.7

(3) Derived from Table 2.9

Notes: Area of operation is divided into Urban and Non-Urban areas. For all road transport other than buses and trams Urban refers to 'Capital city and environ' and 'Provincial urban', and Non-urban refers to 'rest of state' and 'Interstate'; for buses and trams the subdivision is between 'Capital Cities' and 'rest of state'.

Source: Refer to notes hereunder.

number of passenger-kilometres is estimated below using as a basis the number of passenger-kilometres per head of population in the cities for which the task is known.

In Melbourne, Adelaide and Hobart, the average numbers of passenger-kilometres per head was 866, 211 and 56 respectively. On the assumption of a simple relationship between passenger-km/head and population, figures for passenger-kilometres per head may be estimated for those cities served by urban railways for which no data is available. Upon this assumption, a total task, for all cities, of 5.9×10^9 passenger-kilometres is obtained.

It is assumed here that suburban rail services in metropolitan areas are solely passenger carrying; that is, in the analysis to follow of energy usage, the total consumption of urban rail services is attributable wholly to the carriage of passengers.

2.2.2 Non-Urban Rail Services: Freight

The non-urban railway task is carried both by government-owned services (which move both passengers and freight) and private services (which are used mainly for the carriage of ores and minerals and other bulk commodities such as sugar cane, but carry no passenger traffic).

Table 2.14 shows the output of the rail freight sector for the year 1970-71.

Because of the difference in operating characteristics of heavy ore haulage systems, it would be useful to determine their share of the total rail freight output. Available data are, however, limited. The Annual Report of the Western Australian Government Railways suggests that the carriage of ores and minerals represented just under 45 percent of the total tonne-kilometres of the W.A.G.R. system in 1970-71, but it is not known to what extent this percentage is applicable to other State railways. It is probable that ore and mineral traffic represents about one half of the total freight task of all railway systems in Australia, both government and private.

TABLE 2.14 - ESTIMATES FREIGHT TASK OF GOVERNMENT AND PRIVATE RAILWAYS, 1970-71

Private Railways[(a)]		Govt. Railways[(b)]		All Railways	
Tonnes ($\times 10^6$)	Tonne-km ($\times 10^9$)	Tonnes ($\times 10^6$)	Tonne-km ($\times 10^9$)	Tonnes ($\times 10^6$)	Tonne-km ($\times 10^9$)
79.99	13.78	87.30	25.20	167.29	38.98

Source: (a) ABS Year Book Australia 1973
(b) CBCS Transport and Communications 1970-71, Bulletin No. 62, Canberra, Feb. 1973.

The inference that possibly 50 per cent of the total freight task is comprised of ore and mineral traffic may be supported with the information provided by Table 2.15 (Estimates of the Government Railway Freight Task). Total ore and mineral traffic consists of a private railways total of 13.78×10^9 tonne-kilometre (from Table 2.14), plus a value of 8.53×10^9 tonne-kilometre derived for Government railways in Table 2.15. Thus, ore and mineral traffic may account for 22.310×10^9 tonne-kilometres, being 57 per cent of the total railway freight task of 38.978×10^9 tonne-kilometres.

TABLE 2.15 - ESTIMATE OF THE GOVERNMENT RAILWAY FREIGHT TASK, 1970-71

(10^9 tonne-km)

State or	State Rly	C'wealth Rlys task(a)	Total	Minerals, Ores & Coal(b)	Remaining Freight Task
NSW	9.06	-	9.06	2.70	6.36
VIC	3.47	-	3.47	0.25	3.22
QLD	5.42	-	5.42	2.71	2.71
SA	1.61	1.39	3.01	1.20	1.81
WA	3.40	0.49	3.89	1.54	2.35
TAS	0.15	-	0.15	-	0.15
NT	-	0.21	0.21	0.13	0.08
Total	23.11	2.10	25.21	8.53	16.68

Notes: (a) Commonwealth Railways traffic is allocated to States on an approximate basis according to track length.

(b) Estimates of minerals, ores and coal task are based on the following assumptions:

NSW	30% of total task
VIC	1.5m (approx.) tonnes of brown coal hauled 160m km
QLD	50% of total task (revenue from minerals were 40% of freight revenue)
SA	40% of combined State and CR task (26% of State freight revenues were from minerals)
WA	Reported minerals task
NT	60% of total task.

Source: Annual reports of the various government railways. See also notes below.

It should be noted that the published statistics for the rail freight task include a portion attributable to movements on which both passengers and freight were carried. This is of some importance, as will be seen in the next Chapter, when calculations are made of the amount of energy consumed in performing the respective tasks.

2.2.3 Non-Urban Rail Services: Passenger

The total number of passenger kilometres by all rail systems in Australia was approximately 10,000 million in 1970-71[(1)]. Of these, about 5,900 million have been estimated above to be attributable to urban traffic, leaving 4,100 million carried by non-urban State and Commonwealth systems.

Again, it should be noted that a portion of these are carried on mixed, passenger-freight, trains, a point considered further in Chapter 3.

No information is available to enable the estimated task to be separated into categories by area of operation or journey purpose.

2.2.4 Total Rail Transport

The results of the preceding analyses, concerning urban and non-urban rail services, are summarised in Table 2.16, which shows the estimated tasks performed by rail transport.

TABLE 2.16 - SUMMARY OF ESTIMATED TASK PERFORMED BY RAIL TRANSPORT, 1970-71, BY AREA OF OPERATION

Task	Urban Areas	Non-Urban Areas	Total
Passenger movement (10^9 passenger-km)	5.9	4.1	10.0
Freight movement (10^9 tonne-km)	-	39.0	39.0

Source: Refer to text.

(1) Commonwealth Bureau of Roads Report on Roads in Australia, 1973.

The passenger task is fairly evenly split between the urban and non-urban services, whilst the freight task is almost entirely carried out by non-urban rail services.

2.3 DOMESTIC AIR SERVICES

In 1970-71, 4,973 million passenger-kilometres were performed by the regular internal air services of Australia[1].

This estimate excludes movements on non-scheduled flights, both of the domestic airlines, other commercial airlines, and private aircraft. In 1970-71, 267,622 hours were flown on the domestic airlines' internal scheduled services[2], and 1,129,000 hours by general aviation operators[2]. In addition, some 50,050 hours were flown in 1970-71 by all airlines (domestic and Qantas) in general aviation operations[3].

Whilst non-scheduled flying time is therefore far in excess of scheduled flying time (more than four times as great), it must not be inferred that the non-scheduled passenger task is greater than that performed by scheduled services. It is probably far less, due to differences in average load factor, though exactly how much less is impossible to estimate with available information.

Air transport provides only a very modest contribution to the total domestic freight task. It is estimated that 87 million tonne-km were performed by the regular internal airline services in 1970-71[4].

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(1) ABS Year Book Australia, 1973.

(2) Department of Civil Aviation, Civil Aviation 1971-72.

(3) Department of Civil Aviation, Civil Aviation 1970-71.

(4) ABS Year Book Australia 1973.

2.4 COASTAL SHIPPING

Total interstate movements by coastal shipping in 1970-71 involved the loading and discharging of 52.18 million tonnes of freight(1). By assuming an average distance travelled by sea of 1300 km(2), it is possible to estimate the freight task performed by coastal shipping as around 68,000 million tonne-kilometres.

Alternatively, an estimate of the coastal shipping freight task for 1969-70 is known(3); this is 66,000 million tonne-kilometres. The same source estimates the average annual growth rate in the sea freight transport task to be approximately 7.5%, and applying this information to the 1969-70 figure results in an estimate of 70,950 million tonne-kilometres for 1970-71.

A figure of 70,000 million tonne-kilometres is therefore suggested as being a reasonable estimate of the coastal shipping freight task. This represents just over one half of the total domestic freight task in Australia.

The number of passenger-kilometres performed by domestic sea transport is not very significant, being estimated at approximately 257 million passenger-kilometres(3). For this reason, in the analysis of energy consumption in Chapter 3, the contribution of domestic shipping to the total pattern of energy usage for passenger transport has been ignored.

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(1) ABS Year Book Australia 1973.

(2) Commonwealth Department of Shipping and Transport, Australian Domestic Traffic Task 1969-70, Table 9, Paper No. 5, February 1972.

(3) Commonwealth Bureau of Roads, Report on Roads in Australia, 1973.

2.5 TOTAL DOMESTIC TRANSPORT

The domestic transport task is summarised in Table 2.17. Significant points which emerge from the table are:

(i) the high portion (90 per cent) of total personal mobility carried by road;

(ii) the relative importance of freight traffic in non-urban areas (93 per cent of the total tonne-kilometres); and

(iii) the significance of coastal shipping in the total domestic freight task.

2.6 INTERNATIONAL TRANSPORT

Just as Australia's national energy consumption is not complete without consideration of the energy used for international transport movements, passenger and freight, attributable to Australia, so too is the transport task incomplete without an evaluation of such movements. Just what is Australia's share of international shipping and air traffic is, however, difficult to determine. The conceptual problem is discussed in more detail in the next Chapter, but for the purposes of this study the assumption is made that of the total tonne-kilometres and passenger-kilometres of traffic originating and terminating in Australia's ports and airports, one half is attributable to Australia and the other to the other countries with which these movements are associated.

TABLE 2.17 - SUMMARY OF ESTIMATED DOMESTIC TRANSPORT TASK, 1970-71

Mode and Purpose	Passenger Task (10^9 person-km)			Freight Task (10^9 tonne-km)		
	Urban	Non-Urban	Total	Urban	Non-Urban	Total
Cars and station wagons						
Business	9.7 (6)	5.3 (3)	15.0 (10)	-	-	-
Work	16.2 (11)	3.6 (2)	19.9 (13)	-	-	-
Private	35.8 (23)	57.3 (37)	93.1 (61)			
Motor cycles	0.7 (<1)	0.4 (<1)	1.1 (<1)	-	-	-
Commercial vehicles	-	-	-	9.1 (7)	18.1 (13)	27.2 (20)
Buses	4.7 (3)	4.2 (3)	8.9 (6)	-	-	-
Tram	0.5 (<1)	-	0.5 (<1)	-	-	-
Total Road:	67.6	70.8 (46)	138.5 (90)	9.1 (7)	18.1 (13)	27.2 (20)
Train	5.9 (4)	4.1 (3)	10.0 (7)	-	39.0 (29)	39.0 (29)
Air	-	5.0 (3)	5.0 (3)	-	<0.1 (<1)	<0.1 (<1)
Sea	-	<0.1 (<1)	<0.1 (<1)	-	70.0 (51)	70.0 (51)
Total	73.5 (48)	80.0 (52)	153.6 (100)	9.1 (7)	127.2 (93)	136.3 (100)

Note: Figures in brackets represent percentage of total.

Source: See text.

2.6.1 International Shipping

In 1970-71, a total of 123.6 million tonnes of international freight were loaded and discharged at Australia's ports[1]. Although information does exist to allocate this traffic to geographic trade areas, detailed information on voyage distances is not readily available, and an assumption of 8,000 kilometres average trip length had to be made. Using this figure, and assuming 50 per cent of the total indicated task is attributable to Australia, gives a value of approximately 494,000 million tonne-kilometres for Australia's international freight task.

The validity of this estimate depends, of course, on the assumption concerning average trip length. Table 2.18 shows the major trading areas associated with the shipping movements and forms the broad basis for the assumption of 8,000 kilometres average trip length.

2.6.2 International Air Services

In 1970-71, 615,699 passengers disembarked and 583,449 embarked on international air services to and from Australia, a total of 1,199,148 passengers[1],[2].

The bulk of international air passenger movements to and from Australia are presented in Table 2.19. The (weighted) average distance travelled on international flights to and from Australia may therefore be estimated as being of the order of 9,000 km. The total passenger task indicated is therefore approximately 10,792 million passenger-kilometres, of which half, 5,396 million passenger-kilometres, may be considered attributable to Australia.

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(1) CBCS Transport and Communication 1970-71, Bull. No. 62, Canberra, February 1973.

(2) This figure arises from movements by all airlines into and out of an area embracing Australia, Papua-New Guinea and Norfolk Island. Movements between Australia, and Papua-New Guinea and Australia and Norfolk Island are excluded. The Australian passenger and freight task estimates are therefore subject to some overvaluing.

TABLE 2.18 - AUSTRALIA'S INTERNATIONAL SHIPPING: CARGO DISCHARGED AND LOADED BY MAJOR TRADE AREA, 1970-71

(tonnes)

Major Trade Area	Cargo Discharged	Cargo Loaded
North America & Hawaiian Islands	1,794,694	4,671,959
South America	47,346	602,461
Europe	782,657	16,135,460
U.S.S.R.	944	104,969
Africa	273,859	2,188,182
Asia	16,428,694	76,172,665
P.N.G., N.Z. and Pacific Islands	1,784,935	1,908,490
Indian Ocean Islands and Antarctic Area	639,355	29,516
Total	21,752,483	101,813,700

Source: CBCS Transport and Communication, 1970-71. Bulletin No. 62, Canberra, February 1973.

TABLE 2.19 - INTERNATIONAL AIR PASSENGER MOVEMENTS TO AND FROM AUSTRALIA

Route	Approx. distance (km)	Total passenger movements
Australia - New Zealand	2,400	437,356
Australia - U.K.	16,000	309,909
Australia - U.S.A.	12,800	98,900
Australia - Japan	9,500	55,858
All International	-	1,199,148

In addition, a total of 44,855 tonnes of freight and mail wdre loaded and discharged[(1),(2)], representing approximately 201.8 million tonne-kilometres attributable to Australia (again assuming an average trip length of 9,000 km).

2.6.3 Total International Transport

Australia's estimated international transport task is summarised in Table 2.20. The overwhelming importance of international shipping in the total freight task is illustrated by comparing Tables 2.20 and 2.17. The international shipping task, in terms of tonne-kilometres, may well be five times as great as the total domestic freight task indicated in Table 2.17. Its importance from the point of view of energy consumption is discussed in the next Chapter.

TABLE 2.20 - AUSTRALIA'S ESTIMATED INTERNATIONAL TRANSPORT TASK, 1970-71

Mode	Freight task (10^9 tonne-km)	Passenger task (10^9 passenger-km)
Sea	494.0	n.a.
Air	0.2	5.4
Total	494.2	n.a.

Source: Refer to text.

(1) CBCS Transport and Communication 1970-71, Bulletin No. 62, Canberra, February 1973.

(2) See footnote 2, page 28.

CHAPTER 3 DIRECT ENERGY CONSUMPTION

3.1 INTRODUCTION

In this Chapter, the direct energy consumption by categories of Australian transport is estimated. In most cases, assumptions have had to be made in order to allocate aggregate fuel sales to the various sub-divisions of the transport task; where this has occurred, the bases for the calculations are explained. In some cases, also, proxy estimates for specific consumption rates have been derived from overseas sources; again, where this has proved necessary, the sources are given.

A distinction should be drawn between direct and indirect energy consumption. This Chapter addresses the question of direct consumption, that is the amount of energy utilised by the various transport vehicles in performing their traffic task. This takes no account, however, of the amount of energy consumed by activities less directly associated with the transport task, but rightfully categorised as elements in the transport sector. These activities include, for example: vehicle construction, maintenance and sales; road, rail and airport construction; transport insurance; transport fuel refining and electricity generation; and other transport infrastructure activities. Indirect energy consumption of this nature is discussed in Chapter 4.

3.2 PUBLISHED ESTIMATES OF DOMESTIC TRANSPORT CONSUMPTION

The Department of National Development[(1)] estimated that in 1970-71, the domestic transport sector accounted for some 26 per cent of the national consumption of approximately 2200×10^{12} kJ. Information published

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(1) <u>Australia's Natural Resources</u>, Ministerial Statement and Review, September 1972.

by the Petroleum Information Bureau(1) and the Electricity Supply Association of Australia(2) provides a breakdown of this energy consumption by source. Thus, 542×10^{12} kJ are derived from petroleum products(3) and 2.4×10^{12} kJ from utility electricity, although the heat value of primary energy used for generating this electricity will be greater than this because of conversion losses. A further amount derives directly from coal, although in view of the small contribution to the total transport task provided by coal-burning vehicles, this amount is probably quite small.

The overwhelming importance of petroleum as a domestic transport fuel is clearly illustrated in the figures above. Over 90 per cent of direct transport energy appears to be derived from petroleum products. Motor spirits contribute 66 per cent of the energy arising from petroleum products used in transport, automotive diesel distillate 24 per cent, and aviation fuels nine per cent.

On a per capita basis, Australia consumes about 4×10^{7} kJ per capita/year in its domestic (internal) transport operations.

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(1) Petroleum Information Bureau, Oil and Australia 1972: The figures behind the facts. Melbourne 1972.

(2) Electricity Supply Association of Australia. The Electricity Supply Industry in Australia, Year 1970-71. Melbourne, 1972.

(3) Petroleum product sources may additionally be broken down as follows:

	(10^{12} kJ)
aviation gasoline	3.2
aviation turbine fuel	47.9
'super' motor spirit	290.7
'standard' motor spirit	65.0
power kerosene	2.6
automotive distillate	132.9
Total	542.3

Kalma et al[1] reported a more detailed study of energy directly consumed by transport in New South Wales in 1970-71. The total consumption of 189 x 10^{12} kJ was made up in the manner set out in Table 3.1. The figures are, however, based on New South Wales fuel sales, and therefore may include an element of consumption by certain interstate traffic categories.

3.3 ROAD TRANSPORT

3.3.1 Cars and Station Wagons

The analysis of energy consumption by cars and station wagons in Australia is based on information from the CBCS Survey of Motor Vehicle Usage for the year ended 30th September, 1971.

All the cars and station wagons surveyed during the CBCS study comprised petrol-driven vehicles, and, on the basis of reported estimates of fuel consumption and distance travelled, averaged 8.1 kilometres per litre. Little data exist to check this figure.

In view of the proportion of large-engined vehicles in Australia's car population, and the possibility of understatement on the part of CBCS respondents of fuel purchased, the estimate of 8.1 km/l may be a little high, but in the absence of better information, this figure is used in the subsequent calculations.

A further likely source of error, though insignificant, in using this estimate may occur due to a small proportion of cars and station wagons using fuels other than petrol (principally diesel and liquid petroleum gas).

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(1) Kalma, J.D., Aston, A.R., and Millington, R.J. <u>Energy Use in the Sydney Area</u>. Proc. Ecological Society of Australia, 7, 1973.

TABLE 3.1 - DIRECT ENERGY CONSUMPTION BY TRANSPORT IN NEW SOUTH WALES, 1970-71

(10^{12} kJ)

Mode	Direct Energy Consumption, New South Wales, 1970-71						
	Coal (direct)	Electricity	Aviation fuels	Motor spirit	Kerosene	Automotive Dist.	Total
Railways	3	1	-	-	-	8	12 (6.3)
Aviation	-	-	20	-	-	-	20(10.6)
Motor vehicles	-	-	-	119	1	37	157(83.1)
Total	3(1.6)	1(0.5)	20(10.6)	119(62.9)	1(0.5)	45(23.8)	189(100)

Note: Figures in brackets represent percentage of total energy consumption.

Source: Kalma, J.D., Aston, A.R., and Millington, R.J., Energy Use in the Sydney Area. Proc. Ecological Society of Australia, 7, 1973.

The CBCS estimates that the total number of kilometres travelled by cars and station wagons in Australia amounted to 63,801.9 million kilometres. This figure, divided by the average fuel consumption rate of 8.1 km/l, gives the total amount of fuel consumed by cars and station wagons in Australia: 7,876.8 million litres of petrol, resulting in a consumption of approximately 270.9×10^{12} kJ of energy.

Estimates of the distances travelled by these types of vehicle for particular purposes and by area of operation enable a breakdown to be made of this total energy consumption figure. Table 2.3 above shows how the total distance travelled is broken down according to these categories.

An initial matrix of energy consumption may be developed from Table 2.3 using the overall average petrol consumption rate of 8.1 kilometres per litre and the energy content of petrol. Table 3.2 shows this distribution of energy usage.

The assumption of a stable fuel consumption rate of 8.1 km/l for all areas of operation, however, is probably invalid. Using data from Britain(1) where it has been observed that fuel consumption rates (km/l) for typical rural conditions were approximately 30 per cent less than those under typical urban conditions, the energy consumption distribution of Table 3.2 may be amended to account for this order of difference between the two areas of operation. Table 3.3 shows the amended values.

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(1) Everall, P.F., The Effect of Road and Traffic Conditions on Fuel Consumption. Min. of Transp., RRL Report LR226, 1968.

TABLE 3.2 - INITIAL ESTIMATE OF ENERGY CONSUMPTION BY CARS AND STATION WAGONS, BY PURPOSE AND AREA OF OPERATION, 1970-71

(10^{12} kJ)

Purpose	Area of Operation				Total
	Capital City and Environs	Provincial Urban	Rest of State	Interstate	
Business	30.8 (11.4)	3.8 (1.4)	17.3 (6.4)	3.0 (1.1)	55.0 (20.3)
Paid to and from work	9.3 (3.4)	1.0 (0.4)	2.3 (0.8)	0.4 (0.1)	13.0 (4.8)
Unpaid to and from work	38.0 (14.0)	5.0 (1.8)	9.7 (3.6)	1.7 (0.6)	54.3 (20.0)
Private	72.5 (26.8)	12.8 (4.7)	46.7 (17.2)	16.6 (6.1)	148.6 (54.9)
Total	150.6 (55.6)	22.6 (8.3)	76.0 (28.1)	21.7 (8.0)	270.9 (100.0)

Note: Figures in brackets represent percentage of total energy consumption.

Source: Derived from Table 2.3, assuming an average petrol consumption rate of 8.1 km/l for all categories.

TABLE 3.3 - ADJUSTED ESTIMATE OF ENERGY CONSUMPTION BY CARS AND STATION WAGONS, BY PURPOSE AND AREA OF OPERATION, 1970-71

(10^{12} kJ)

Purpose	Area of Operation				Total
	Capital City and Environs(a)	Provincial Urban(a)	Rest of State(b)	Inter-state(b)	
Business	33.6 (12.4)	4.1 (1.5)	14.5 (5.4)	2.5 (0.9)	54.7 (20.2)
Paid to and from work	10.2 (3.8)	1.1 (0.4)	1.9 (0.7)	0.3 (0.1)	13.5 (5.0)
Unpaid to and from work	41.4 (15.3)	5.5 (2.0)	8.1 (3.0)	1.4 (0.5)	56.4 (20.8)
Private	79.0 (29.2)	14.0 (5.2)	39.2 (14.5)	13.9 (5.1)	146.1 (53.9)
Total	164.2 (60.6)	24.6 (9.1)	63.8 (23.6)	18.2 (6.7)	270.9 (100.0)

Note: (a) Based on a fuel consumption rate of 7.43 km/l.

(b) Based on a fuel consumption rate of 9.65 km/l.

Figures in brackets represent percentage of total energy consumption.

Source: See text.

A comparison of the two Tables shows the extent of the dependence of the distribution of energy use between the various tasks on the assumed fuel consumption. The change in fuel consumption between the two Tables, for example, is sufficient to increase the energy consumed in capital cities from 55.6 per cent to 60.6 per cent. It is unfortunate that more detailed information on average fuel consumption rates in urban areas does not exist for Australia. If it did, it may show that the amount of energy consumed in State capitals by cars and station wagons is different from that shown in Table 3.3, where the consumption rate is assumed to be 7.43 km/l, a value which cannot be confirmed by any Australian studies.

Table 3.3 is worthy of comment. Of the total energy consumption by cars and station wagons (essentially passenger vehicles) of 270.9×10^{12} kJ, 61 per cent is used in the major metropolitan areas, the capital cities and their environs as defined in the CBCS survey. Private car travel, that is excluding business and work trips, is by far the most significant single purpose category, contributing as much as 54 per cent of the total.

3.3.2 Motor Cycles

In 1970-71, motor cycles travelled an estimated 1.014×10^9 km(1) with an average petrol consumption rate of approximately 23.0 kilometres per litre(2). They thus consumed a total of 44.05 million litres, equivalent to 1.5×10^{12} kJ of energy.

This figure, though small, may be broken down by purpose and area of operation by using the figures for vehicle-kilometres quoted in Table 2.6. Table 3.4 shows this estimated subdivision.

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(1) CBCS Survey of Motor Vehicle Usage, 1971; unpublished figure subsequent to that in Preliminary Report.

TABLE 3.4 - ESTIMATED ENERGY CONSUMPTION BY MOTOR CYCLES, BY PURPOSE AND AREA OF OPERATION, 1970-71

(10^{12} kJ)

Purpose	Area of Operation				Total
	Capital City and Environs	Provincial Urban	Rest of State	Interstate	
Business	0.05	0.00	0.08	0.00	0.13
Paid to and from work	0.05	0.01	0.03	0.00	0.09
Unpaid to and from work	0.35	0.07	0.10	0.01	0.53
Private	0.41	0.07	0.25	0.05	0.78
Total	0.86	0.17	0.45	0.06	1.53

Source: See text.

3.3.3 Commercial Vehicles

The CBCS Survey of Motor Vehicle Usage again provides the basis for an estimation of energy consumption by commercial vehicles in 1970-71. Its estimates of fuel consumption by vehicle type and kind of fuel are shown in Table 3.5. In terms of energy consumption, the contribution of each type of vehicle is shown in Table 3.6.

The survey also provides a breakdown of fuel consumption by category of vehicle usage, from which the energy consumption figures of Table 3.7 have been calculated. It should be noted that ancillary freight transport contributes at least 60 per cent of the total energy consumption of commercial vehicles, and that petrol produces over 68 per cent of the total energy used by commercial vehicles.

TABLE 3.5 - TOTAL FUEL CONSUMPTION FOR COMMERCIAL VEHICLES, BY VEHICLE TYPE AND KIND OF FUEL, 1970-71

('000 litres)

Vehicle Type	Fuel Consumption		
	Petrol	Automotive Distillate	Other
Light commercial vehicles -			
Open	645,823	2,232	477
Closed	278,924	145	-
Trucks: rigid and articulated			
1 & under 4 tonnes(1)	658,934	23,135	2,396
4 & under 8 tonnes	381,132	131,002	636
Trucks: rigid -			
8 tonnes & over	116,873	189,777	3,382
Trucks: articulated -			
8 & under 12 tonnes	29,985	48,351	550
12 & under 16 tonnes	75,595	134,189	655
16 tonnes & over	44,219	393,715	177
Other truck type vehicles	18,016	5,223	-
Total	2,249,502	927,775	8,274

(1) Actually tons, but the two are practically equivalent (1 tonne = 1.016 ton).

Note: Distance travelled within each category derived from unpublished information from the CBCS Survey of Motor Vehicle Usage, 1971-73.

Source: Based in part on fuel consumption figures published in CBCS Survey of Motor Vehicle Usage, 12 months ended 30th September 1971 (Preliminary), Canberra, September 1973.

TABLE 3.6 - ESTIMATED TOTAL ENERGY CONSUMPTION FOR COMMERCIAL VEHICLES, BY VEHICLE TYPE, 1970-71

(10^{12} kJ)

Vehicle Type	Energy Consumption
Light commercial vehicles -	
Open	22.3
Closed	9.6
Trucks: rigid and articulated -	
1 and under 4 tonnes(1)	23.6
4 and under 8 tonnes	18.2
Trucks: rigid -	
8 tonnes and over	11.5
8 and under 12 tonnes	2.9
12 and under 16 tonnes	7.8
16 tonnes and over	16.7
Other truck type vehicles	0.8
Total	113.4

(1) See footnote to Table 3.5.

Source: Derived from Table 3.5.

TABLE 3.7 - ESTIMATED TOTAL ENERGY CONSUMPTION FOR COMMERCIAL VEHICLES, BY TYPE OF FUEL AND VEHICLE USAGE, 1970-71

(10^{12} kJ)

Type of Fuel	Vehicle Usage				Total
	Hire & Reward		Ancillary	Not Stated	
	1 Client	>1 Client			
Petrol	7.4 (6.5)	9.8 (8.6)	59.1 (52.1)	1.0 (0.9)	77.4 (68.3)
Automotive distillate	7.9 (0.0)	18.5 (16.3)	9.1 (8.0)	0.3 (0.3)	35.7 (31.5)
Other	0.0 (0.0)	0.2 (0.2)	0.1 (0.1)	0.0 (0.0)	0.3 (0.3)
Total	15.4 (13.6)	28.4 (25.0)	68.3 (60.2)	1.3 (1.1)	113.4 (100.0)

Note: Figures in brackets represent percentage of total energy consumption by commercial vehicles.

Source: CBCS Survey of Motor Vehicle Usage, 1971-73.

Table 3.8 indicates the estimated distribution of energy use between journey purpose and area of operation. The basis of its calculated figures is developed in Annex A, where the necessary assumptions are also noted. It shows that of the total energy consumption by (road) commercial vehicles, 113.4 x 10^{12} kJ, 87 per cent is used by business traffic. Energy consumption by laden vehicles is only 56 per cent of the total, indicating an 'unproductive' consumption of 44 per cent of the total.

Table 3.8 also shows that 46 per cent of the total consumption by commercial vehicles is used in capital city areas, 8 per cent in provincial urban areas, 34 per cent in rural areas and 13 per cent on interstate movements.

TABLE 3.8 - ESTIMATED ENERGY CONSUMPTION FOR COMMERCIAL VEHICLES, BY JOURNEY PURPOSE AND AREA OF OPERATION, 1970-71

(10^{12} kJ)

Purpose	Area of Operation				Total
	Capital City and Environs	Provincial Urban	Rest of State	Inter-state	
Laden Business	28.9 (25.5)	4.6 (4.0)	19.1 (16.9)	10.3 (9.1)	62.9 (55.5)
Unladen Business	15.5 (13.7)	2.8 (2.5)	14.7 (13.0)	2.9 (2.5)	98.8 (31.6)
Total Business	44.4 (39.2)	7.4 (6.5)	33.8 (29.8)	13.2 (11.6)	98.8 (87.1)
Paid to and from work	1.0 (0.9)	0.1 (0.1)	0.3 (0.3)	0.0 (0.0)	1.5 (1.3)
Unpaid to and from work	2.6 (2.3)	0.5 (0.4)	1.2 (1.1)	0.2 (0.1)	4.4 (3.9)
Private	3.9 (3.4)	0.9 (0.8)	3.0 (2.7)	0.9 (0.8)	8.8 (7.7)
Total	51.9 (45.8)	8.9 (7.8)	38.3 (33.8)	14.3 (12.6)	113.4 (100.0)

Note: Figures in brackets represent percentage of total commercial vehicle consumption.

Source: See text.

3.3.4 Buses

The ABS Bus Fleet Operations Survey[1] provides an estimate of the total annual fuel consumption of bus fleets, by major usage of fleet, type of fuel and state of registration. Its figures, converted to litres, are shown in Table 3.9 and the energy equivalence is shown in Table 3.10. The latter indicates that only 7.2×10^{12} kJ are used by buses in Australia; i.e., only 1.8 per cent of the total energy consumed by road vehicles.

TABLE 3.9 - TOTAL ANNUAL FUEL CONSUMPTION OF BUS FLEETS, BY STATE OF REGISTRATION, MAJOR USAGE OF FLEET AND TYPE OF FUEL, 1970-71

(million litres)

State of Registration	Major Usage of Fleet			
	Primarily Hire and Reward		All Usages	
	Petrol	Diesel	Petrol	Diesel[1]
NSW (incl. ACT)	12.3	56.8	15.5	56.8
VIC	20.9	17.3	24.5	17.3
QLD	7.7	17.7	9.1	17.7
SA	5.5	14.1	6.8	14.1
WA	5.5	13.2	6.8	13.2
TAS	7.7	1.4	8.6	1.4
NT	0.9	0.5	0.9	0.5
Australia	60.5	121.3	72.3	121.7

(1) A small percentage of diesel fuel is used for purposes other than primarily for hire and reward; this accounts for the apparently anomalous totals given for columns 2 and 4. The apparent identity of complementary entries in the two columns is due to rounding.

Source: ABS Bus Fleet Operations Survey, Twelve Months Ended 30th June 1971. Reference No. 14.18.

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(1) Australian Bureau of Statistics. Bus Fleet Operations Survey, Twelve Months Ended 30th June 1971. Reference No. 14.18., Canberra, January 1974.

TABLE 3.10 - TOTAL ANNUAL ENERGY CONSUMPTION OF BUS FLEETS, BY STATE OF REGISTRATION, MAJOR USAGE OF FLEET AND TYPE OF FUEL, 1970-71

(10^{12} kJ)

State of Registration	Major Usage of Fleet					
	Primarily Hire & Reward			All Usages		
	Petrol	Diesel	Total	Petrol	Diesel(1)	Total
N.S.W. (incl. A.C.T.)	0.42	2.19	2.61	0.53	2.19	2.72
VIC.	0.72	0.67	1.39	0.84	0.67	1.51
QLD.	0.26	0.68	0.94	0.31	0.68	0.99
S.A.	0.19	0.54	0.73	0.23	0.54	0.77
W.A.	0.19	0.51	0.70	0.23	0.51	0.74
TAS.	0.26	0.05	0.31	0.30	0.05	0.35
N.T.	0.03	0.02	0.05	0.03	0.02	0.05
Australia	2.08	4.67	6.75	2.49	4.69	7.18

(1) See footnote to Table 3.9.

Source: Refer to text.

Thirty-eight per cent of the total energy consumption by buses occurs in New South Wales and the Australian Capital Territory.

A further subcategorisation of energy usage by buses may be developed from ABS estimates of vehicle-kilometres by area of operation, identifying the contribution of the major metropolitan areas: Table 3.11 shows this, with figures again based on the assumption that energy consumption rates (kJ/km) are 30 per cent greater in urban areas than in urban areas. For convenience, Table 3.12 summarises this information, and shows that hire and reward traffic contributes by far the greatest portion of energy consumption and, somewhat surprisingly, that traffic in areas other than the capital cities contributes as much as 38 per cent of the total energy consumption by buses in Australia.

TABLE 3.11 - ENERGY CONSUMPTION OF BUS FLEETS, BY AREA OF OPERATION AND MAJOR USAGE OF FLEET, 1970-71

(10^{12} kJ)

Area of Operation	Major Usage of Fleet: Primarily Hire and Reward	Major Usage of Fleet: All Usages
NEW SOUTH WALES		
Sydney	1.7	1.7
Rest of NSW (incl. ACT)	1.0	1.0
TOTAL	2.6	2.7
VICTORIA		
Melbourne	0.9	1.0
Rest of Victoria	0.5	0.5
TOTAL	1.4	1.5
QUEENSLAND		
Brisbane	0.5	0.6
Rest of Queensland	0.4	0.4
TOTAL	0.9	1.0
SOUTH AUSTRALIA		
Adelaide	0.5	0.5
Rest of South Australia	0.3	0.3
TOTAL	0.7	0.8
WESTERN AUSTRALIA		
Perth	0.5	0.5
Rest of Western Australia	0.2	0.2
TOTAL	0.7	0.7
TASMANIA		
Hobart	(1)0.1	0.1
Rest of Tasmania	(1)0.2	0.2
TOTAL	(1)0.3	0.3
NORTHERN TERRITORY		
Darwin	0.0	0.0
Rest of Northern Territory	0.0	0.0
TOTAL	0.1	0.1
TOTAL - AUSTRALIA	6.7	7.1

(1) Veh-km not published for reasons of confidentiality. Hire and reward energy consumption assumed equal to that for all usages.

Source: ABS Bus Fleet Operations Survey, Twelve Months Ended 30th June, 1971. Ref. No. 14.18, Canberra, Jan. 1974.

TABLE 3.12 - SUMMARY OF ENERGY CONSUMPTION BY BUS FLEETS, BY AREA OF OPERATION AND MAJOR USAGE OF FLEET, 1970-71

(10^{12} kJ)

Area of Operation	Major Usage of Fleet	
	Primarily Hire & Reward	All Usages
Capital cities	4.2	4.4
Rest of States	2.6	2.7
Total - Australia	6.7	7.1

Source: Developed from Table 3.11, assuming that energy consumption rates (kJ/km) are 30% greater in urban areas than in urban areas.

3.3.5 Trams

Only Melbourne and Adelaide were provided with tram services in 1970-71. The total number of tram kilometres travelled was 25,806 million(1). The annual report for 1970-71 of the Melbourne and Metropolitan Tramways Board quotes for its trams a specific electrical energy consumption rate of 11.196 MJ per tram-mile (6.957 x 10^3 kJ per tram-kilometre), a figure which, for the purposes of this report, has to be converted to account for the energy loss involved in converting coal into electricity. Taking, from Fryer's study(2), a value for conversion losses of 74 per cent, it may be concluded that Melbourne's trams utilise approximately 26.76 x 10^3 kJ of primary energy for every tram-kilometre travelled.

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(1) CBCS Transport and Communication, 1970-71. Bulletin No. 62, Canberra, February 1973.

(2) Fryer, J.J. Energy for Australia's Future and its Implications for Marine Waters. Proc. Institution of Engineers, Thermo-Fluids Conference on Thermal Discharge, Sydney, December 1972.

No similar figures exist for Adelaide. It is probably reasonable to assume, however, that its trams operate with similar specific energy consumption rates, and therefore that the total (primary) energy consumption of trams in Australia amounts to 0.69 x 10^{12} kJ (25.806 x 10^6 km at 26.758 x 10^3 kJ per km).

3.3.6 Total Road Transport

The analysis so far has indicated aggregate values for direct energy consumption by road transport in Australia in 1970-71 as shown in Table 3.13.

TABLE 3.13 - DIRECT ENERGY CONSUMPTION BY TOTAL AUSTRALIAN ROAD TRANSPORT, 1970-71

Mode	Energy Consumption (10^{12} kJ)
Cars and station wagons	270.9
Motor cycles	1.5
Commercial vehicles	113.4
Buses	7.1
Trams	0.7
Total	393.6

Source: Refer to text.

Total fuel sales(1) of motor spirit (petrol) and automotive distillate amount to an equivalent of approximately 489 x 10^{12} kJ. These derived estimates of energy consumption indicate a difference of 95 x 10^{12} kJ. Some part of this difference may be transport energy but another part is the energy consumption of a range of uses including power boats, tractors, construction equipment, motor mowers, etc. No data are

(1) Petroleum Information Bureau. Oil and Australia, 1972: The Figures Behind the Facts. Melbourne, December 1972.

available to make allowance for these categories of use. Accordingly no adjustment to these derived estimates is possible, nor is it necessary.

3.4 RAIL TRANSPORT

3.4.1 Urban Rail Services

The total heat value of electricity sold for traction purposes in Australia amounted to 2.4×10^{12} kJ in 1970-71[1], equivalent to a primary energy consumption of about 9.23×10^{12} kJ. These purposes are essentially confined to tram services in Melbourne and Adelaide and suburban rail services in Melbourne and Sydney. Subtracting the energy consumption of the trams (0.69×10^{12} kJ, estimated above), the remainder of the total energy consumption may be assumed to be attributed to the urban passenger rail services in Melbourne and Sydney, approximately 8.54×10^{12} kJ.

All other cities with urban rail services use non-electric locomotives and publish no estimates of their energy usage. The only way of estimating this, given the available information, is to assume that electric and non-electric traction utilise the same energy input per train-km and then to multiply the energy consumption for Melbourne's and Sydney's services by a factor approximating the likely ratio of energy usage. If this factor can be assumed to be based on service train-kilometres, the amount of energy consumed by urban passenger rail services in cities other than Melbourne and Sydney is approximately 2.91×10^{12} kJ. Thus, the total primary energy consumption of urban rail services in Australia is approximately 11.45×10^{12} kJ.

The estimate of 11.45×10^{12} kJ is, of course, not an accurate one because of the assumptions used to derive it. Although it is likely that the use of different power units in Australian cities is more

(1) Electricity Supply Association of Australia. The Electricity Supply Industry in Australia, Year 1970-71. Melbourne, 1972.

directly related to local prices of supplied energy, rather than to the similarity of energy conversion efficiencies provided by the units themselves, no information exists to suggest large differences between the energy requirements per train-km of electric and non-electric urban systems.

The contribution to total energy consumption by urban rail services of the Sydney and Melbourne electric systems is, however, large and is estimated with some degree of confidence. It is likely, therefore, that the figure of 11.45×10^{12} kJ for the total lies within 10-15 per cent of the actual value.

As mentioned in Chapter 2, it is assumed in this study that the energy consumed by suburban rail services is devoted solely to the carriage of passengers. The small amount of mail and parcels traffic is regarded only as a secondary function of these urban passenger services.

3.4.2 Non-Urban Rail Services

Figures derived from the annual reports of the various State and Commonwealth railway authorities, and summarised by the CBCS(1), show that Government rail services directly consumed 118,355 tonnes of coal, approximately 77.28 million litres of oil, and 110,722 litres of petrol, equivalent, in total, to approximately 23.4×10^{12} kJ. Subtracting the assumed energy consumption of urban non-electric services, 2.9×10^{12} kJ, the total consumption of non-urban Government services was about 20.5×10^{12} kJ in 1970-71.

The Government services, examined above, move both passengers and freight. It is necessary, therefore, to split the energy consumed by those services into the

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(1) CBCS Transport and Communications, 1970-71. Bulletin No. 62, Canberra, February, 1973.

respective shares, an exercise which depends critically on the conceptual basis for determining the energy requirements of each category. Whilst a certain number of trains are solely freight-carrying, goods and mail are also carried on passenger services. The annual reports of the respective operating authorities do, however, provide a means of estimating the shares on the basis of the number of train-kilometres travelled by each type of service. In 1970-71, 35.167 million train-kilometres were performed by Government country passenger trains, 2.408 million by mixed service trains, and 79.606 million by goods trains. Assuming the mixed service train-kilometres to be split evenly between passenger and goods categories, it is estimated that the total energy consumption by Government non-urban services, 20.5×10^{12} kJ, is made up of 6.4×10^{12} kJ by passenger services and 14.1×10^{12} kJ by goods services.

The validity of these estimates, however, depends on the assumption that the performance of an average goods train-kilometre requires essentially the same amount of energy as does that of an average passenger train-kilometre.

There is no available estimate of energy usage by private railways in Australia. These services contributed fully 35 per cent of the rail freight task in 1970-71. With the available information, the only way of determining their contribution of energy consumption is to factor the Government rail freight consumption according to the tonne-kilometres performed (see Table 2.14). On this basis, the energy consumption by private railways, all of which are devoted solely to goods movements, is calculated as 7.7×10^{12} kJ (i.e., 35/65 of 14.1×10^{12} kJ).

The validity of the assumption that rates of energy usage (i.e., per tonne-kilometre) are similar for private and Government freight services is difficult to determine. The private railways generally haul heavy mineral loads over large distances and in doing so probably derive economies of scale from the point of view of fuel usage. But they also operate with lower back-haul loadings. Overall, it is probably reasonable to assume similar energy-performance relationships.

Table 3.14 illustrates the estimates relating to energy consumption by Government and private non-urban rail services.

TABLE 3.14 - ENERGY CONSUMPTION BY GOVERNMENT AND PRIVATE NON-URBAN RAIL SERVICES, 1970-71

(10^{12} kJ)

	Government Services	Private Services	Total
Passenger	6.4	-	6.4
Freight	14.1	7.7	21.8
Total	20.5	7.7	28.2

Source: Refer to text.

3.5 DOMESTIC AIR SERVICES

The Petroleum Information Bureau's(1) figures for the consumption of oil products in Australia in 1970-71 show a consumption of 95.393 million litres of aviation gasoline and 1,321.472 million litres of aviation turbine fuel (of which 713.090 million litres were subject to excise tax, and were therefore utilised by domestic aircraft). The heat value of the gasoline and excised turbine fuel is approximately 29.6 x 10^{12} kJ.

(1) Petroleum Information Bureau. Oil and Australia, 1972: The Figures Behind the Facts. Melbourne, December 1972.

There is no published information relating to the likely contribution of non-scheduled aircraft movements to this total energy consumption by domestic aircraft. A reasonable division, in view of the nature of the aircraft used to generate the two types of movements[1], is to ascribe usage of aviation turbine fuel to the scheduled services alone. Assuming that the quantity of aviation turbine fuel consumed by the non-scheduled services is roughly equal to the quantity of aviation gasoline consumed by the scheduled services suggests that the consequent error in estimating fuel usage by the scheduled services is unlikely to be large. Thus, the total energy usage of the scheduled services is estimated as 25.9×10^{12} kJ (the heat content of 713.09 Ml of aviation turbine fuel) with the energy usage of non-scheduled services being ignored in this analysis.

Again, problems arise in allocating this energy consumption to passenger and freight operations. The majority of air freight (approximately two thirds of the total of 101,296 tonnes, including mail, in 1970-71) is carried on passenger-carrying aircraft. Three possible bases for subdividing the total energy consumption are:

(i) according to the revenue derived from each category of operation;

(ii) according to tonne-kilometres, by determining the equivalent weight of each passenger and the services (seat, floor, buffet, cabin staff, etc.) provided for him; and,

(iii) by assuming that cargo is mainly carried in surplus aircraft space or services required solely for the carriage of passengers (i.e., that the marginal energy cost of freight is almost zero.

(1) CBCS Transport and Communication 1970-71, Bulletin No. 62, Table No. 89.

The validity of the first method depends on whether or not the airlines' pricing policy is directly related to the respective cost of fuel used to carry passengers and freight. This is doubtful. A study of airline pricing procedures cannot be made here, but it is likely that the price charged for the carriage of an item of freight exceeds the marginal cost of moving that item. It is more likely that the airlines essentially regard the passenger market as that which determines the supply of air services.

The second means of allocating energy is probably the most rational. It is based on the reasonable premise that the use of energy for each category is directly related to the weight component of the respective services. TAA's experience with the Fokker F27 Friendship aircraft in its QC (Quick Change) configuration gives some indication of the effective conversion between passenger-kilometres and tonne-kilometres. Loaded but without fuel in its palletised passenger configuration, an F27 weighs 14,810 kg (assuming a 63 per cent passenger load factor, which corresponds to a load of 23 passengers). In its cargo configuration it weighs 15,117 kg (at 63.3 per cent weight load factor). Assuming the average weight of passenger plus luggage is 90 kg, 1 tonne-kilometre is therefore found to be approximately equivalent to 7 passenger-kilometres. Of course, the F27 may not be indicative of the same ratio for other aircraft, and the point should be made that other all-cargo aircraft do operate scheduled services, but no other information exists to determine a more typical figure based on system-wide comparisons.

The third method derives some justification from the fact that airline capacity is essentially provided in Australia to meet the passenger market. The aircraft in use in Australia are of optimum design for passenger carriage over the medium ranges typical to Australian inter-city traffic, and cargo capability tends to be a secondary consideration. It must, however, be argued that the energy used in aircraft, particularly on take-off, a period of concentrated energy use, is physically directed towards moving a combined cargo of passengers and freight, and that (again, principally on take-off) the contribution of each to the total energy used is closely related to the comparative weights.

It is therefore assumed, in subdividing total domestic airline energy use, that it is permissible to allocate on the basis of passenger- or tonne-kilometres, with one tonne-kilometre equivalent to 7 passenger-kilometres. Doing so gives a breakdown of energy usage as shown in Table 3.15.

TABLE 3.15 - ENERGY USE BY DOMESTIC AIR SERVICES, 1970-71

Type of traffic	Task performed	Energy use (10^{12} kJ)
Passenger	4,973 M pass-km	23.1
Freight	87 M tonne-km	2.8
Total		25.9

Source: Refer to text.

3.6 COASTAL SHIPPING

The energy consumption of shipping is extremely difficult to estimate. Whilst the Petroleum Information Bureau publishes statistics of bunker fuel sales, there is no means of determining the proportions of the total used for domestic coastal traffic and international shipping movements.

Nor is it possible to determine accurately energy usage from the other end, as it were, by establishing a value for the specific fuel consumption rate by a typical coastal vessel and multiplying this by the estimated ship-kilometres travelled. However, it has been suggested[1] that a 15,000 tonne (10,000 tonnes DWT) containership achieves a propulsion efficiency of approximately 65 cargo tonne-kilometres per litre of fuel consumed (that is, per 38,000 kJ of fuel energy consumed, approximately).

Applying this figure to the total task performed by coastal shipping in 1970-71, 71,682 million tonne-kilometres, gives a total energy consumption of approximately 41.9×10^{12} kJ.

3.7 TOTAL DOMESTIC TRANSPORT

The preceding discussion and analysis is summarised in Table 3.16, which shows the breakdown of direct energy consumption by domestic transport operations. It is important to bear in mind, though, that the table does not show the total energy use attributable to each transport mode. Indirect energy consumption, of some significance, is discussed in Chapter 4.

Referring to direct energy consumption alone for the moment, it is interesting to note the importance of road transport, and particularly the contribution of personal travel, within the domestic energy economy. Road transport uses about 79 per cent of all domestic transport energy, and as much as 55 per cent of the total is attributable to personal travel by the private car. Of the energy used by private cars and station wagons (referring to Table 3.3), approximately 55 per cent is consumed for purposes other than business

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(1) Rice, R.A., System Energy as a Factor in Considering Future Transportation. Paper presented to ASME Winter Annual Meeting, New York, Nov.-Dec. 1970.

travel or the journey to work; i.e., for social, recreational and shopping travel, representing 30 per cent of the total domestic transport consumption.

The contributions of the rail and air modes to energy consumption for both personal travel and freight movement are small compared with those of the two main road transport modes, cars and commercial vehicles and (for freight) coastal shipping, although energy use for personal travel by air is becoming significant in the context of the rapid growth in air passenger travel in the last decade.

The importance of car and air transport modes for personal mobility is further discussed in Chapter 5, when the energy consumption by each mode is related to the task which it performs and comments are made on likely trends in energy consumption.

Table 3.16 may be compared with estimates of the modal shares of direct transport energy consumption in the US in 1970 provided by Hirst[1] and Ellis[2] and shown in Table 3.17. Most of the differences between the Australian estimates and those for the US can be explained by the comparatively higher degree of urbanisation in Australia, by differences in the levels of provision of certain modes, and by the more advanced development of air transport (both passenger and freight) in the US.

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(1) Hirst, E., Energy Intensiveness of Passenger and Freight Transport Modes, 1950-1970. Report ORNL-NSF-68-44, Oak Ridge National Laboratory, Oak Ridge, Tennessee, April 1973.

(2) Ellis, J.C., Energy and the Automobile. Paper presented at the National Convention of SAE-Australasia, Melbourne, November 1973.

TABLE 3.16 - SUMMARY OF ESTIMATED DIRECT ENERGY CONSUMPTION BY MODES OF DOMESTIC TRANSPORT, 1970-71

(10^{12} kJ)

Mode	Personal Travel			Goods Movement			TOTAL
	Urban	Non-Urban	Total	Urban	Non-Urban	Total	
Cars and station wagons	188.8 (38)	82.0 (16)	270.9 (55)	-	-	-	270.9 (55)
Motor cycles	1.0 (<1)	0.5 (<1)	1.5 (<1)	-	-	-	1.5 (<1)
Commercial vehicles	9.0 (2)	5.6 (1)	14.7 (3)	51.8 (10)	47.0 (9)	98.8 (20)	113.4 (23)
Buses	4.4 (<1)	2.7 (<1)	7.1 (1)	-	-	-	7.1 (1)
Tram	0.7 (<1)	-	0.7 (<1)	-	-	-	0.7 (<1)
Total Road	203.9 (41)	90.8 (18)	294.9 (59)	51.8 (10)	47.0 (9)	98.8 (20)	393.7 (79)
Train	11.5 (2)	6.4 (1)	17.9 (4)	-	21.0 (4)	21.8 (4)	39.7 (8)
Air	-	23.1 (5)	23.1 (5)	-	2.8 (<1)	2.8 (<1)	25.9 (5)
Sea	-	-	-	-	41.9 (8)	41.9 (8)	41.9 (8)
TOTAL DOMESTIC	215.4 (43)	120.3 (24)	335.9 (67)	51.8 (10)	113.5 (22)	165.3 (32)	501.2 (100)

Note: Figures in parentheses represent percentage of total.

Source: Summary of estimates referred to in the text.

TABLE 3.17 - ESTIMATES OF THE MODAL SHARES OF PRIMARY ENERGY DIRECTLY CONSUMED BY TRANSPORT IN THE US, 1970

Mode	Percentage of total (direct) transport energy consumption		
	Hirst (1973)		Ellis (1973)
Automobiles - urban	34.2		
- intercity	20.0	54.2	53
Trucks - intercity freight	6.9		
- other	14.2	21.1	22
Buses	0.8	0.8	—
Total Road		76.1	75
Railroads - freight	3.1		
- passenger	0.2	3.3	3
Aircraft - freight	0.8		
- passenger	5.6		
- general aviation	0.6		
- military	3.8	10.8	13
Pipelines	1.2	1.2	-
Marine	-		4
Other	8.6	8.6	5
Total (all modes)	100.0	100.0	100

Sources: Hirst, E., Energy Intensiveness of Passenger and Freight Transport Modes, 1950-1970. Report ORNL-NSF-68-44, Oak Ridge National Laboratory, Oak Ridge, Tennessee, April 1973.

Ellis, J.C., Energy and the Automobile. Paper presented at the National Convention of SAE-Australasia, Melbourne, November 1973.

3.8 INTERNATIONAL TRANSPORT

3.8.1 Introduction

As is mentioned in Chapter 2, the national pattern of energy consumption by transport is not complete unless consideration is given to the share of international air transport and shipping (each discussed separately in the following sections) which is attributable to Australia. Australia generates and attracts both passenger and freight movements by each of these modes, and it is appropriate to allocate to Australia a portion of their energy use.

It is difficult, however, to argue a conceptual yet workable basis for such apportioning: for example, (i) should all movement into and out of Australia be charged to Australia's energy account; or, (ii) should only those movements into Australia or only those movements out of Australia be charged; or, alternatively, (iii) should Australia be charged with one half of the total of all movements into and out of Australia? Taking a more specific example, is it appropriate to regard the shipment of iron ore to Japan as taking place solely for the export benefit of Australia, solely for the import benefit of Japan, or as a combination of each? This latter case suggests that for the purpose of establishing balanced international accounts of energy usage, it would be appropriate to divide the energy used in such tasks by two; i.e., by assuming that half of the energy used in such movements is attributable to each country.

The question is complicated by the fact that purchases of fuel for international movements do not always take place in the country to which the task is attributable. It is common, for example, for vessels to load up in the Middle East or Singapore with sufficient fuel for the voyage to Australia and back, with no associated demand for bunkering in Australian ports. In the case of shipping, it is virtually impossible to determine Australia's share of the amount of fuel purchased at international supply terminals or made by spot purchases throughout the world.

3.8.2 International Shipping

Rice[1] has suggested that a 100,000 tonne supertanker shows a propulsion efficiency of approximately 400 cargo tonne-km per litre of fuel consumed (that is, per 38,000 kJ of fuel energy consumed approximately).

Applying this figure to the total task performed (from Chapter 2) gives a total energy consumption of 47×10^{12} kJ for international freight shipping.

If, however, it is assumed that the specific energy consumption rate of the vessels used for Australia's shipping task is closer to that of a 15,000 tonne containership (of the sort assumed for the domestic shipping task), the total consumption is approximately 290×10^{12} kJ.

The actual figure undoubtedly lies between the two extremal estimates, and for the purpose of comparison, a rough approximation of 200×10^{12} kJ is taken in the ensuing discussion. It should be recognised that such an estimate is little better than an educated guess, based on broad assumptions concerning average trip length and specific fuel consumption rates.

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(1) Rice, R.A., System Energy as a Factor in Considering Future Transportation. Paper presented to ASME Winter Annual Meeting, New York, Nov.-Dec. 1970.

3.8.3 International Air Services

In the following analysis, it is implicitly assumed that sales of excise-exempt aviation turbine fuel in Australia represent Australia's share of the total demand for international air transport. This may, of course, not necessarily be so, and it should be recognised that estimates based on this assumption may err on the low side, both because of Qantas' fuel purchases in other countries and because of the contribution of other airlines to the movement of freight and passengers to and from Australia.

The heat equivalent of the excise-exempt turbine fuel sold in Australia (608.382 million litres) is approximately 23.0×10^{12} kJ. In order to split this consumption into that associated with passenger and freight movements, it is again assumed that 1 tonne-kilometre is equivalent to 7.0 passenger-kilometres, and that weight provides the best basis for such an allocation. 44,855 tonnes of freight (including mail) were loaded and discharged at Australia's international air terminals in 1970-71, and 1,199,148 passengers embarked and disembarked. Thus, the energy usage is separated in the ratio of 171,307 to 44,855 (passengers to freight), giving 18.2×10^{12} kJ attributable to passengers and 4.8×10^{12} kJ attributable to freight.

3.8.4 Total International Transport

The order-of-magnitude estimates of energy usage by international movements of passengers and freight by sea and air are brought together in Table 3.18. They show that energy use by air transport is overshadowed by the large consumption by international freight shipping.

TABLE 3.18 - SUMMARY OF ESTIMATED DIRECT ENERGY CONSUMPTION BY AUSTRALIA'S INTERNATIONAL TRANSPORT MOVEMENTS, 1970-71

(10^{12} kJ)

Mode	Passenger	Freight	Total
Shipping	n.a.(1)	200	n.a.
Air	18.2	4.8	23.0
Total	n.a.	204.8	n.a.

(1) The required information is unavailable.

Source: Refer to text.

Comparing Table 3.16 with Table 3.18 above, it may be observed that international shipping uses about as much primary energy as is used for travel by private car within Australia. It is second only to car travel as a consumer of energy. It is also interesting, though perhaps not surprising, to note that the two modes which use the largest amounts of energy are those which, at the moment, rely on petroleum products for their fuel. This point is developed further in Chapter 5.

CHAPTER 4 INDIRECT ENERGY CONSUMPTION

Chapter 3 discusses the primary energy used directly in moving passengers and freight by the various modes of transport in Australia. But its estimates do not include consideration of the amount of energy consumed by the infrastructure associated with each mode. For the purposes of national energy accounting this category of energy usage is concealed within industrial and commercial usage categories, but inter-modal comparisons of transport energy usage cannot be fully made if recognition is not given to the fact that associated with private car travel, for example, is a series of economic activities necessary to provide the means and the facilities for such travel. It would not be right to suggest that the efficiency in terms of task performance with which each mode utilises primary energy is related solely to its direct energy usage. Rather, if it may be assumed that infrastructure usage is also directed towards the output task, full consideration must be given to both direct and indirect usages.

It could be argued, of course, that energy used in, for example, the manufacture of cars is directed towards more than the sole objective of performing the car's traffic task; that such energy usage contributes to employment and national economic development. Nevertheless, it must be claimed that if intermodal comparisons of energy usage are to be attempted, the implications of policy measures designed to reduce energy consumption by any particular mode, or to achieve economies of energy use by shifting the demand for travel by particular modes through the use of pricing measures, will apply as much to the infra-structure activities, and their associated energy demands, as to direct energy usage by each mode. On the other hand, indirect energy consumption may well be relatively insensitive to the task performed by a particular mode. Thus, energy split and modal split may exhibit independent behaviour for some modes. The need for an examination of indirect energy consumption, however, remains valid.

What, specifically, is meant by indirect energy usage? The following list may be incomplete, but essentially indirect energy usage by the various transport modes mainly comprises the consumption of primary energy by the following activities:

<u>Cars, station wagons and commercial vehicles</u> - the manufacture, distribution and sales of vehicles and parts, vehicle maintenance, fuel production, refining and retailing, the provision of roadspace and associated works, insurance, medical, police and other facilities and services related to road travel;

<u>Trams and trains</u> - vehicle manufacture, service administration, vehicle and track maintenance, and electricity and fuel distribution;

<u>Aircraft</u> - manufacture (whether overseas or not), distribution, sales and maintenance, airport construction and operation, the provision of insurance, medical and emergency services, the provision and operation of navigational aids, and the production and distribution of fuels;

<u>Shipping</u> - ship construction, distribution and maintenance, port construction and operation, insurance, medical and other services, and the production and distribution of fuels.

It has not been possible, in this report, to provide an analysis of energy usage by each of these infrastructure activities. In the only Australian study in this field, Beck[1] has examined the amount of energy required to produce a typical Australian passenger car. He estimates this to lie between 48×10^{12} kJ and 60×10^{6} kJ by assuming that the energy required to assemble a "knocked down" motor car on importation is negligible compared with the energy required to construct and assemble a locally produced vehicle. 312,583 new locally produced cars and station wagons were registered in Australia in 1970-71. If each required 54×10^{6} kJ to manufacture, the total energy consumed is approximately 16.9×10^{12} kJ per annum.

No Australian study provides figures for the energy consumption by other activities associated with the car mode or by activities associated with other modes. A few US estimates are available, solely relating to the private car. The results of the most recent study are shown in Table 4.1. In view of the similarities of car ownership and infrastructure associated with the car between the US and Australia, it is probably reasonable to assume that the indirect consumption by the Australian car bears a similar relationship with direct consumption to that shown for the US in the Table. The results of such an assumption for Australia are shown in Table 4.2.

Beck's figure for the energy consumed in producing passenger cars is approximately two-thirds of that produced under the assumption of similarity with American conditions. Whether or not the difference is explained by differences in approach or by fundamental

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(1) Beck, J.A., <u>Energy Used in Producing Passenger Motor Cars</u>. Bulletin No. 10, Transport Section, Department of Civil Engineering, University of Melbourne, 1973.

TABLE 4.1 - ESTIMATED INDIRECT ENERGY CONSUMPTION BY CARS IN THE US, 1970

Category	Energy consumption (10^{15} kJ	Percentage of total (direct & indirect) consumption
Petrol refining and retail sales	2.18	14.3
Oil consumption, refining and retail sales	0.12	0.8
Car manufacturing	0.84	5.5
Car retail sales	0.22	1.4
Repairs, maintenance, parts	0.39	2.6
Parking construction and maintenance	0.46	3.0
Tyre manufacturing and retail sales	0.24	1.6
Insurance	0.33	2.2
Highway construction and maintenance	1.06	6.9
Total - Indirect energy consumption	5.84	38.2
Fuel consumption (direct energy consumption)	9.43	61.8
Total - Direct and Indirect consumption	15.27	100.0

Source: Hirst, E., and Herendeen, R. Total Energy Demand for Automobiles. SAE Paper 730065, International Automotive Engineering Congress, Detroit, January 1973.

TABLE 4.2 - ESTIMATED INDIRECT CONSUMPTION BY CARS IN AUSTRALIA, 1970-71

(10^{12} kJ)

Category	Total energy consumption
Petrol refining and retail sales	66
Oil consumption, refining and retail sales	4
Car manufacturing	26 (1)
Car retail sales	7
Repairs, maintenance, parts	12
Parking construction and maintenance	14
Tyre manufacturing and retail sales	7
Insurance	10
Highway construction and maintenance	32
Total - Indirect energy	178
Direct energy	287
Total	465

(1) Compare with the estimate derived from Beck's work of approximately 17 x 10^{12} kJ.

Source: Developed by applying the estimates of Table 4.1 to estimated direct energy usage in Australia.

differences between the two countries is difficult to say, but the important point about Table 4.2 concerns the importance of indirect energy consumption in relation to the direct consumption of energy by cars in Australia. Indirect consumption is a very significant category, contributing an amount equivalent to over 60 per cent of the direct energy consumption attributable to cars.

It is unlikely that indirect energy associated with other modes is of the same relative importance as that for private cars. No information exists, though, to enable a full analysis to be made. If one were to hazard a guess at the indirect energy use of other modes as a percentage of the total (direct and indirect) usage, the following ranges might be appropriate:

Mode	Indirect energy as a percentage of total energy
Commercial vehicle	25-40
Rail	15-35
Air	45-60
Sea	5-20

Obviously, further studies need to be made to establish better estimates of indirect energy consumption by all modes of transport in Australia. The scale of this category for cars in the US, however, suggests that it is of considerable importance in the total energy budget.

CHAPTER 5 EFFICIENCY OF ENERGY USAGE

5.1 INTRODUCTION

In this Chapter, the estimates of traffic task from Chapter 2, and those of direct energy consumption from Chapter 3 are combined to give an indication of the relative efficiency with which each category of Australian transport utilises primary energy in the performance of its particular task. This efficiency is commonly measured in terms of the amount of energy required to perform one tonne-kilometre or one person-kilometre, and is often called the 'energy-intensiveness' of the respective modes. The term 'propulsion-efficiency' is also commonly quoted in similar studies; this represents the number of tonne-kilometres or passenger-kilometres performed for each unit of primary energy consumed; i.e., the 'propulsion-efficiency' of any mode is the inverse of its 'energy-intensiveness'. In this study, the 'energy-intensiveness' is used as a measure of energy utilisation efficiency.

A particularly important conceptual point relating to such measures is the fact that, technically, both direct and indirect energy consumption should be considered for each mode. The value of measures of energy-intensiveness lies in their provision of a means for making modal comparisons of energy usage on a common basis. Obviously, if one mode is associated with a significantly higher level of indirect energy consumption (as is, thought to be the case; see Chapter 4), then a comparison between modes of energy-intensiveness based on direct comsumption alone would give an incomplete indication of the full nature of energy usage and would favour the highest user of indirect energy.

Despite these qualifications, in the analysis to follow, a comparison is made of energy-intensiveness based on direct energy usage alone. This is because of a lack of sufficiently detailed data relating to the amount of energy consumed by infrastructure services associated with each mode, a matter discussed in Chapter 4. The likely influence of indirect energy consumption on these derived measures of energy utilisation efficiency is, however, discussed later in this Chapter.

It has been made clear in the analysis of the transport task and energy consumption for international (sea and air) transport movements attributable to Australia (see Chapters 2 and 3) that the assumptions made necessary by the lack of reliable and detailed information render the estimates no better than indicators of orders of magnitude. For this reason, no analysis is attempted in this Chapter of the energy-intensiveness of these categories of Australian transport; to do so would be to attribute to the estimates a level of accuracy which they do not possess.

5.2 DIRECT ENERGY-INTENSIVENESS OF AUSTRALIAN TRANSPORT

5.2.1 Cars and Station Wagons

Table 5.1 shows the results of dividing Table 3.3, representing direct energy consumption, by Table 2.5, representing the passenger task (in passenger-km) performed by cars and station wagons in 1970-71. Obviously, the distribution of values within Table 3.3 reflects the assumption made in the analysis of energy consumption concerning the specific fuel consumption rates for particular areas of operation. For this reason, comparisons between rows in the Table are probably more valid than between columns. A further source of error may stem from the car occupancy

TABLE 5.1 - ESTIMATED DIRECT ENERGY-INTENSIVENESS FOR CARS AND STATION WAGONS, BY PURPOSE AND AREA OF OPERATION, 1970-71

(kJ per passenger-kilometre)

Purpose	Area of Operation				Total
	Capital City & Environs	Provincial Urban	Rest of State	Interstate	
Business	3,900	4,100	3,200	3,100	3,600
Paid to and from work	3,600	3,700	3,200	3,000	3,600
Unpaid to and from work	3,600	3,700	3,200	3,500	3,500
Private	2,600	2,700	900	1,000	1,600
All purposes	3,100	3,100	1,200	1,200	2,100

Note: Figures rounded to nearest 100 units.

Source: Developed by dividing Table 3.3 by Table 2.5.

figures, calculated in Chapter 2, some of which were pointed out as seeming to be too large. In particular, the inference is that the private/rest-of-State and private/interstate energy intensiveness figures might be regarded with caution.

Nevertheless, it is generally apparent from the Table that business and journey-to-work travel is more energy-intensive (i.e., requires a greater amount of energy per passenger-kilometre of output) than is private travel, for which vehicle occupancy ratios are generally higher.

5.2.2 Motor Cycles

Because of the small variation in vehicle occupancy and specific fuel consumption rates for motor cycles in various areas of operation and travelling for various purposes, it is sufficient only to report the overall direct energy-intensiveness, approximately 1400 kJ per person-kilometre.

5.2.3 Commercial Vehicles

Table 5.2 shows the estimated direct energy-intensiveness of commercial vehicles, by vehicle usage. It is derived from Tables 2.11 and 3.7, and shows, in particular, that commercial vehicles operating ancillary services are considerably less efficient, in terms of aggregate energy usage, than vehicles operating for hire and reward. This may be partly due to the greater likelihood of empty return trips, an observation confirmed to some extent by the differences between hire and reward vehicles operating for one client only and those operating in the size of vehicles used for the respective services.

TABLE 5.2 - ESTIMATED DIRECT ENERGY-INTENSIVENESS OF COMMERCIAL VEHICLES, BY VEHICLE USAGE, 1970-71

(kJ per tonne-km)

Vehicle Usage	Direct Energy-Intensiveness
Hire and reward	
1 client	2,900
>1 client	2,300
Ancillary	7,300
Not stated	7,800
Total	4,200

Note: Figures rounded to nearest 100 units.

Source: Developed by dividing Table 3.7 by Table 2.11.

Table 5.3 shows how the direct energy-intensiveness of commercial vehicles varies with area of operation. Not surprisingly, less energy per tonne-km is required for rural and interstate journeys than for journeys in urban areas.

TABLE 5.3 - ESTIMATED DIRECT ENERGY-INTENSIVENESS OF COMMERCIAL VEHICLES, BY AREA OF OPERATION, 1970-71

(kJ per tonne-km)

Area of operation	Direct energy-intensiveness
Capital city and environs	5,800
Provincial urban	4,900
Rest of state	3,700
Interstate	1,500
All areas	3,600

Note: Figures rounded to nearest 100 units.

Source: Developed by dividing Table 3.8 by Table 2.9.

5.2.4 Buses

The variation in energy-intensiveness for buses, by area of operation is derived from Tables 2.12 and 3.12, and shown in Table 5.4.

TABLE 5.4 - DIRECT ENERGY-INTENSIVENESS OF BUSES BY AREA OF OPERATION, 1970-71

Area of Operation	Direct energy-intensiveness (kJ per passenger-km)
Capital cities	900
Rest of States	600
All areas	800

Note: Figures rounded to nearest 100 units.

Source: Developed by dividing Table 3.12 by Table 2.12.

5.2.5 Trams

The derived direct energy-intensiveness of Adelaide's and Melbourne's tram services ranged around 1300 kJ per passenger-kilometre. This is the best estimate that can be made using the available data (see pages 18 and 49).

5.2.6 Urban Rail Services

The estimation of total passenger-kilometres by urban rail services may not be accurate (see Chapter 2), but on the basis of an assumed task of 5.9×10^9 passenger-kilometres, the direct energy-intensiveness of all urban rail services in Australian cities is approximately 1900 kJ per passenger-kilometre.

5.2.7 Non-Urban Rail Services

Because of the way in which total energy consumption estimates were allocated to the various categories of rail freight task according to tonne-kilometres performed (see Chapter 3) the energy-intensiveness of each category appears the same, approximately 600 kJ per tonne-kilometre. It is unfortunate that more detailed information does not permit an examination of the variation in this figure by type of operator (Government and private).

Non-urban passenger rail services perform 4,100 million passenger-kilometres and, in doing so, use 6.4×10^{12} kJ of primary energy, a direct energy-intensiveness of approximately 1600 kJ per passenger-kilometre.

5.2.8 Domestic Air Services

The calculated direct energy-intensiveness of domestic air carriers is approximately 4,600 kJ per passenger-kilometre, and 32,200 kJ per tonne-kilometre of freight, although the assumptions made in allocating total energy use between passenger and freight movements and the fact that energy consumption by non-scheduled aircraft has been ignored should be clearly recognised.

5.2.9 Coastal Shipping

The coastal shipping task of 70,000 million tonne-kilometres is associated with an estimated energy usage of about 42×10^{12} kJ; i.e., shipping achieves an energy-intensiveness of about 600 kJ per tonne-kilometre of freight.

5.2.10 Summary

The calculated energy-intensiveness of the various modes of Australian transport are brought together in Table 5.5. Taking the passenger figures first, at least two important points can be made.

Firstly, with the exception of aircraft and buses, the most common forms of passenger transport (car, tram and train) seem not to differ a great deal in their energy-intensiveness. The car is more energy-intensive than the others, but not much more so. This is, perhaps, due to the fact that the average occupancy of a private car for all journeys is approximately 2.0, while certain public transport mode vehicles operate over a high proportion of their travelled mileage at very low occupancies. This factor must, to some extent, negate inherent energy efficiencies of mass transport vehicles. On the other hand, the energy-intensiveness of bus services appears low, and although the accuracy of the bus passenger task estimate is unknown (section 2.1.4), it does seem that bus transport is more efficient than all other forms of transport. This is possibly due to higher load factors.

TABLE 5.5 - SUMMARY OF ESTIMATED ENERGY-INTENSIVENESS OF VARIOUS MODES OF AUSTRALIAN TRANSPORT, 1970-71

Mode	Passenger task (kJ/pass.-km)			Freight task (kJ/tonne-km)		
	Urban	Non-urban	Australia	Urban	Non-urban	Australia
Cars and station wagons	3,100	1,200	2,100	-	-	-
Motor cycles	-	-	1,400	-	-	-
Commercial vehicles	-	-	-	5,700	2,600	3,600
Buses	900	600	800	-	-	-
Trams	1,300	-	1,300	-	-	-
Trains	1,900	1,600	1,800	-	600	600
Aircraft	-	4,600	4,600	-	32,000	32,000
Coastal vessels	-	-	-	-	600	600
All Australian transport	2,900	1,500	2,200	5,700	900	1,200

Note: Figures rounded to nearest 100 units.

Source: Summary of derived estimates; see text.

Secondly, aircraft are, by comparison, considerably more energy-intensive than all other passenger modes, requiring more than five times the energy input of a bus to achieve one passenger-kilometre.

For freight movements, shipping and railways are by far the least energy-intensive, while aircraft again use more energy per tonne-kilometre than any other mode (whether they do so to the extent indicated in Table 5.5 is, however, a matter for debate; obviously, a more detailed study is required to refine the air freight figure shown).

5.3 SOME INFLUENCES ON THE VALIDITY OF ENERGY-EFFICIENCY ESTIMATES

5.3.1 The Effect of Indirect Energy Consumption

If the relative values of indirect energy consumption by the various modes may be taken to be as suggested in Chapter 4, the total energy-intensiveness of each mode will be somewhat different from that shown in Table 5.5. The figures for indirect consumption are not sufficiently accurate to develop detailed estimates of total energy-intensiveness, but it is sufficient to note that the private car requires an increased amount of energy to achieve one passenger-kilometre, the increase being larger than that required to adjust the energy-intensiveness figures for the other modes. The estimated indirect energy consumption suggested in Chapter 4 would have the effect of increasing the <u>total</u> energy-intensiveness of Australia's domestic transport modes to the values shown in Table 5.6.

Few conclusions may be made from the absolute values in the Table, but their relative values suggest that, if both direct and indirect energy consumption are considered, the private car is significantly more energy-intensive than other personal travel modes, with the exception of aircraft. Trams and trains exhibit similar characteristics of energy efficiency.

TABLE 5.6 - SUMMARY OF ESTIMATED TOTAL (DIRECT AND INDIRECT) ENERGY-INTENSIVENESS OF VARIOUS MODES OF AUSTRALIAN TRANSPORT, 1970-71

Mode	Total energy-intensiveness	
	Passenger task (kJ/pass.-km)	Freight task (kJ/tonne-km)
Cars and station wagons	3,600	-
Motor cycles	3,700	-
Commercial vehicles	-	5,500
Buses	1,200	-
Trams	1,700	-
Trains	2,300	700
Aircraft	9,800	(1)67,000
Coastal vessels	-	700

(1) This estimate is of doubtful value, because of the assumptions used to derive it.

Note: Figures are rounded to nearest 100 units.

Source: See text.

For freight movements, the rail and coastal shipping modes do not differ greatly, but are considerably less energy-intensive than commercial vehicles and aircraft.

5.3.2 The Effect of Type of Fuel

It is important that the energy consumption by transport is derived from a variety of primary sources. It is also important to note that the modes which use the greatest amounts of energy (principally the road modes), and those which are most energy-intensive, are those which exhibit the following characteristics:

(i) they are the modes, the demands for and, consequently, tasks of which are growing at the fastest rates;

(ii) they are the modes which are powered by petroleum-based fuels.

The importance of these considerations is highlighted by the estimation(1) that by the year 2000, the expected cumulative requirement for energy resources in Australia as a percentage of the present known indigenous reserves of each resource will be as follows:

Energy Resource	Percentage
Black coal	13
Brown coal	18
Petroleum fuels	820
Natural gas	75

5.3.3 Effect of Indirect Routing

So far in this report, the transport task has been evaluated in terms of passenger-kilometres or tonne-kilometres performed. But this measure of task takes no account of the fact that some modes of transport travel by more indirect routes than others in performing the primary objective: that of transferring persons or goods between two points. To take a simple example, the airline distance between two major cities is obviously less than the road or sea route distance, and as a result, the airlines

(1) Fuels Branch, Department of Minerals and Energy.

achieve a greater degree of what may be called here 'route efficiency', thus influencing comparative measures of energy intensiveness in performing the primary traffic task.

There is no convenient measure of the extent to which some modes follow longer routes than others for all categories of movement. For this reason, it is not possible to adjust the estimates of energy-intensiveness to account for route efficiencies. But an indication of their likely effect may be provided by examining the respective distances between major capital cities in Australia by significant interstate modes. These are shown in Table 5.7, where it can be seen that, taking the Sydney-Adelaide route as an illustrative example, sea, rail and road routes are, respectively, 1.50, 1.38 and 1.20 times the airline distance. Obviously, these factors are different for other intercity routes, as is shown in the Table. In general, however, there is not a great deal of difference between the route lengths by road and rail, but the distance by sea is consistently much greater and the distance by air consistently less.

This means, of course, that derived figures for the transport task should really be modified by the factors appropriate for each type of trip. In the context of this study, and the available information, all that can be said is that the estimates of energy-intensiveness made in this Chapter probably tend to favour slightly the sea mode and, to a lesser extent, the rail and road modes.

TABLE 5.7 - DISTANCES BETWEEN CAPITAL CITIES IN AUSTRALIA

(kilometres)

Origin/ Destination	By Rail	By Sea	By Air	By Road
Canberra to -				
Sydney	327	-	248	306
Melbourne	842	-	483	655
Brisbane	1,313	-	954	1,316
Adelaide	1,619	-	988	1,212
Perth	4,272	-	3,204	3,953
Hobart	-	-	916	883
Darwin	-	-	3,405	4,404
Sydney to -				
Melbourne	959	1,078	743	893
Brisbane	986	969	771	1,010
Adelaide	1,654	1,788	1,195	1,432
Perth	3,960	3,997	3,411	4,174
Hobart	-	1,173	1,052	1,126
Darwin	-	4,584	3,157	4,521
Melbourne to -				
Brisbane	1,945	2,020	1,409	1,903
Adelaide	777	954	660	747
Perth	3,430	3,150	2,875	3,488
Hobart	-	876	623	233
Darwin	-	5,650	3,426	3,939
Brisbane to -				
Adelaide	2,640	2,742	1,966	2,442
Perth	4,946	4,936	4,182	5,184
Hobart	-	2,114	1,833	2,137
Darwin	-	3,795	2,887	3,511
Adelaide to -				
Perth	2,653	2,553	2,216	2,742
Hobart	-	1,431	1,282	1,665
Darwin	-	5,893	2,766	3,192
Perth to -				
Hobart	-	3,389	3,501	3,722
Darwin	-	3,424	3,006	4,125

Source: CBCS Transport and Communication, 1970-71. Bulletin No. 62, Canberra, February 1973.

CHAPTER 6 CONCLUDING COMMENTS

This study has attempted to evaluate the energy consumption of categories of Australian transport, and to indicate the efficiency with which each mode, system-wide, utilises its input of energy in performing its transport task. As such, it is valuable in providing assistance in the development of policies for energy utilisation within a sector of total energy consumption which is of considerable significance(1). Alone, however, it does not indicate the likely effects of these policy measures. Any attempt to influence the redistribution of energy usage, both nationally and within the transport sector, should only be made with a knowledge of the effects of those measures on the demand for each category of transport and the associated energy consumption patterns.

In Chapter 5 of this report, the estimates of the transport task and energy usage have been combined to give the energy-intensiveness of each mode of Australian transport. The figures summarise much of the preceding analysis in a way which permits the various modes to be compared on a common basis. They show that, with the exception of rail transport, which relies in part on petroleum fuel, the petroleum-driven modes (road and air transport) are significantly more energy-intensive than other public transport modes if indirect energy consumption is taken into account.

Superficially, it might be expected that changes in the supply or price of transport fuels would affect the demand for each mode in some relationship with its energy-intensiveness, (i.e., an increase in the price of petroleum products, for example, would be reflected

(1) The transport sector accounts for approximately 26 per cent of the total national energy consumption (Section 3.2).

in a greater reduction in demand for those petrol-driven modes which are energy-intensive than for those which are less so). Whether or not this is so, however, depends on the elasticity of demand for each mode with respect to price changes, a matter which requires further study.

For this reason, this study should be seen to form part of a continuing series of studies of transport energy consumption in Australia.

ENERGY CONSUMED BY COMMERCIAL VEHICLES

The energy consumption distribution for commercial vehicles, by purpose and area of operation, is developed from estimates of energy consumption per vehicle kilometre by type of vehicle, factored according to driving conditions, and CBCS figures for total annual mileage under each category.

Table 3.6 shows the gross annual energy consumption for all classes of commercial vehicle. These vehicles travel the distances shown in Table A.1, which is drawn from CBCS estimates. Assuming that energy efficiency rates, for all vehicles, in terms of units of energy used per kilometre travelled are 50 per cent less in urban areas than in rural areas, the energy consumption rates of Table A.2 may be calculated.

Table A.2 may now be applied to CBCS estimates of total vehicle kilometres travelled by commercial vehicles (by vehicle type, purpose and area of operation) to produce Table A.3, a matrix of energy use by purpose and area of operation, in which interstate traffic has been adjusted according to the same reciprocity assumption used for interstate car and station wagon traffic.

TABLE A.1 - TOTAL DISTANCE TRAVELLED BY COMMERCIAL VEHICLES BY VEHICLE TYPE AND AREA OF OPERATION, 1970-71

('000 kilometres)

Vehicle Type	Area of Operation		Total
	Urban	Rural	
Light commercial vehicles -			
Open	2,388,380	3,432,027	5,820,429
Closed	1,960,451	786,394	2,746,862
Trucks: rigid and articulated -			
1 & under 4 tonnes (1)	2,083,123	1,485,133	3,568,266
4 & under 8 tonnes	708,029	896,182	1,604,266
Trucks: rigid -			
8 tonnes & over	413,240	415,725	828,968
Trucks: articulated			
8 & under 12 tonnes	55,947	134,476	190,425
12 & under 16 tonnes	125,154	352,378	477,531
16 tonnes & over	184,759	719,438	904,200
Other truck type vehicles	60,738	33,706	94,444
Total	7,979,819	8,255,459	16,235,340

(1) Refer to footnote to Table 3.5.

Source: CBCS Survey of Motor Vehicle Usage, 1971-73, unpublished data.

TABLE A.2 - ENERGY CONSUMPTION RATES OF COMMERCIAL VEHICLES, BY AREA OF OPERATION

(kilometres per 10^9 kJ)

Vehicle Type	Area of Operation			
	Capital City and Environs	Provincial Urban	Rest of State	Interstate
Light commercial vehicles -				
Open	209,327	209,328	313,993	313,993
Closed	258,824	258,824	388,237	388,237
Trucks: rigid and articulated				
1 & under 4 tonnes (1)	130,000	130,000	195,001	195,001
4 & under 8 tonnes	71,835	71,835	107,753	107,753
Trucks: rigid -				
8 tonnes & over	60,243	60,243	90,365	90,365
Trucks: articulated -				
8 & under 12 tonnes	49,976	49,976	74,964	74,964
12 & under 16 tonnes	46,202	46,202	69,304	69,304
16 tonnes & over	39,799	39,799	59,699	59,699
Other truck type vehicles	101,474	101,474	152,211	152,211

(1) Refer to footnote to Table 3.5.

Source: See text.

TABLE A.3 - ENERGY CONSUMPTION BY COMMERCIAL VEHICLES BY PURPOSE AND AREA OF OPERATION, 1970-71

(10^{12} kJ)

Purpose	Area of Operation				Total
	Capital City & Environs	Provincial Urban	Rest of State	Interstate	
Laden business	28.90	4.57	19.12	10.31	62.90
Unladen business	15.52	2.79	14.70	2.86	35.87
All business	44.42	7.36	33.82	13.17	98.77
Paid to and from work	1.03	0.12	0.29	0.02	1.46
Unpaid to and from work	2.57	0.46	1.21	0.16	4.40
Private	3.91	0.91	3.02	0.94	8.78
All purposes	51.93	8.85	38.34	14.29	113.41

Source: See text.