1993–94

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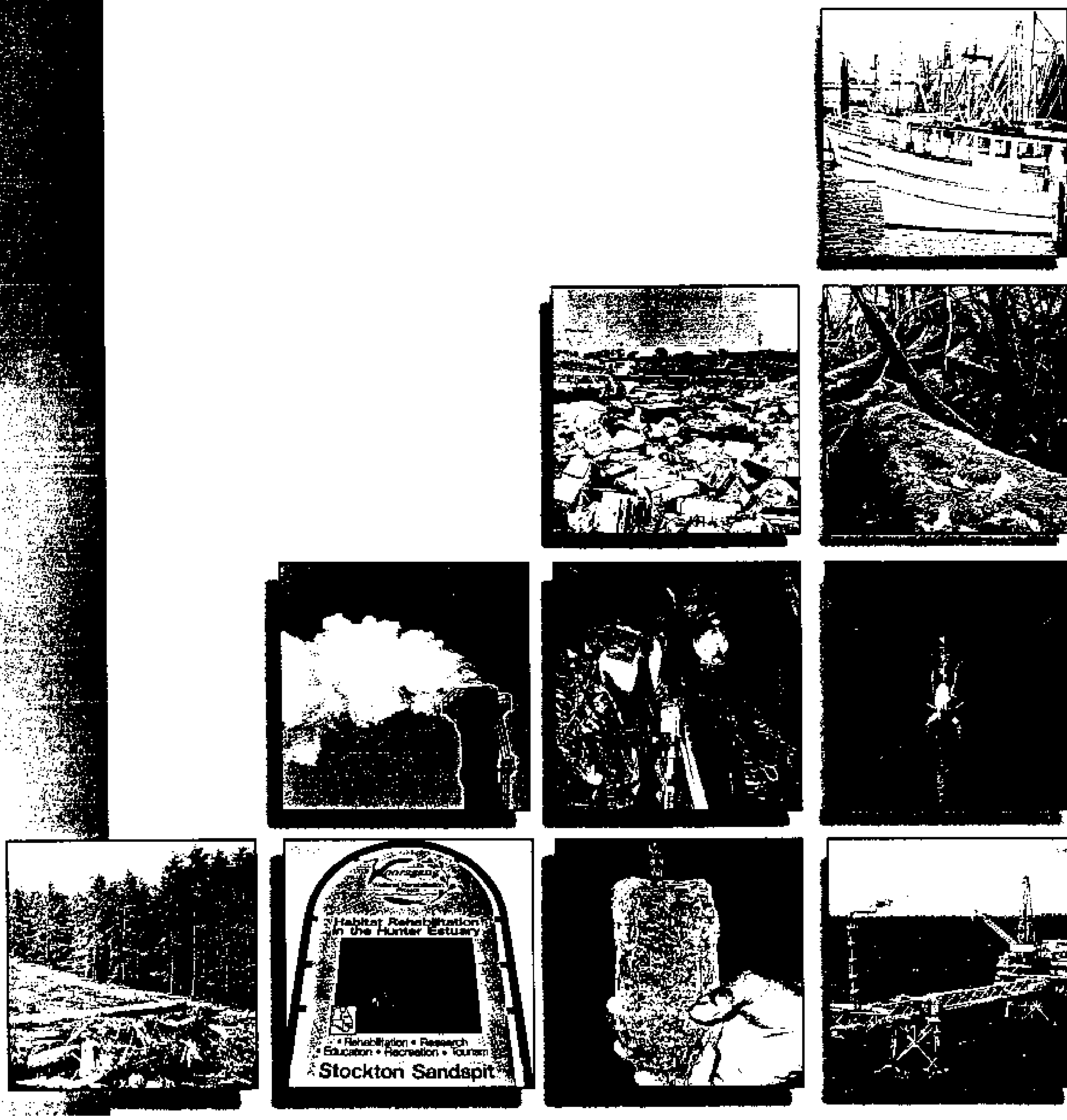
Energy Accounts for Australia



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NEW ISSUE

ENERGY ACCOUNTS FOR AUSTRALIA
1993–94

W. McLennan
Australian Statistician

AUSTRALIAN BUREAU OF STATISTICS

CATALOGUE NO. 4604.0

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INQUIRIES

- *for further information about statistics in this publication and the availability of related unpublished statistics*, contact Graeme Oakley on (06) 252 7369 or any State Office.
- *for information about other ABS statistics and services*, please refer to the back page of this publication

PREFACE

The publication of *Energy Accounts for Australia* provides comprehensive energy statistics in a newly developed accounting framework. The focus of this work is on the physical aspects of energy rather than those involved with economic valuation. To reflect the major energy forms used in Australia, the accounts include six major energy categories: petroleum, coal, electricity, uranium, biomass (wood and bagasse), and other renewable resources such as wind and solar energy. Three major accounts, namely stocks, flows and residuals in physical units, describe the various aspects of energy resources, its production, conversion and consumption, as well as residuals discharged into the natural environment.

Energy Accounts for Australia is part of a current project being carried out by the Australian Bureau of Statistics (ABS) to develop a set of accounts for a number of Australia's natural resources. This work follows the guidelines in the United Nations System for Integrating Environmental and Economic Accounts which is a component of the Revised System of National Accounts (1993). Physical resource accounts, in general, are considered useful for other applications such as assisting environmental and natural resource management, and economic and environmental decision-making processes.

The ABS has a broad range of data collections on social and economic activities in Australia but current data collection in the energy field, particularly using physical units, is limited. In this publication, many of the statistics were derived from other agencies' data collection. The ABS wishes to thank those organisations which kindly supplied data for *Energy Accounts for Australia*.

Comments on this publication would be most welcome and should be sent to the Director, Environment and Energy Statistics.

W. McLennan
Australian Statistician

Australian Bureau of Statistics
October 1996

ACKNOWLEDGEMENT

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LIST OF ABBREVIATIONS, UNITS AND OTHER USAGES

ABBREVIATIONS

ADO	Automotive diesel oil
Av.	average
Avgas	Aviation gasoline
Avtur	Aviation turbine fuel
bill.	billion
CFC	Chlorofluorocarbon
EAR-I	Estimated Additional Resources – Category I
EAR-II	Estimated Additional Resources – Category II
EDR	Economic demonstrated resources
EUR	Estimated ultimate recovery
FOE	Fuel oil equivalent
IDF	Industrial diesel fuel
incl.	including
LNG	Liquefied natural gas
LPG	Liquefied petroleum gas
MC	McKelvey Classification
mill.	million
n.a.	not available
n.e.c.	not elsewhere classified
NG	Natural gas
NMVOC	Non-methane volatile organic compounds
ORF	Other refinery feedstocks
PV	Photovoltaic
RAR	Reasonably assured resources
SR	Speculative resources
TCE	Tonnes of coal equivalent
TOE	Tonnes of oil equivalent
VOC	Volatile organic compounds

ACRONYMS

ABARE	Australian Bureau of Agricultural and Resource Economics
ABS	Australian Bureau of Statistics
AGSO	Australian Geological Survey Organisation
ANZSIC	Australian and New Zealand Standard Industrial Classification
AUSLIG	Australian Surveying and Land Information Group
BMR	Bureau of Mineral Resources
BRS	Bureau of Resource Sciences

ACRONYMS – *continued*

CRDC	Coal Resources Development Committee
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DASETT	Department of the Arts, Sport, the Environment, Tourism and Territories
DEST	Department of the Environment, Sport and Territories
DPIE	Department of Primary Industries and Energy
ESAA	Electricity Supply Association of Australia
ESD	National Strategy for Ecologically Sustainable Development
IAEA	International Atomic Energy Agency
IEA	International Energy Agency
IPCC	International Panel on Climate Change
NEA	Nuclear Energy Agency
NGGIC	National Greenhouse Gas Inventory Committee
OECD	Organisation for Economic Cooperation and Development
RAC	Resource Assessment Commission
SECV	State Electricity Corporation of Victoria
SEEA	United Nations System for Integrating Environmental and Economic Accounts
SMHEA	Snowy Mountains Hydro-electric Authority
SNA	System of National Accounts
UNCED	United Nations Conference on Environment and Development
UNSO	United Nations Statistical Office

SYMBOLS/UNITS

—	nil or rounded to zero
Btu	British thermal unit
CH_4	Methane
CO	Carbon monoxide
CO_2	Carbon dioxide
°C	degrees Celsius
cal	calories
cm^2	square centimetre
ft^3	cubic feet
g	grams
Gg	gigagram
GJ	gigajoules
GL	gigalitre
Gt	gigatonnes
GW	gigawatt
GWh	gigawatt-hours

SYMBOLS/UNITS — *continued*

h	hour
ha	hectares
J	joules
kg	kilograms
km^2	square kilometre
kt	kilotonnes
kWh	kilowatt-hours
L	litre
m/s	metres per second
m^2	square metre
m^3	cubic metres
Mg	megagrams
MJ	megajoules
ML	mega litres
mm	millimetres
MW	megawatts
mWh	milliwatt-hours
NO_x	Oxides of nitrogen
N_2O	Nitrous oxide
O_3	Tropospheric ozone
Pa	pascal
PJ	petajoules
SO_2	Sulphur dioxide
SO_x	Oxides of sulphur
t	tonnes
U	uranium
U_3O_8	Uranium oxide

OTHER USAGES

billion	thousand million
trillion	million billion

INTERNATIONAL SYSTEM OF UNITS

Prefix	*Symbol*		
peta	P	10^{15}	1 000 000 000 000 000
tera	T	10^{12}	1 000 000 000 000
giga	G	10^{9}	1 000 000 000
mega	M	10^{6}	1 000 000
kilo	k	10^{3}	1 000
hecto	h	10^{2}	100
deca	D	10^{1}	10
		10^{0}	1
deci	d	10^{-1}	0.1
centi	c	10^{-2}	0.01
milli	m	10^{-3}	0.001
micro	μ	10^{-6}	0.000 001
nano	n	10^{-9}	0.000 000 001
pico	p	10^{-12}	0.000 000 000 001

CHAPTER 1 NATURAL RESOURCE ACCOUNTING

BACKGROUND

This publication on energy is the first in what is expected to be a series containing natural resource accounts for Australia. Commencing in 1995–96, the Australian Bureau of Statistics (ABS) is receiving funding for the development of a program of environmental and resource statistics in an accounting framework. As part of this program the ABS expects to develop accounts for a variety of resources including: water, forests, minerals and fisheries; and accounts on wastes, emissions, land use and biodiversity will also be considered. These topics will present varying problems and degrees of difficulty.

Energy has been chosen first because:

- it is all-pervading in economic and environmental terms;
- there is a strong demand for the data; and
- many of the basic data have already been assembled by the Australian Bureau of Agricultural and Resource Economics and other agencies.

Similar work is proceeding in many countries around the world and will provide a substantial response to national and international recommendations. 'Agenda 21', the action document arising out of United Nations Conference on Environment and Development, proposes 'a program to develop national systems of environmental and economic accounting in all countries'. This is accompanied by increasing demand for environmental indicators to complement traditional economic indicators.

Australia has established a further requirement for such accounts through the National Strategy for Ecologically Sustainable Development (ESD). Objective 14.2 of the strategy is: 'to enhance the quality, accessibility and relevance of ESD-related data'. Amongst the proposed strategies are work on conceptual issues underlying development of environmental accounts, and review of national and sector balance sheets within the Australian National Accounts.

To assess the sustainability of economic activities and national income, some account should be taken of environmental costs and the depletion and degradation of natural resources. For this purpose, an information system is needed which links the measurement of human activities to changes in the environment and the resource base. Hence the desirability of aligning/integrating environmental accounts and indicators with the System of National Accounts (SNA) which is the international standard.

A system for Integrating Environmental and Economic Accounts (SEEA) was provided as an adjunct to the 1993 Revised SNA. The SEEA framework proposes several 'satellite' accounts for recording environmental costs and changes to natural resources. The ABS plans to undertake this work in stages:

- accounts for separating out environment protection related expenditures;
- compilation of natural resource accounts (stocks and flows) in physical units, including residuals (wastes and emissions) and some other special aspects; and
- exploration of valuation issues which is necessary before the derivation of monetary estimates directly relatable to national accounting aggregates such as national product and income.

Regarding the last point, valuation is a problematical aspect and some of the approaches that can be considered are discussed in the ABS publication *National Balance Sheets for Australia — Issues and Experimental Estimates, 1989 to 1992* (5241.0) issued in March 1995. The valuation question will not be pursued here, given that the energy accounts in this publication are expressed only in physical units and accounting in monetary terms is not immediately under consideration.

USE OF RESOURCE ACCOUNTS

Physical resource accounts are proposed in SEEA as a fully-formed framework which can stand alone for applications such as resource management and the formulation of long-term economic and environmental policy. The following examples give an indication of the uses of resource accounting in other countries:

- likely effects of changes in economic activity on the environment and on the stock of economic resources; and
- implications of policies to limit emissions/discharges and the use of particular natural assets, whether through legislative control or the use of economic instruments (e.g. taxes, subsidies).

NATURE OF RESOURCE ACCOUNTS

Physical resource accounts provide measures of:

- stocks (by category);
- flows of materials and energy through the various sectors of the economy; and
- eventual releases of wastes (some of them re-usable) and emissions.

An appropriate degree of dissection by industry sector and activity enables links to be made with input-output tables. Indeed the input-output framework is well suited to showing flows from the natural environment as inputs to economic activities, and flows of residuals of production and consumption activities back into the natural environment. Development along these lines is envisaged.

While some resource issues may be viewed nationally, many interactions between the environment and the economy need also to be addressed at a regional level (e.g. soil degradation, water pollution, forestry issues). Desirably, therefore, underlying data sets used to compile national level statistics should maintain spatial detail. Again, this is a direction for future work and is being progressively catered for in the development of national databases. It is anticipated that regional level studies will find some data limitations and so national level data, with suitable assumptions, may be needed to fill the data gaps.

CHAPTER 2 EXPLANATION OF ENERGY ACCOUNTS

This chapter describes the structure of energy accounts, the format for presenting the statistics, and the data sources used.

STRUCTURE OF THIS PUBLICATION

This publication focuses on the physical measurement of energy, providing accounts showing energy resources, production, conversion and consumption, as well as residuals discharged into the natural environment.

Reflecting the major energy forms used in Australia, the accounts are for six major categories which are the basis for the respective chapters: petroleum, coal, electricity, uranium, biomass (wood and bagasse), and other renewable resources such as wind and solar energy.

Electricity is not a naturally occurring energy resource, being generated in power stations by converting other energy forms such as fossil and nuclear fuels, or from hydro, solar, wind and other renewable sources. However, in recognition of the special importance of electricity in industrial and domestic applications, and its place in energy flows, electricity is given separate treatment.

As recommended by United Nations Statistical Office (UNSO 1991), physical accounts of natural resources generally consist of three major parts, namely, stock accounts, flow accounts and residual accounts. Stock accounts deal with the deposits of natural resources and changes in the deposits over a period of time. For flow accounts, production, conversion and consumption are the major elements. To quantify the wastes (particularly environmental pollutants) generated from a full cycle of production, conversion and consumption, residual accounts are used in conjunction with the flow accounts, providing detailed information on type of wastes and pollutants and emission rates.

Each of the main chapters contains separate stock, flow and residual accounts, plus a background section which provides some basic information about the energy form. It should be noted that definitions may differ amongst chapters, particularly for stock accounts. For example, the stock accounts of petroleum, coal and uranium focus on underground deposits. Wood and bagasse stocks only include those used as fuels. In the case of hydro, wind and solar-renewable energy resources, the concept of 'potential' is more appropriate than 'stock'.

FORMAT OF STOCK, FLOW AND RESIDUAL ACCOUNTS

Because natural resource accounting is still in the early stage of development, there is no international standard to be followed in establishing these three accounts. The Australian Bureau of Statistics (ABS) has made reference to the experience of some other countries such as Norway, and has also tried to align with the recommendations made by UNSO 1991 while taking account of data availability in Australia. The format for each account is described below.

Stock account

To present the status of energy resources and changes over time, the stock account consists of five components: opening stock, closing stock, net change, production and adjustment. A typical format is shown in table 2.1.

2.1 STOCK ACCOUNT (PHYSICAL QUANTITY UNIT)

	Year 1	*Year 2*	*Year 3*
Opening stock			
Adjustment			
Production			
Closing stock			
Net change			

Opening and closing stock refer to estimates of the energy resources at the beginning and end of the accounting period, (normally the financial or calendar year). The estimates of energy resources depend upon the systems of classification used. For petroleum and coal, 'stock' refers to economic and sub-economic demonstrated resources, according to the McKelvey system of classification. 'Stock' in Uranium refers to reasonably assured resources and estimated additional resources — category I, established by the Organisation for Economic Cooperation and Development Nuclear Energy Agency and the International Atomic Energy Agency. More detailed information is provided in the individual chapters.

Production shows the amount of raw energy product produced (representing a depletion of resource stock during a particular year) and relates to the amount of mine production. Note that some energy products from mine production can be used directly as final energy products.

Adjustment is used to account for other changes in the assessment of resources, resulting from:

- new deposit discoveries;
- improved development technology, allowing a greater proportion of in-place deposits to be exploited; and
- revised assessments of deposit properties, leading to higher (or lower) recovery factors than those originally calculated.

It should be noted that in this publication, the data on adjustment are derived simply as a balancing item, from the stock and production data as shown in the following:

Adjustment = Closing stock – Opening stock – Production.

Hence, the amount of adjustment can be positive or negative, depending upon whether the amount of new discovery is sufficient to offset production in a particular year. In many cases, the adjustment is zero, i.e. the net change in stock is equal to production.

Net change is the difference between opening and closing stock. Changes in stock mainly result from production (shown as a negative value).

However, upgrading of the energy resources may add or subtract to stock and contributes the remaining difference.

Flow account

Flow accounts provide information on production, conversion and consumption over the reference period. They consist of three major parts: supply, conversion and end use as shown in table 2.2.

2.2 FLOW ACCOUNT

	1987–88	1988–89	1989–90	1990–91	1991–92	1992–93
	J	J	J	J	J	J
Supply						
Production[1]						
Imports (+)						
Exports (–)						
Stock change (+ or –)[2]						
Total (A)						
Conversion						
Coke ovens						
Briquetting						
Petroleum refining						
Gas manufacturing						
Electricity generation						
Other conversion						
Fuel use						
Total conversion (B)						
Net supply (A–B)						
End use						
Agriculture						
Mining						
Iron and steel						
Chemical						
Other industry						
Construction						
Road transport						
Rail transport						
Air transport						
Water transport						
Commercial						
Residential						
Others[3]						
Consumption						

1 Includes the energy produced from a conversion process, e.g. coke from coal, electricity from various primary sources.
2 Includes discrepancies.
3 Includes lubricants, greases, bitumen and solvents.

The format of flow accounts adopted here is taken from publications by the United Nations (1982) and the Australian Bureau of Agricultural and Resource Economics (ABARE) (1995). The tables present energy balances consistent with the format of stock accounts.

Table 2.2 lists all possible entries in a flow account but for a particular energy source, the items listed will vary. For example, uranium is mainly produced for export and the domestic use of uranium can be ignored. Hence, for uranium, only the supply part of the account is shown.

Derived energy products are presented in separate accounts, unlike stock accounts which mainly present primary energy resources. Supply of derived energy products, such as petroleum products, coke, briquettes and coal by-products, should be equivalent to the amount of conversion from primary energy forms (such as from crude oil and other refinery feedstock, and coal). Thus, for example, coke is produced by converting coal and is shown as such in the coal account. In the coke flow account, the amount of coke converted from coal is repeated as supply production.

Supply covers a number of flows, namely production, imports, exports and stock change. Export is shown as a negative value since it reduces the quantity of energy products in domestic use. For some energy products such as crude oil and other refinery feedstocks, supply is partially supplemented by transfer from a conversion process. As mentioned before, the ABS treats these as a part of supply and this differs from the usual international presentation. Electricity generation is in this category. In supply, trading stock change including statistical discrepancies is also shown and this can be positive or negative. Total supply indicates the availability of a particular energy product which includes use both for conversion to other energy forms and for final energy consumption.

Conversion provides information on conversion of products from one energy form into another, such as from crude oil to petroleum products; from coal to coke, briquettes and coal by-products; and from coal to electricity. Some miscellaneous conversions are grouped in the category Other conversion, as follows: returning streams to refineries from the petrochemical industry; consumption of coke in blast furnaces; blast furnace gas manufacture; electricity produced through co-generation and brown coal tar produced in char manufacture. If any of the products are used as fuel in the conversion process, this is listed separately. The energy used in the process of conversion can be traced between primary flow accounts and secondary flow accounts. Examples are the consumption of petroleum products, gas and electricity in a conversion process.

End use is the sum of final energy consumption by different industrial sectors, where fuels release their stored energy, with or without residuals. Final energy consumption excludes any quantities converted into other forms of fuels or into electricity, as well as own use of energy by producing industries. The industrial sectors shown are based on the Australian and New Zealand Standard Industrial Classification but the emphasis is placed on the major energy consumers. In flow accounts, the sectors include Agriculture, Mining, Iron and steel industry, Chemical industry, Other industry, Construction, Road transport, Rail transport, Air transport, Water transport, Commercial and residential.

Residual account

Residual accounts contain the statistical information on residuals discharged from energy production, conversion and consumption. In a broad definition, the accounts might include environmental impact and pollution from energy-related activity, such as land use and noise level. In Australia, air pollutants and greenhouse gas emissions are major environmental concerns, and the residual accounts focus on these. Others such as water pollution and solid-waste pollution are important but are not covered in this publication because of data limitations at this stage.

Air pollution and greenhouse gas emissions can be considered in two broad categories: fuel-combustion emissions and fugitive-fuel emissions. The first group form the bulk of emissions and are proportional to energy use. The latter include the activity sources such as preproduction, production, processing and venting, transmission and storage, distribution as well as accidents and system upsets. The major air pollutants are carbon monoxide, sulphur dioxide, oxides of nitrogen, lead, suspended particulates and dust, tropospheric ozone, and fluoride. The common greenhouse gases are carbon dioxide, methane, nitrous oxide and non-methane volatile organic compounds. It should be noted that some air pollutants, such as nitrous oxide and tropospheric ozone, are also regarded as greenhouse gases, due to their indirect greenhouse warming effects.

UNITS OF MEASUREMENT

Two kinds of measurement units are in general use: original quantity units and a common energy-equivalence unit. The original units are those in which fuels and electricity are most naturally measured, such as tonnes for coal; litres or barrels for petroleum; kilowatt hours for electricity; cubic metres or cubic feet for gas. There are several energy-equivalence units available, such as joules or multiples of joules, tonnes of coal equivalent (TCE), tonnes of oil equivalent (TOE), the British thermal unit (Btu), and calories or multiples of calories. The joule is the unit most widely recommended. It had been hoped in this publication to provide a complete picture of energy stocks and flows in a common unit of measurement. However, on this initial occasion, the available data have not made such a presentation possible. For stock accounts, data were available in original quantity units, and for flow accounts could be compiled only in energy units. Residual accounts are presented in original quantity units.

2.3 ENERGY CONTENT OF FUELS

Fuel type	*Energy content*
SOLID FUEL (GJ/t)	
Black coal	
New South Wales	
Exports — coking coal	29.0
Exports — steaming coal	27.0
Electricity generation	23.5
Steelworks	30.0
Washed steaming coal	27.0
Unwashed steaming coal	23.9
Queensland	
Exports — coking coal	30.0
Exports — steaming coal	27.0
Electricity generation	24.2
Other	25.2
South Australia	13.5
Western Australia	19.7
Tasmania	22.8
Brown coal	
Victoria	
Coal	9.5
Briquettes	22.1
Coke	27.0
Wood (dry)	16.2
Bagasse	9.6
LIQUID FUEL (MJ/L)	
LPG	
Propane	25.3
Butane	27.7
Mixture	25.7
Natural	26.5
Aviation gasoline	33.0
Automotive gasoline	34.2
Power kerosene	37.5
Aviation turbine fuel	36.8
Lighting kerosene	36.6
Heating oil	37.3
Automotive diesel oil	38.6
Industrial diesel fuel	39.6
Fuel oil	
Low sulphur	39.7
High sulphur	40.8
Refinery fuel (FOE[1])	40.9
Naptha	31.4
Lubricants and greases	38.8
Bitumen	44.0
Solvents	34.4
Waxes	38.8

For footnotes see end of table.

2.3 ENERGY CONTENT OF FUELS — *continued*

Fuel type	*Energy content*
LIQUID FUEL (MJ/L) — *continued*	
Crude oil and ORFs[2]	
Indigenous	37.0
Imports (average)	38.7
Ethanol	23.4
Liquefied natural gas (NW Shelf)	25.0
GASEOUS FUEL (MJ/m^3)	
Natural gas (sale quality)	
Victoria	38.6
Queensland	39.6
South Australia, New South Wales	39.1
Western Australia	38.2
Northern Territory	40.4
Ethane	66.0
Town gas	
Synthetic natural gas	39.0
Reformed gas	20.0
Tempered LPG	25.0
Tempered natural gas	25.0
Coke oven gas	18.1
Blast furnace gas	4.0

1 FOE — fuel oil equivalent.
2 ORF — other refinery feedstocks.

Source: DPIE 1988.

When converting from original quantity units of measure to the common energy-equivalent unit, the conversion factors used are based on the gross energy content of the fuel (the total amount of heat that will be released by combustion). Conversion factors for individual types of fuels vary according to location of production and grades of fuels as well as temperature and pressure of the atmosphere. Therefore, calculation should be based on individual conversion factors and then the results aggregated to State or national level. Table 2.3 lists indicative conversion factors for solid, liquid and gaseous fuels, at a temperature of 15°C and pressure of 1 atmosphere (101.3 kilopascals). For Australian-produced uranium, the oxide contains 84.8% of the metal by weight. The conversion factor for the usable energy content of uranium metal is 0.56 petajoules per tonne and for uranium oxide is 0.47 petajoules per tonne (ABARE 1995).

DATA SOURCES

Most of the statistics used for this publication were assembled, with the cooperation of the organisations concerned, from external sources rather than ABS collections. The data sources used are as follows:

- Stock of natural resources:
  - Bureau of Resource Sciences (former Bureau of Mineral Resources);

  - Australian Surveying & Land Information Group, Department of Administrative Services;
  - Joint Coal Board of New South Wales and Queensland Coal Board;
  - Australian Institute of Petroleum; and
  - Australian Gas Association.
- Flow of energy supply, conversion and consumption:
  - Department of Primary Industries and Energy;
  - ABARE;
  - Joint Coal Board of New South Wales and Queensland Coal Board; and
  - Electricity Supply Association of Australia Limited.
- Residuals from energy sectors:
  - ABARE;
  - Bureau of Transport and Communications Economics; and
  - National Greenhouse Gas Inventory Committee.

Discrepancies between sources

Because a variety of external sources have been used, some statistical differences can be observed. For example, the sum of resources reported on a State basis did not necessarily agree with national totals derived independently. National data are based on estimation for mining basins (regardless of administrative boundaries), collected by the Commonwealth Government. The States have tended to collect data on a basis consistent with State jurisdictions, mainly from company sources.

CHAPTER 3

SUMMARY OF RESULTS

Australia has abundant energy resources and a significant component of its economic progress has been based on the development of energy industries. These are involved with direct energy supply (including to energy-intensive activities such as aluminium smelting and steel making) and with export. This chapter provides a summary of energy accounts for Australia; more detailed information on each specific energy form is given in later chapters.

AUSTRALIA'S ENERGY SITUATION

Australia is one of only five Organisation for Economic Cooperation and Development countries that are net energy exporters (the other four are Canada, Norway, Netherlands and the United Kingdom), and has become:

- the world's largest exporter of black coal;
- a major uranium producer and exporter; and
- an exporter of Liquefied Petroleum Gas (LPG) and petroleum products, and a major exporter of Liquefied Natural Gas.

Table 3.1 provides information on the significance of energy exports in the national economy. Exports of energy products were about 16% of total export income in 1994–95.

3.1 EXPORTS OF ENERGY PRODUCTS, 1994–95

Commodity exports	*Value* $m	*Proportion of total* %
Coal, whether or not pulverised but not agglomerated	6 889	10
Gas, natural and manufactured	1 335	2
Petroleum oils and oils obtained from bituminous minerals, crude	1 644	2
Petroleum products	1 307	2
Uranium and thorium ores and concentrates	188	—

Source: ABS 1996.

Major non-renewable resources in Australia include petroleum, black and brown coal, and uranium. Renewable energy resources are mainly hydro, biomass, solar and wind energy.

Petroleum

Major oil discoveries were made before 1970 and the major sales gas, condensate and LPG discoveries were made before 1980. About 950 gigalitres (6,000 million barrels) of crude oil and 3,490 billion cubic metres (123 trillion cubic feet) of sales gas had been identified by the end of 1994. On the basis of figures for the world's identified resources at the beginning of 1993, Australia's initial identified resources of crude oil make up about 0.3% of the world total, and natural gas makes up 1.8%. Over the last 25 years Australia has enjoyed a high level of oil self-sufficiency which has fluctuated between 60% and 90% of domestic oil consumption.

Oil production began from the Moonie field in 1964 and increased significantly as Barrow Island was brought into production in 1967 and the Gippsland Basin in 1970. Production of crude oil reached 20 gigalitres a day in 1973 and has fluctuated between about 20 and 30 gigalitres a day since then. About 625 gigalitres (3,930 million barrels) of crude oil had been produced by the end of June 1995.

Gas production commenced in the 1960s and pipelines were built to connect gas fields in the Moomba area to Adelaide (1969), Gippsland to Melbourne (1969), Roma to Brisbane (1969), Dongarra to Perth (1971) and Moomba to Sydney (1976). Since then, a 1,500 kilometre gas pipeline has been built from Palm Valley (central Australia) to Darwin, a 1,600 kilometre pipeline has been built from North Rankin and Goodwyn platforms (north-west Australia) to Perth and a 1,400 kilometre pipeline is presently under construction from Yarraloola (north-west Australia) to Kalgoorlie (south-west Australia). Currently, more than 64 million cubic metres of natural gas is produced per day, 10% of the total energy production of primary fuels. About 320 billion cubic metres (11.35 trillion cubic feet) of sales gas had been produced by the end of June 1995.

Coal

Australia is well endowed with coal resources. About 8% of black coal and 15% of brown coal resources in the world are located in Australia. Many of them are positioned in convenient places close to the coast and population centres, and sufficiently close to the surface so that they can be developed as open cut mines. A large part of Australia's coal production is exported. At current production levels, Australia's economically recoverable coal resources would support coal production for several centuries (if there were no land use constraints). Black coal mines in Australia are largely centred in the Sydney Basin in New South Wales and Bowen Basin in Queensland, while other parts of New South Wales and Queensland, as well as Western Australia, South Australia and Tasmania, have significant deposits. Brown coal is mainly mined in the Latrobe Valley of Victoria with over 93% of Australia's brown coal reserves. Much smaller brown coal deposits are found in Tasmania, South Australia and Western Australia, although there is currently no production.

Compared with other energy sources, coal is relatively cheap and reliable, easy to transport and use. Black coal has been a major export earner for Australia. About 75% of black coal production is for export. Of the remaining 25%, about 4% is used to produce coke. In domestic consumption, coal is mainly used for electricity generation, iron and steel production, metal treatment, and cement and paper manufacture.

Electricity

In Australia, for public electricity supply, about 90% of electricity is generated from fossil fuels with about 10% being produced by hydro-power stations. Wind farm electrical generation is still very minor, with 4.2 million kilowatt hours produced in 1993–94. Coal-fired power stations contribute the major part of electricity generation since Australia has vast coal resources available and the price of coal gives this fuel source a competitive advantage.

At 30 June 1994, the total installed generating capacity of plants was 39.8 gigawatts, of which 94% (37.3 gigawatts) was installed for the public supply of electricity and about 6% (2.5 gigawatts) was installed by private organisations for their own use. (The statistics exclude some mining and business private electricity generation due to data limitations.) In public electricity supply, New South Wales has about 33% of capacity, Victoria about 19%, Queensland about 17%, South Australia about 6%, Western Australia about 8%, Tasmania about 7% and the Northern Territory less than 1%. The remaining 10% was located in the Snowy Mountains Scheme.

Uranium

Australia has the world's largest resources of low-cost uranium. The Ranger mine in the Northern Territory is one of the largest uranium mines in the world. At the time of writing, current government legislation only allows the Ranger and Nabarlek mines in the Northern Territory and the Olympic Dam mine in South Australia to continue production.

Ranger consists of an open cut mining operation and a concentrating plant. The plant has a production capability of 3,000 tonnes of uranium oxide per year. Production for the year ended 31 December 1994 was 1,462 tonnes of uranium oxide. Olympic Dam consists of an underground mining operation and a metallurgical complex. Production for the year ended 31 December 1994 was 1,142 tonnes of uranium oxide.

Current government legislation does not allow nuclear power stations to be built in Australia. Domestic consumption is limited to minor use in medical, industrial and scientific applications. Uranium produced in Australia is exported to countries which use uranium for generation of electricity, or for other peaceful purposes. There are stringent nuclear safeguard conditions applied to exports, and subsequent use of Australian uranium is bound by international legal obligations in bilateral nuclear safeguards agreements. The *Nuclear Non-Proliferation (Safeguards) Act (1987)* provides for safeguards concerning the possession and transport of nuclear material and other physical items related to nuclear reactors in Australia.

Wood and bagasse

There are a variety of biomass energy resources that can be considered as alternative fuels, but currently only wood fuel and bagasse are used significantly in Australia. Both wood and bagasse are combusted to release stored energy.

Common solid wood fuels are firewood, woodchips, fuel pellets and charcoal as well as wood wastes. Wood and wood wastes have been used as energy in manufacturing such as paper and paper products, and even for electricity generation. Wood fuels are continuously consumed for conventional heating by many households in Australia (Australian Bureau of Statistics (ABS) 1984, 1985–86).

Bagasse is the fibrous residue from sugar cane after extraction of the juice, and is burnt to provide energy for electricity generation in sugar mills. The stock of bagasse depends upon farm production levels, and processing and storage capacity. Bagasse is the second largest renewable resource used for electricity generation after hydro. The use of bagasse as fuel is limited to New South Wales and Queensland where sugar is grown.

Apart from using wood and bagasse, there is increasing capability in Australia to use landfill gas for electricity generation. Landfill gas is produced by anaerobic decomposition of organic matter in rubbish tips to form methane gas. The gas is collected, filtered and then used in a gas turbine to generate electricity. The total installed capacity of landfill gas power plants is about 12 megawatts.

Production of alcohol fuels can also use biomass feedstocks such as cereal grains and straw, bagasse, cassava and forest plantations. The Australian Government is encouraging all producers of ethanol through the Ethanol Bounty Scheme, with a total budget of $25 million over three years. International research shows that alcohol fuels might be used as alternatives or supplements to petrol for transport vehicles or other combustion engines. For diesel engines, vegetable oils such as sunflower, rapeseed and peanut oil have also been considered as potential alternatives.

Wind energy

The use of wind energy has been regarded as promising and a low cost option for generating electricity in Australia. Australia's large wind resources are located in coastal and island localities of southern Australia, particularly in Tasmania, South Australia and Western Australia where many sites are ranked with the world's best. There is the potential that wind energy in these States would be sufficient to supply at least 10–20% of their present electricity needs (Department of the Arts, Sport, the Environment, Tourism and Territories (DASETT) 1991b). Wind farms for electricity generation are particularly suitable for those communities in remote areas that cannot be connected with the electricity supply grid.

In Australia wind energy has traditionally been used for windmills for water pumping. In recent years, wind farms for electricity generation have been established in some States as prototypes. So far, the installed wind farm capacity in Esperance, Western Australia is about 2 megawatts, in South Australia about 150 kilowatts and in Tasmania about 55 kilowatts.

Solar energy

Australia has vast high quality solar energy resources, which for most of the continent exceed 1,600 kilowatt hours per square metre per year of solar radiation. Some areas over the Western Australia–Northern Territory border exceed 2,500 kilowatt hours per square metre per year. Because Australia's best solar resources are located in areas where land is marginal for agricultural purposes, the use of solar energy would have a relatively low impact on other land uses. As with wind energy, solar power generation has particular importance in remote areas of Australia.

There are other solar energy uses in Australia, such as solar evaporative ponds used for salt production, and passive solar space heating. Telstra Australia (former Telecom Australia) was among the first organisations in the world to apply solar systems in remote communications power applications. In Australia the current dominant use of solar energy is domestic water heating, with about 6% of Australian residences having domestic solar hot water units. Water heating and process steam used for industrial and commercial purposes have also grown in recent years. Other applications such as swimming pool heating, and space heating and cooling, have been developed. For solar electricity generation, there are small, self-contained solar power systems installed in conjunction with a diesel generator, for remote areas. It is expected that solar electricity generation will grow quickly although the contribution of solar power to total electricity supply will remain very small.

SUMMARY OF STOCK ACCOUNTS

The stock account for major non-renewable economic energy resources is given in table 3.2. For purposes of comparison across all energy resources, stocks are defined in terms of the McKelvey Classification.

Australia's identified non-renewable energy resources are estimated to be about 6% of the world's total (Department of Primary Industry and Energy (DPIE) 1992). Black coal's share is about 65% of Australia's total, brown coal's 20%, uranium's about 13%, natural gas's about 2%, and crude oil, condensate and LPG's about 1%. It is considered that Australia is still relatively under-explored for energy resources and that there are good prospects for further substantial discoveries.

3.2 STOCK ACCOUNT FOR MAJOR NON-RENEWABLE ENERGY RESOURCES, 1993–94

	Crude oil	*Condensate*	*Natural gas*	*LPG*	*Black coal*	*Brown coal*	*Uranium*
	GL	GL	Gm^3	GL	Gt	Gt	'000 t
			ECONOMIC DEMONSTRATED RESOURCES				
Opening stock	247.0	135.0	999.0	134.0	[1]52.0	[1]41.00	[2]631.00
Adjustment	51.0	16.0	174.0	14.0	–2.8	0.1	4.3
Production	–25.0	–4.0	–26.0	–4.0	–0.2	–0.1	–2.3
Closing stock	273.0	147.0	1 147.0	144.0	49.0	41.0	633.0
Net change	26.0	12.0	148.0	10.0	–3.0	0.0	2.0
			SUB-ECONOMIC DEMONSTRATED RESOURCES				
Opening stock	35.0	54.0	1 136.0	88.0	5.0	3.0	76.0
Adjustment	–4.0	5.0	60.0	1.0	0.0	0.0	1.0
Closing stock	31.0	59.0	1 196.0	89.0	5.0	3.0	77.0

[1] The data collection period for coal ended at September each year. Here black and brown coal refer to 'recoverable' resources.
[2] Uranium data was based on calendar year.

Source: BRS 1996.

In table 3.2, it can be seen that the opening stock in 1993–94 for economic demonstrated resources of crude oil was 247 gigalitres and the closing stock was 273 gigalitres. Production was 25 gigalitres during this year. Through upgrading of the resources, 51 gigalitres were added so that the net change was an increase of 26 gigalitres to the opening stock. At current production rates, the resources can support a further 11 years crude oil demand assuming no further changes in technology or extension of resources.

For condensate, the production level was relatively low, only about 4 gigalitres in 1993–94. The adjustment added 16 gigalitres to the opening stock so that the closing stock was up by 12 gigalitres to 147 gigalitres. If 4 gigalitres a year production continues, the condensate stock would last for a further 37 years with the same caveats as above.

The closing stock of natural gas was 1,147 giga cubic metres, an increase of 148 giga cubic metres due to new estimates. With production of 26 giga cubic metres a year, the stock is sufficient to meet a further 44 years production, again with the same caveats.

Stocks of LPG have also increased, from 134 gigalitres to 144 gigalitres, with upgrading of 14 gigalitres minus production of about 4 gigalitres. At the current production level, present LPG stocks will last for a further 36 years, while the same caveats apply.

Proven economic coal resources are very extensive. The opening stock of black coal was 52 gigatonnes and the closing stock decreased 3 gigatonnes to 49 gigatonnes. Production was only 0.2 gigatonnes which indicates that a further 245 years production would be possible if there is no land constraints. Brown coal also has vast economic resources, with closing stock being 41 gigatonnes. At a steady rate of production around 0.05 gigatonnes a year, present stock could last for many centuries.

Australia also has large sub-economic energy resources as shown in table 3.2. In the future, the market situation and changing technology, could see these resources being upgraded to economic resources.

3.3 CLOSING STOCK OF MAJOR NON-RENEWABLE ENERGY RESOURCES

Year	*Crude oil* GL	*Condensate* GL	*Natural gas* Gm^3	*LPG* GL	*Black[1] coal* Gt	*Brown[1] coal* Gt	*Uranium[2]* '000 t
			ECONOMIC DEMONSTRATED RESOURCES				
1981–82	261	78	624	123	30	36	314
1982–83	249	71	629	112	31	37	474
1983–84	231	82	616	85	35	42	463
1984–85	231	81	691	85	34	42	465
1985–86	224	80	691	88	34	42	462
1986–87	231	118	832	97	50	42	470
1987–88	240	118	1 043	85	50	42	480
1988–89	252	121	1 030	128	51	42	474
1989–90	278	107	941	106	51	42	469
1990–91	258	124	950	108	51	42	474
1991–92	251	129	978	133	52	41	462
1992–93	247	135	999	134	52	41	631
1993–94	273	147	1 147	144	49	41	633
			SUB-ECONOMIC DEMONSTRATED RESOURCES				
1981–82	34	27	284	33	0	0	22
1982–83	46	24	398	25	3	71	64
1983–84	57	29	840	11	1	1	63
1984–85	42	28	830	11	1	1	56
1985–86	54	37	803	20	1	1	56
1986–87	31	64	1 406	12	2	2	56
1987–88	28	48	984	13	2	2	58
1988–89	27	46	1 052	37	2	2	58
1989–90	31	66	1 163	58	4	3	60
1990–91	82	71	1 293	94	5	3	55
1991–92	39	55	1 109	86	5	3	55
1992–93	35	54	1 136	88	5	3	76
1993–94	31	59	1 196	89	5	3	77

1 The data collection period for coal ended at September each year. Here black and brown coal refer to 'recoverable' resources.
2 Uranium data was based on calendar year.

Source: BRS 1996.

Table 3.3 shows trends of major non-renewable energy resources over the period of 1981–82 to 1993–94. Despite 13 years mining production, stocks increased for all of the economic resources shown in table 3.3, as a result of continual upgrading of existing resources and discoveries. As compared with the stock levels in 1981–82, condensate increased about 88%, natural gas about 84% and LPG about 17%. The estimate of black coal was up about 63% and uranium doubled.

SUMMARY OF FLOW ACCOUNTS

Compared with Australia's vast energy resources, energy production and consumption are relatively low in absolute terms, being 2.5 to 3% of the world's non-renewable primary fuel production and just over 1% of the world's primary energy consumption (DPIE 1992). On the other hand, Australia's energy intensity assessed in terms of energy used per unit of output was higher than many other countries (Australian Bureau of Agricultural and Resource Economics (ABARE) 1995).

A summary of the flow account showing energy supply, conversion and consumption for Australia, is given in table 3.4. By definition, total energy supply is equal to the total conversion plus consumption. Energy supply here is domestic production, plus imports minus exports (plus industrial stock changes and statistical discrepancies). The figures in conversion show the energy consumed in the conversion process. The sum of end use consumption is equivalent to net supply after conversion.

Over the period of 1982–83 to 1993–94, energy production in Australia has increased about 34% from 6,730.2 petajoules to 9,035.7 petajoules. The major part of the increase in energy production was used to boost energy exports, which almost doubled during the 12 years. Net domestic supply took about 36% of the increase. To supplement the demand for certain energy products such as crude oil and feedstock, imports of energy products were up by 60%.

In the conversion process, energy used for making coke and briquettes was reduced due to a decline in the coke and briquette markets. Public electricity generation increased its energy intake by 35%. The use of town gas has been reducing for some time. Natural gas production has doubled over the 12-year period.

Energy consumption for industrial, commercial and residential use between 1982–83 and 1993–94 has increased about 36%. Road transport was the dominant sector in energy consumption, and increased about 31% during this period. The mining sector had the highest proportional increase (160%) in energy consumption, from 75 petajoules in 1982–83 to 196 petajoules in 1993–94. Energy consumption for the air transport sector has also increased, up about 73%, while the commercial sector increased by 54%. The iron and steel industry used 96 petajoules (up 17%). Water transport reduced its energy demand by 36% as a result of a decline in Australian-owned shipping activity.

In terms of energy products, the separate flow accounts for 1993–94 are summarised in tables 3.5 and 3.6 respectively. Table 3.5 is the flow account for primary energy products and table 3.6 the flow account for derived energy products (except LPG included in liquid products of petroleum).

3.4 FLOW ACCOUNT FOR ENERGY SUPPLY, CONVERSION AND CONSUMPTION

	1982 83	1983–84	1984–85	1985-86	1986–87	1987–88	1988-89	1989–90	1990 91	1991–92	1992 93	1993–94
	PJ	PJ	PJ	PJ	PJ	PJ	PJ	PJ	PJ	PJ	PJ	PJ
SUPPLY												
Production	6 730.2	6 992.7	7 613.4	8 106.8	8 552.7	8 098.6	8 570.6	8 923.8	9 299.4	9 603.2	8 981.0	9 035.7
Imports	557.6	428.5	389.7	345.0	451.2	495.4	619.7	625.6	625.2	672.8	860.4	890.9
Exports	3 884.2	–3 697.7	–4 388.3	–4 437.2	–5 142.7	5 480.1	–5 584.2	–5 257.4	-6 785.8	–6 517.7	–5 584.0	–6 414.1
Stock change[1]	280.7	–502.9	–245.1	-611.3	–346.3	508.3	225.9	–346.4	807.9	245.5	–178.4	661.6
Total supply	*3 122.9*	*3 220.4*	*3 369.6*	*3 403.0*	*3 514.8*	*3 622.3*	*3 832.1*	*3 945.2*	*3 946.6*	*4 003.2*	*4 079.2*	*4 174.2*
CONVERSION												
Coke ovens	38.9	45.2	50.0	41.2	50.7	39.2	50.9	29.8	36.0	36.0	31.9	28.9
Briquetting	0.6	0.5	0.9	0.2	0.2	0.2	0.3	0.3	0.3	0.5	0.2	0.5
Petroleum refining	16.9	15.6	14.2	13.3	11.5	12.4	11.7	13.9	13.3	13.2	13.2	13.6
Gas manufacturing	0.6	0.8	0.6	0.1	0.4	0.3	0.2	0.3	0.4	0.8	0.7	0.3
Electricity generation	773.4	787.3	833.2	828.8	869.5	893.7	973.4	991.0	993.2	1 020.0	1 019.9	1 045.8
Other conversion	44.9	40.9	38.2	30.6	26.6	26.9	28.8	61.6	60.3	55.8	41.2	43.0
Own fuel use	154.2	162.0	167.5	170.7	174.2	173.4	181.6	181.2	180.8	184.2	189.3	188.2
Total conversion	*1 029.5*	*1 052.3*	*1 104.6*	*1 084.9*	*1 133.1*	*1 146.1*	*1 246.9*	*1 278.1*	*1 284.3*	*1 310.5*	*1 296.4*	*1 320.3*
Net supply[2]	2 093.4	2 168.1	2 265.2	2 319.2	2 381.5	2 475.9	2 585.0	2 667.1	2 662.5	2 693.5	2 783.6	2 853.5

For footnotes see end of table.

3.4 FLOW ACCOUNT FOR ENERGY SUPPLY, CONVERSION AND CONSUMPTION — *continued*

	1982–83	*1983–84*	*1984–85*	*1985–86*	*1986–87*	*1987–88*	*1988–89*	*1989–90*	*1990–91*	*1991–92*	*1992–93*	*1993–94*
	PJ	PJ	PJ	PJ	PJ	PJ	PJ	PJ	PJ	PJ	PJ	PJ
END USE												
Agriculture	49.7	55.5	54.6	53.8	56.2	55.1	58.1	57.6	58.4	58.5	60.3	62.3
Mining	75.3	83.5	97.3	99.0	106.3	118.1	130.7	162.8	167.8	173.5	192.3	196.1
Iron and steel	82.1	84.9	89.1	97.4	102.4	96.4	97.5	99.1	95.7	90.9	95.7	96.3
Chemical	107.0	110.7	112.9	116.5	113.1	126.1	126.1	129.8	132.9	135.7	128.6	130.1
Other industry	483.3	506.8	549.3	561.7	579.6	602.4	638.8	645.1	642.6	643.4	657.5	679.0
Construction	34.9	33.3	31.2	34.7	34.9	39.4	41.5	41.0	37.2	38.7	41.6	42.8
Road transport	646.3	676.8	700.7	719.4	728.6	760.1	792.8	808.9	791.3	801.4	828.8	849.9
Rail transport	28.4	30.7	32.4	31.6	32.7	32.7	31.1	30.7	30.5	31.1	29.4	29.5
Air transport	84.1	83.8	89.6	93.6	97.7	107.2	114.2	109.4	122.7	131.0	140.1	145.3
Water transport	74.8	68.5	64.8	55.3	58.3	59.6	60.1	56.3	49.1	48.8	45.6	47.7
Commercial	109.6	110.2	114.5	121.0	127.3	134.1	141.7	150.8	156.4	157.8	164.5	169.1
Residential	273.2	276.1	282.1	288.4	298.3	296.5	302.0	323.0	328.6	334.4	347.1	349.3
Others[3]	44.8	47.0	46.6	47.0	47.0	48.0	50.4	52.7	49.3	48.3	52.1	56.0
Consumption	*2 093.4*	*2 168.1*	*2 265.2*	*2 319.3*	*2 381.5*	*2 475.9*	*2 585.0*	*2 667.1*	*2 662.5*	*2 693.5*	*2 783.6*	*2 853.5*

[1] Includes discrepancies.
[2] After conversion industrial sector use and losses. Equals total final energy consumption.
[3] Includes lubricants, greases, bitumen and solvents.

Source: ABARE 1995.

In table 3.5 amongst the primary energy products, black coal production (4,787 petajoules), accounted for 53.6% of total primary energy production. Uranium was the next highest, being 14.5% of the total (virtually all exported), followed by crude oil and other refinery feedstock (11.9%), natural gas (11.8%) and brown coal (5.5%). Australia's renewable energy resources are minor contributors to total energy production: wood fuel was 1.2% of the total, bagasse 0.9% and hydro 0.7%.

3.5 FLOW ACCOUNT FOR PRIMARY ENERGY PRODUCTS, 1993–94

	Crude oil and ORF[1]	*Natural gas*	*Black coal*	*Brown coal*	*Uranium*	*Wood*	*Bagasse*	*Hydro-energy*	*Solar energy*[2]	*Total*
	PJ	PJ	PJ	PJ	PJ	PJ	PJ	PJ	PJ	PJ
				SUPPLY						
Production	1 060.8	1 054.1	4 786.6	486.8	1 293.0	107.1	84.5	60.5	2.4	8 935.8
Imports	787.1	—	—	—	—	—	—	—		787.1
Exports	–364.6	–320.7	–3 668.1	—	–1 876.2	—	—	—	—	–6 229.6
Other[3]	21.5	—	78.9	—	583.2	—	—	–0.3	—	683.3
Total supply	*1 504.9*	*733.4*	*1 197.4*	*486.8*	—	*107.1*	*84.5*	*60.2*	*2.4*	*4 176.6*
				CONVERSION						
Coke ovens	—	—	164.3	—	—	—	—	—	—	164.3
Briquetting	—	—	—	13.1	—	—	—	—	—	13.1
Petroleum refining	1 513.0	9.2	—	—	—	—	—	—	—	1 522.2
Gas manufacturing	—	1.6	—	—	—	—	—	—	—	1.6
Electricity generation	—	147.9	913.9	473.2	—	—	—	60.2	—	1 595.2
Other conversion	8.8	—	—	—	—	—	—	—	—	8.8
Own fuel use	—	20.9	—	—	—	—	—	—	—	20.9
Total conversion	*1 521.8*	*179.6*	*1 078.2*	*486.3*	—	—	—	60.2	—	*3 326.1*
Net supply[4]	0.6	553.8	119.2	0.5	—	107.1	84.5	—	2.4	868.1
				END USE						
Agriculture	—	0.1	—	—	—	—	—	—	—	0.1
Mining	0.6	106.1	6.0	—	—	—	—	—	—	112.7
Iron and steel	—	23.1	8.2	—	—	—	—	—	—	31.3
Chemical	—	55.7	3.1	—	—	—	—	—	—	58.8
Other industry	—	228.5	95.6	0.5	—	24.9	84.5	—	—	434.0
Construction	—	0.2	—	—	—	—	—	—	—	0.2
Road transport	—	1.2	—	—	—	—	—	—	—	1.2
Air transport	—	0.4	—	—	—	—	—	—	—	0.4
Water transport	—	0.1	3.8	—	—	—	—	—	—	3.9
Commercial	—	39.7	2.3	—	—	0.6	—	—	—	42.6
Residential	—	98.7	0.1	—	—	81.6	—	—	2.4	182.8
Consumption	*0.6*	553.8	*119.2*	0.5	—	*107.1*	84.5	—	2.4	*868.1*

[1] Includes the energy produced from conversion process and naturally occurring LPG. ORF — Other refinery feedstocks.
[2] Accounts only for hot water systems.
[3] Stock changes and discrepancies.
[4] After conversion sector use and losses. Equals total final energy consumption.

Source: ABARE 1995.

In 1993–94, of the 8,935.8 petajoules of energy products, 25.6% (2,287.1 petajoules) was converted into five main secondary energy products (liquid products of petroleum, town gas, coke, briquettes and electricity) as shown in table 3.6. Most of the energy was used for producing petroleum products (66.2%).

3.6 FLOW ACCOUNT FOR DERIVED ENERGY PRODUCTS, 1993–94

	Products of petroleum[1]	*Town gas*	*Coke*	*Coal by-products*	*Briquettes*	*Electricity*[2]	*Total*
	PJ	PJ	PJ	PJ	PJ	PJ	PJ
			SUPPLY				
Production[3]	99.9	2.5	107.8	28.3	12.8	579.9	831.2
Petroleum refining	1 513.0	—	—	—	—	—	1 513.0
Other conversion	—	—	—	23.2	—	22.1	45.3
Imports	103.8	—	—	—	—	—	103.8
Exports	–168.7	—	–14.3	—	1.5	—	–184.5
Other[4]	–24.0	—	2.9	—	–0.6	—	–21.7
Total	*1 524.0*	2.5	*96.4*	*51.5*	*10.7*	*602.0*	*2 287.1*
			CONVERSION				
Coke ovens	0.6	—	—	—	—	0.1	0.7
Briquetting	—	—	—	—	—	0.2	0.2
Petroleum refining	—	—	—	—	—	4.4	4.4
Gas manufacturing	1.2	—	—	—	—	—	1.2
Electricity generation	28.4	—	—	0.5	1.3	—	30.2
Other conversion	8.8	—	88.3	—	—	—	97.1
Own fuel use	91.2	0.2	—	—	—	75.9	167.3
Total conversion	*130.2*	*0.2*	*88.3*	0.5	*1.3*	*81.0*	*301.5*
Net supply[5]	1 393.8	2.3	8.1	51.1	9.4	520.9	1 985.6
			END USE				
Agriculture	53.1	—	—	—	—	9.1	62.2
Mining	43.0	—	0.2	2.0	—	38.2	83.4
Iron and steel	1.6	—	2.4	42.0	—	19.0	65.0
Chemical	47.3	—	—	7.1	3.4	13.5	71.3
Other industry	60.9	—	5.5	—	4.1	174.5	24.5
Construction	42.5	—	—	—		0.1	42.6
Road transport	848.7	—	—	—	—	—	848.7
Rail transport	23.3	—	—	—	—	6.2	29.5
Air transport	144.5	—	—	—	—	0.4	144.9
Water transport	43.1	—	—	—	—	0.6	43.7
Commercial	13.1	0.7	—	—	1.7	111.0	126.5
Residential	16.5	1.5	—	—	0.2	148.3	166.5
Others[6]	56.0	—	—	—	—	—	56.0
Consumption	*1 393.8*	*2.3*	*8.1*	*51.1*	*9.4*	*520.9*	*1 985.6*

1 Includes naturally occurring LPG.
2 Includes electricity generated from hydro-power station.
3 Includes the energy produced from conversion process. For liquid products of petroleum, production here refers to LPG production; for coal by products, production refers to those produced from coke ovens.
4 Stock changes and discrepancies.
5 After conversion sector use and losses. Equals total final energy consumption.
6 Includes lubricants, greases, bitumen and solvents.

Source: ABARE 1995.

SUMMARY OF RESIDUAL ACCOUNTS

As with most countries in the world, energy production, conversion and end use in Australia have been major sources of air pollutants and greenhouse gas emissions. Compared with Europe or North America, Australia benefits from its lower population densities and lower sulphur content of its indigenous crude oil and coal. However, many Australian urban areas, particularly capital cities, suffer from air pollution problems, such as lead and photochemical smog. Australian greenhouse gas emissions are regarded as significant, ranked at 17th in total world emissions, and fourth in per capita emissions in which energy-related activities are major contributors.

Air pollutants and greenhouse gas emissions can generally be classified into two broad categories: fuel-combustion emissions and fugitive-fuel emissions. The term 'fugitive-fuel emissions' refers to those emissions not related to combustion for energy. The fugitive emissions are generated from those sources associated with production, transmission, storage and distribution of fuel and from mining. In the oil and natural-gas systems, emissions can occur in ways, such as from venting, flaring and system leakage in production; and from evaporation, system or equipment leakage in transmission, storage and distribution system. Fuel-combustion emissions make up the bulk of emissions.

Table 3.7 summarises the residual accounts for some common air pollutants and greenhouse gases emitted into the atmosphere from fuel-combustion activities for the period 1987–88 to 1993–94. During the period 1989–90 to 1993–94, energy use in Australia associated with fuel combustion rose 5%. Consequently, there were general increases for most air pollutants and greenhouse gas emissions from fuel combustion activities.

In the period 1989–90 to 1993–94, carbon dioxide emissions rose by 4% from 262 to 274 million tonnes. Carbon dioxide emissions from energy and transformation (principally electricity generation) rose 6.4%. The total emissions of methane also rose by about 3% from 109 kilotonnes to 113 kilotonnes. For methane emissions, a rise of 10% in emissions from biomass burned for energy was partially offset by a fall of 14% in emissions of methane from transport. Carbon monoxide emissions fell over the period, due entirely to the transport emissions declining.

3.7 RESIDUAL ACCOUNT FOR SELECTED AIR POLLUTANTS AND GREENHOUSE GASES FROM FUEL COMBUSTION

	Units	*1987–88*	*1988–89*	*1989–90*	*1990–91*	*1991–92*	*1992–93*	*1993–94*
Energy consumption	PJ							
Energy and transformation		1 523.1	1 652.3	1 692.0	1 716.7	1 758.2	1 782.5	1 804.6
Industry		629.2	650.8	691.3	683.4	664.3	669.9	681.9
Transport		868.6	890.5	896.3	887.0	909.1	920.7	944.8
Small combustion		189.0	196.2	208.6	210.7	217.5	226.3	228.3
Other		22.2	23.2	23.7	23.2	18.9	25.6	26.5
Biomass burned for energy		164.3	174.4	179.1	178.1	164.9	182.5	191.2
Total fuel combustion		*3 396.4*	*3 587.2*	*3 691.1*	*3 699.1*	*3 732.8*	*3 807.5*	*3 877.4*
Carbon dioxide	Gg							
Energy and transformation		128 087.0	139 504.0	141 807.0	145 297.0	148 513.0	149 791.0	150 851.0
Industry		41 693.0	43 037.0	47 363.0	46 685.0	44 524.0	44 725.0	45 342.0
Transport		57 853.0	59 263.0	59 596.0	58 944.0	60 397.0	61 120.0	62 689.0
Small combustion		11 183.0	11 588.0	12 178.0	12 258.0	12 592.0	13 070.0	13 181.0
Other		1 570.0	1 642.0	1 680.0	1 641.0	1 342.0	1 808.0	1 872.0
Biomass burned for energy		—	—	—	—	—	—	—
Total fuel combustion		*240 386.0*	*255 033.0*	*262 623.0*	*264 824.0*	*267 369.0*	*270 514.0*	*273 934.0*
Methane	Gg							
Energy and transformation		1.6	1.8	1.9	1.9	2.0	2.1	2.1
Industry		1.1	1.1	1.2	1.2	1.2	1.2	1.3
Transport		29.7	29.3	29.9	28.4	26.7	26.3	25.6
Small combustion		0.7	0.7	0.8	0.7	0.7	0.8	0.8
Other		0.1	0.1	0.1	0.1	0.1	0.2	0.2
Biomass burned for energy		71.0	73.3	75.3	77.5	79.6	82.0	82.9
Total fuel combustion		*105.1*	*106.3*	*109.2*	*109.8*	*110.3*	*112.5*	*112.8*
Nitrous oxide	Gg							
Energy and transformation		1.3	1.4	1.4	1.5	1.5	1.5	1.5
Industry		0.3	0.3	0.3	0.3	0.3	0.3	0.3
Transport		3.0	4.1	5.2	5.8	7.1	8.0	8.9
Small combustion		0.1	0.1	0.1	0.1	0.1	0.1	0.1
Other		—	—	—	—	—	—	—
Biomass burned for energy		0.7	0.7	0.7	0.7	0.7	0.8	0.8
Total fuel combustion		*5.4*	*6.6*	*7.7*	*8.4*	*9.6*	*10.6*	*11.6*
Oxides of nitrogen	Gg							
Energy and transformation		405.8	443.9	458.1	470.5	470.5	489.4	489.1
Industry		286.8	300.2	321.5	315.7	311.0	316.8	325.0
Transport		495.9	482.3	470.4	446.9	428.2	421.2	409.6
Small combustion		69.6	73.6	71.5	71.9	71.9	75.4	77.5
Other		8.1	8.2	9.5	9.1	7.5	10.8	11.1
Biomass burned for energy		13.6	14.4	14.8	14.7	13.6	15.1	15.8
Total fuel combustion		*1 279.8*	*1 322.7*	*1 345.8*	*1 328.9*	*1 302.7*	*1 328.6*	*1 328.1*
Carbon monoxide	Gg							
Energy and transformation		35.0	40.3	41.4	42.7	42.7	43.1	43.9
Industry		80.6	86.1	93.0	93.7	94.7	100.6	104.0
Transport		5 433.2	5 155.7	5 190.7	4 612.4	4 106.3	3 936.8	3 514.6
Small combustion		29.5	30.3	29.3	28.9	28.9	29.1	29.9
Other		7.1	7.4	7.8	7.2	6.6	7.4	7.5
Biomass burned for energy		653.3	675.2	692.8	703.1	694.9	735.7	753.9
Total fuel combustion		*6 238.6*	*5 995.0*	*6 055.1*	*5 488.0*	*4 974.1*	*4 852.7*	*4 453.8*

... continued

3.7 RESIDUAL ACCOUNT FOR SELECTED AIR POLLUTANTS AND GREENHOUSE GASES FROM FUEL COMBUSTION — *continued*

	Units	*1987–88*	*1988–89*	*1989–90*	*1990–91*	*1991–92*	*1992–93*	*1993–94*
Non-methane volatile organic compounds	Gg							
Energy and transformation		5.6	6.2	6.6	6.8	6.8	6.8	6.9
Industry		7.9	8.6	9.0	8.8	9.3	9.9	10.3
Transport		682.4	665.4	663.3	609.9	566.0	548.8	521.0
Small combustion		8.3	8.8	8.5	8.5	8.5	8.9	9.2
Other		0.9	1.0	1.0	1.0	0.8	1.1	1.1
Biomass burned for energy		169.9	173.1	177.9	182.9	187.9	193.6	195.9
Total fuel combustion		*875.0*	*862.9*	*866.4*	*817.9*	*799.3*	*769.1*	*744.4*

Source: NGGIC 1996.

CHAPTER 4 PETROLEUM ACCOUNTS

Petroleum is one of the primary fuels which is presumed to be a finite and non-renewable energy resource. Australia's first commercial oil and gas fields were discovered in the 1960s and oil and gas production from these fields soon became one of the major factors in the Australian economy in the late 1960s. Over the last 25 years, Australia has enjoyed a high level of oil self-sufficiency, which has fluctuated between 60 and 90% of domestic oil consumption.

Nevertheless, Australia's resources of crude oil are limited and there is concern as to how much longer the oil production can last. During the 13 years 1982–83 to 1994–95, 332 gigalitres of crude oil were produced while current estimates suggest that only about 190 gigalitres were discovered.

All of the domestic consumption of natural gas is met by production in Australia, and significant additional amounts are exported. About 8% of Australia's resources of sales gas has been produced. There are prospects for significantly increased production for both domestic and export markets.

This chapter presents physical accounts for petroleum resources in Australia. The sections of the chapter contain some background information on petroleum; a discussion about the level of Australia's total petroleum resources and the amounts produced; data on stocks of demonstrated resources of petroleum; flow accounts, which report petroleum supply, conversion and end use; and some information on the residuals discharged into the natural environment.

BACKGROUND

Terms and concepts

Petroleum is broadly defined as a naturally occurring hydrocarbon or mixture of hydrocarbons. As oil or gas, or in solution, it is widespread in Australian sedimentary rocks, but major concentrations are generally rare. Such concentrations which make up Australia's petroleum endowment (Harris 1984) may include: conventional oil and gas accumulations; heavy oil and tar sand accumulations; gas in coal, in tight formations and in geopressure zones; and accumulations of gas hydrate. Australia has hundreds of conventional oil and gas accumulations and large amounts of gas in coal and in tight formations, but no known, major heavy oil or tar sand accumulations (National Energy Advisory Committee 1981).

Petroleum resources are the part of Australia's petroleum endowment that may be produced profitably by currently feasible or near-feasible technology and for specified product prices. Petroleum resources are defined to include only those natural concentrations from which economic extraction of a part is feasible within the range of technology and prices likely to be seen within the next 20–25 years. Hence, petroleum resources are a subset of petroleum endowment that can change according to the assumed technological and economic conditions. The amount of resources is measured or estimated at standard conditions of temperature and pressure, defined as 15°C and 101.325 kilopascals.

Although some production of gas from coal and tight formations is feasible over the next 25 years, only conventional petroleum, that is petroleum produced by the flow of naturally occurring fluids into drilled wells, is considered in the stock account of this chapter.

Petroleum resources can be generally classified into the following categories.

Crude oil is a mixture of hydrocarbons, existing in the liquid state, both in natural underground reservoirs and at atmospheric pressure after passing through surface separating facilities.

Sales gas is derived by processing the natural gas produced from either gas or oil reservoirs. It contains mainly methane, ethane, minor amounts of other hydrocarbon gases and some carbon dioxide. The processing normally removes condensate/crude oil, Liquefied Petroleum Gas (LPG) and any carbon dioxide in excess of 3%.

Condensate is a liquid mixture of pentanes and heavier hydrocarbons that are contained in the vapour phase in natural gas in the reservoir and become liquid at standard field separation conditions. Estimates of identified condensate resources are available only for those accumulations from which condensate is likely to be extracted.

LPG usually consists of propane, butane and isobutane and is derived by processing, through a low pressure separation plant, the natural gas produced from either gas or oil reservoirs. Estimates of identified LPG resources are available only for those accumulations from which LPG is likely to be extracted. LPG is also obtained as a by-product of oil refining.

Liquefied Natural Gas is natural gas which has been processed and then refrigerated to the very low temperatures needed to reach the liquid state.

Primary oils (crude oil and condensate) are the normal feedstocks, but refinery inputs can be other feedstocks, such as a product or a combination of products derived from crude oil destined for further processing, or those finished products imported for refinery intake or returned from other industries.

Refined products are classified into two categories: fuel products and non-fuel products. Fuel products include automotive gasoline and diesel, aviation gasoline and turbine, kerosine and heating oil, industrial diesel and fuel oil, and others such as naphtha and petroleum coke used as fuel. Non-fuel products include solvents, lubricants, bitumen, waxes and others such as sulphur and petroleum coke.

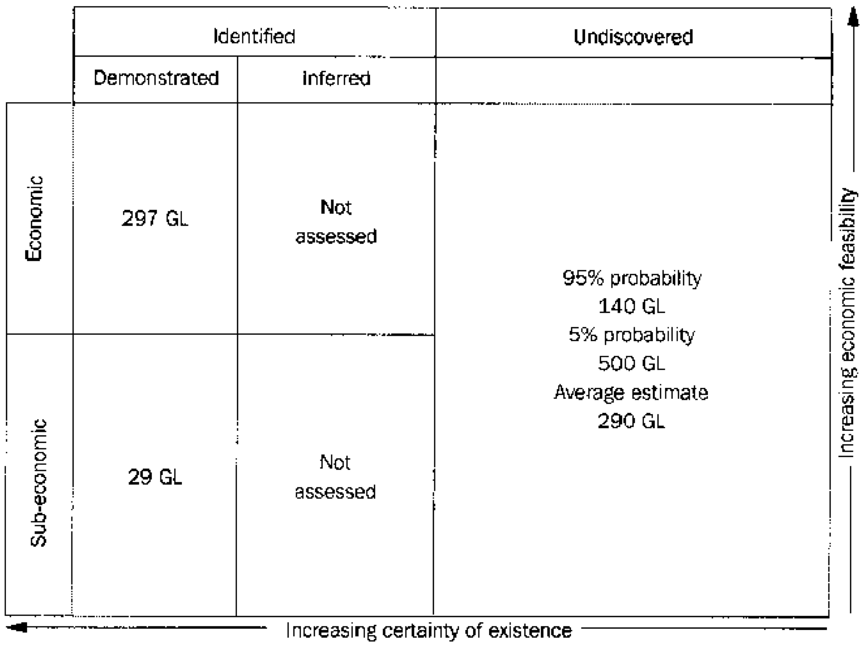
McKelvey system of classification

Because petroleum accumulations occur at considerable depth there is no simple way of locating them or of measuring them, except by production. The existence of an accumulation can be proved only by drilling wells and bringing samples to the surface. The amount of petroleum within the reservoir in which the accumulation occurs and the proportion that could theoretically be produced can then be estimated using information derived from well logs, seismic surveys, analyses of the produced fluids and measurements made during production tests. Consideration of how the accumulation could best be produced and the projected economics of such production are needed to estimate the proportion that could be produced in actual practice and to decide whether or not it forms part of resources (production is likely in the next 25 years).

Geologists and engineers make regular attempts to assess Australia's non-renewable energy resources. However, there is nearly always insufficient information to provide precise numbers and the assessors have adopted the practice of classifying the resources into categories that show how certain they are that the resources actually exist and their best estimate of the economic feasibility of producing them. Over the years, a complex of homegrown classification systems has evolved suited to the individual requirements of reporting petroleum resources. This chapter uses the well-known McKelvey Classification (MC) system throughout in order to achieve a consistent basis for reporting. The former Bureau of Mineral Resources (BMR), now Australian Geological Survey Organisation (AGSO) and the Bureau of Resource Sciences (BRS), formally adopted the MC system in 1975 for general use in categorising petroleum and mineral resources (BMR 1976) and the system was further refined in 1984 (BMR 1984).

Under the MC system, resources are classified in terms of their economic feasibility of production and in terms of their certainty of occurrence as outlined below and shown in figure 4.1.

4.1 THE McKELVEY MINERAL AND PETROLEUM RESOURCE CLASSIFICATION DIAGRAM



Note: Diagram shows Australia's remaining recoverable resources of crude oil in gigalitres (GL), as at 31 December 1994. Includes all of resources within Area A of the Zone of Cooperation which are subject to production sharing agreements between the permit holders and the (Australia–Indonesia) Joint Authority.

Source: BRS 1996.

Categories of petroleum resources

Recoverable resources — Petroleum that can be physically recovered using current recovery technology.

Initial recoverable resources — The amount of recoverable petroleum that existed before any of it had been produced.

Remaining recoverable resources — The amount of recoverable petroleum remaining after production. Remaining recoverable resources equals initial recoverable resources less production.

Economic resources — Petroleum that is, or would be if discovered, economically produced under current and projected prices and costs and with current technology.

Sub-economic resources — Petroleum that is not, or would not be if discovered, currently economically producible, but that may be in the future.

Identified resources — Petroleum, in specific accumulations, that have been confirmed by drilling and (usually) recovery at the surface and which are potentially economic.

Demonstrated — That part of identified resources whose existence is established and whose quantity is considered probable, based on well data and geological projection. The proved and probable reserves of the petroleum industry are considered to be equivalent to demonstrated economic recoverable resources plus part of demonstrated sub-economic recoverable resources.

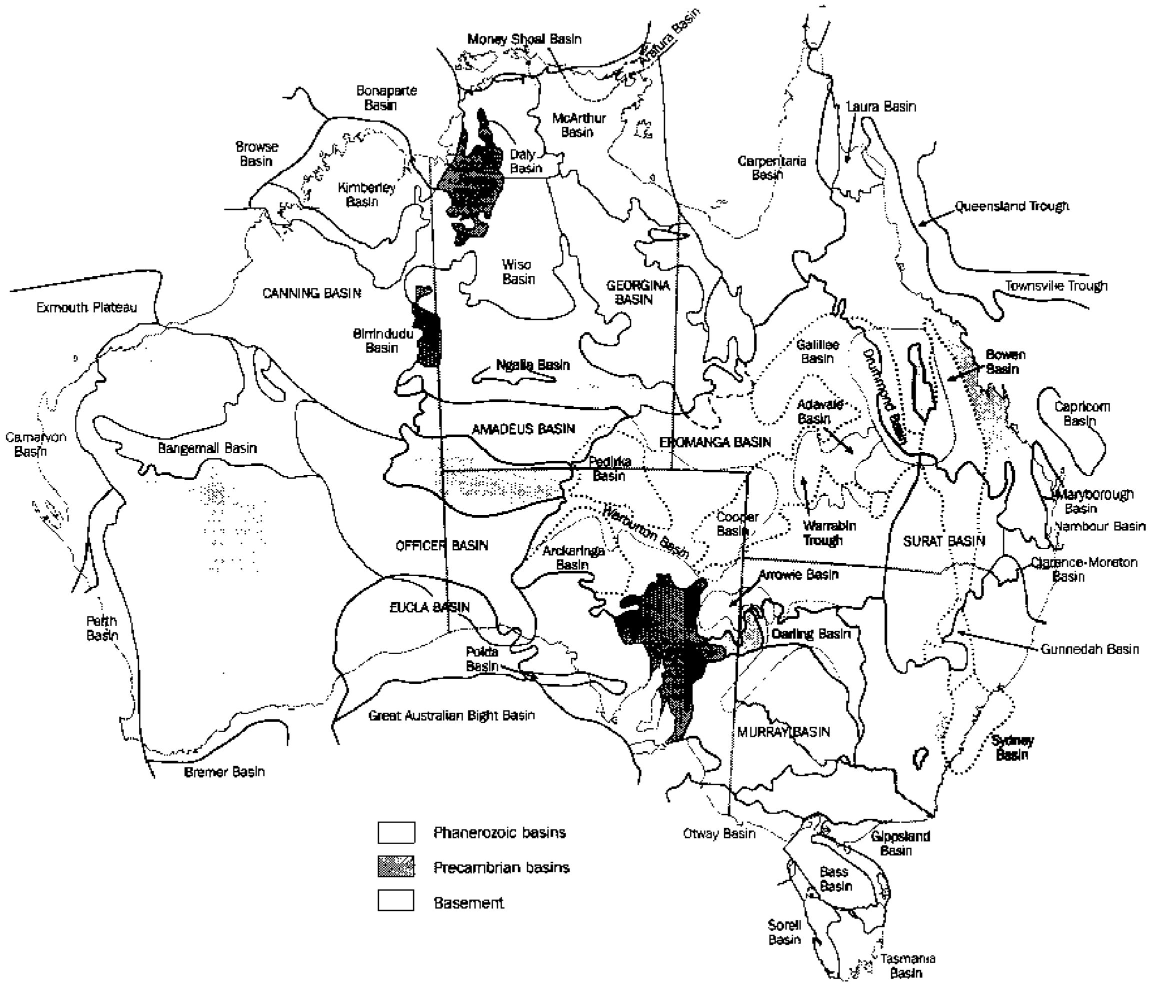
Inferred That part of identified resources whose existence and quantity are considered uncertain because of distance from well control or because of geological situation. The possible reserves category of the petroleum industry can include material equivalent to both inferred recoverable resources and part of the demonstrated sub-economic recoverable resources.

Undiscovered resources Petroleum, in unspecified accumulations, that is surmised to exist on the basis of geological knowledge and theory.

PETROLEUM RESOURCES IN AUSTRALIA

Most petroleum originates by the action of heat on organic matter buried within sedimentary rocks. Australia has a large area onshore and offshore that contains sedimentary rocks potentially capable of containing petroleum (map 4.2). Exploration, essentially over the last 35 years, has identified petroleum resources within 14 sedimentary basins within Western Australia, Queensland, Victoria and Northern Territory. The largest discoveries in terms of energy have been the Bass Strait oil and gas fields in 1960s and 1970s, and the Carnarvon basin oil and gas fields in the 1970s and 1980s.

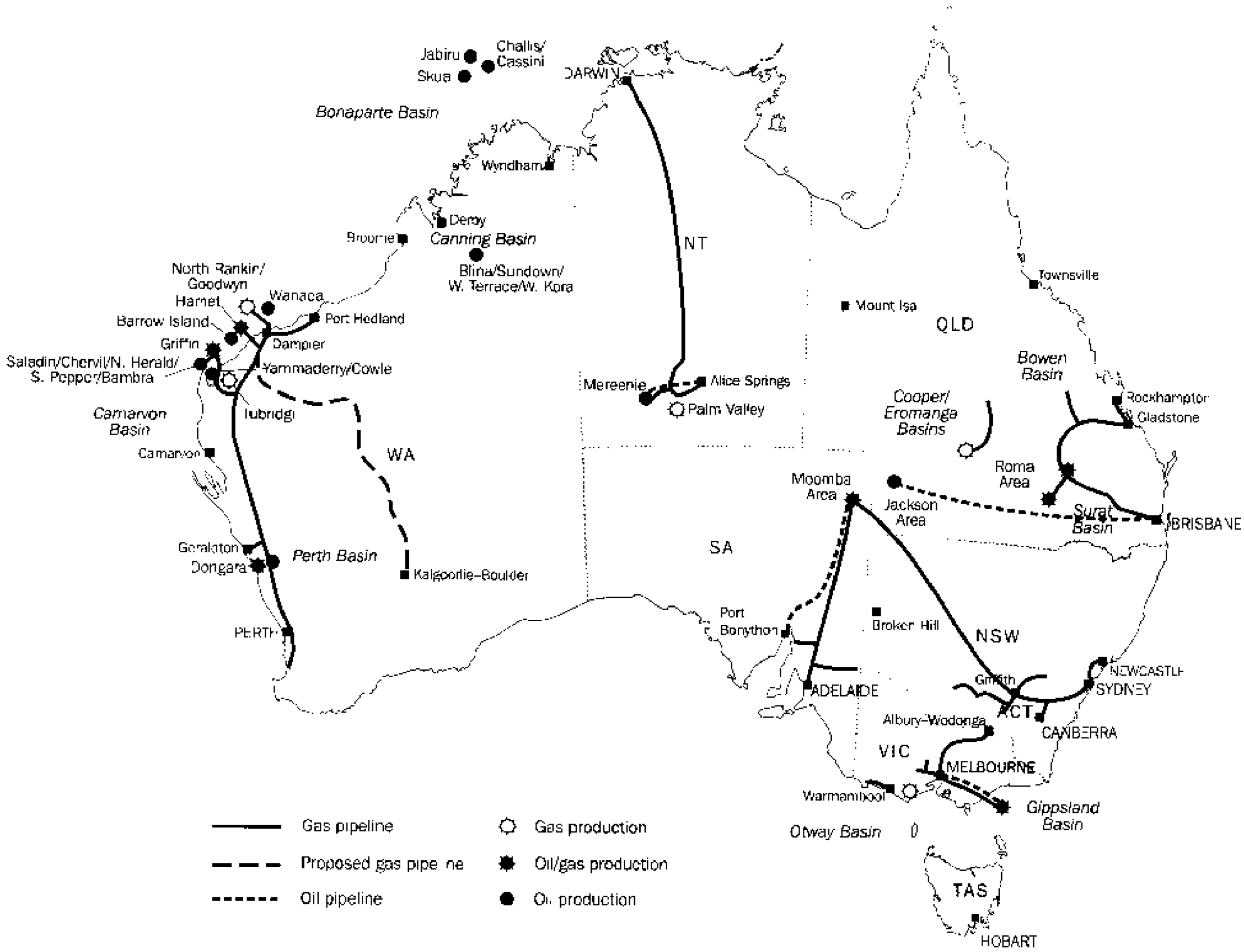
4.2 SEDIMENTARY BASINS



Source: BRS 1996.

Although there are many small fields, most of Australia's identified oil and condensate resources are in the so-called 'major fields' of more than 16 gigalitres (100 million barrels), shown in map 4.3. They contain a large fraction suitable for production of motor spirit and only a small fraction suitable for production of lubricant, fuel oil and bitumen which are mainly produced from imported crude.

4.3 LOCATION OF PETROLEUM RESOURCES AND PIPELINES

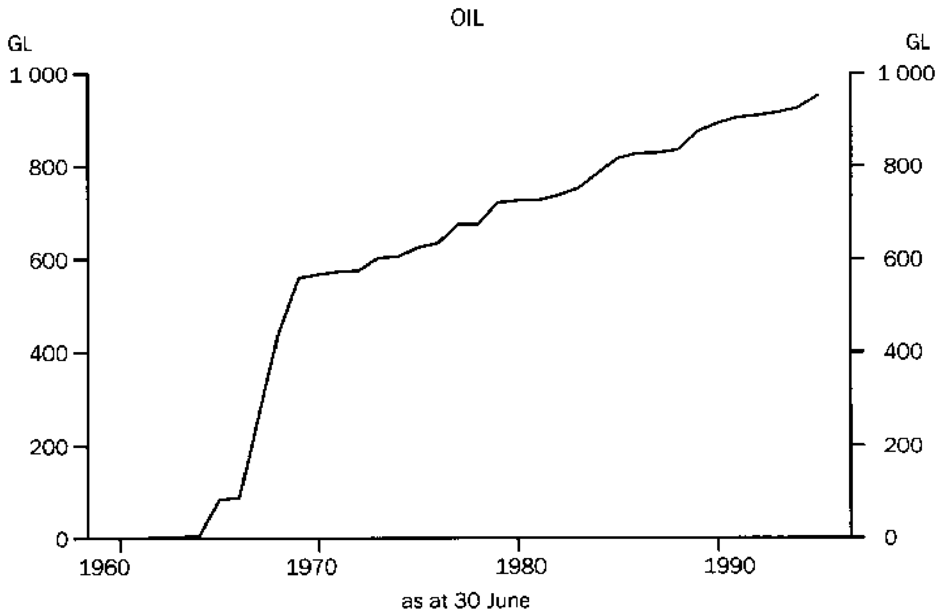


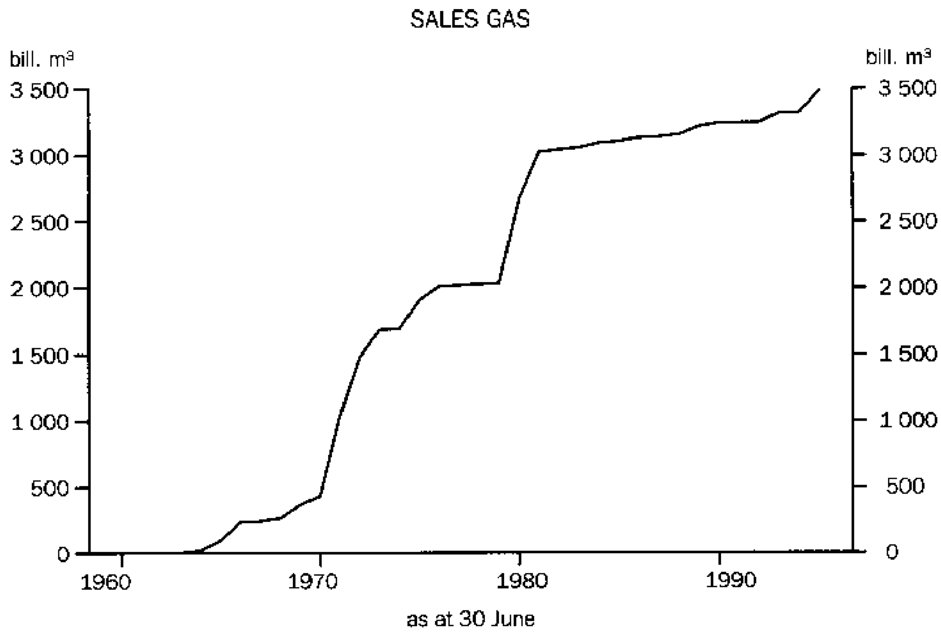
Source: BRS 1996.

Identified resources

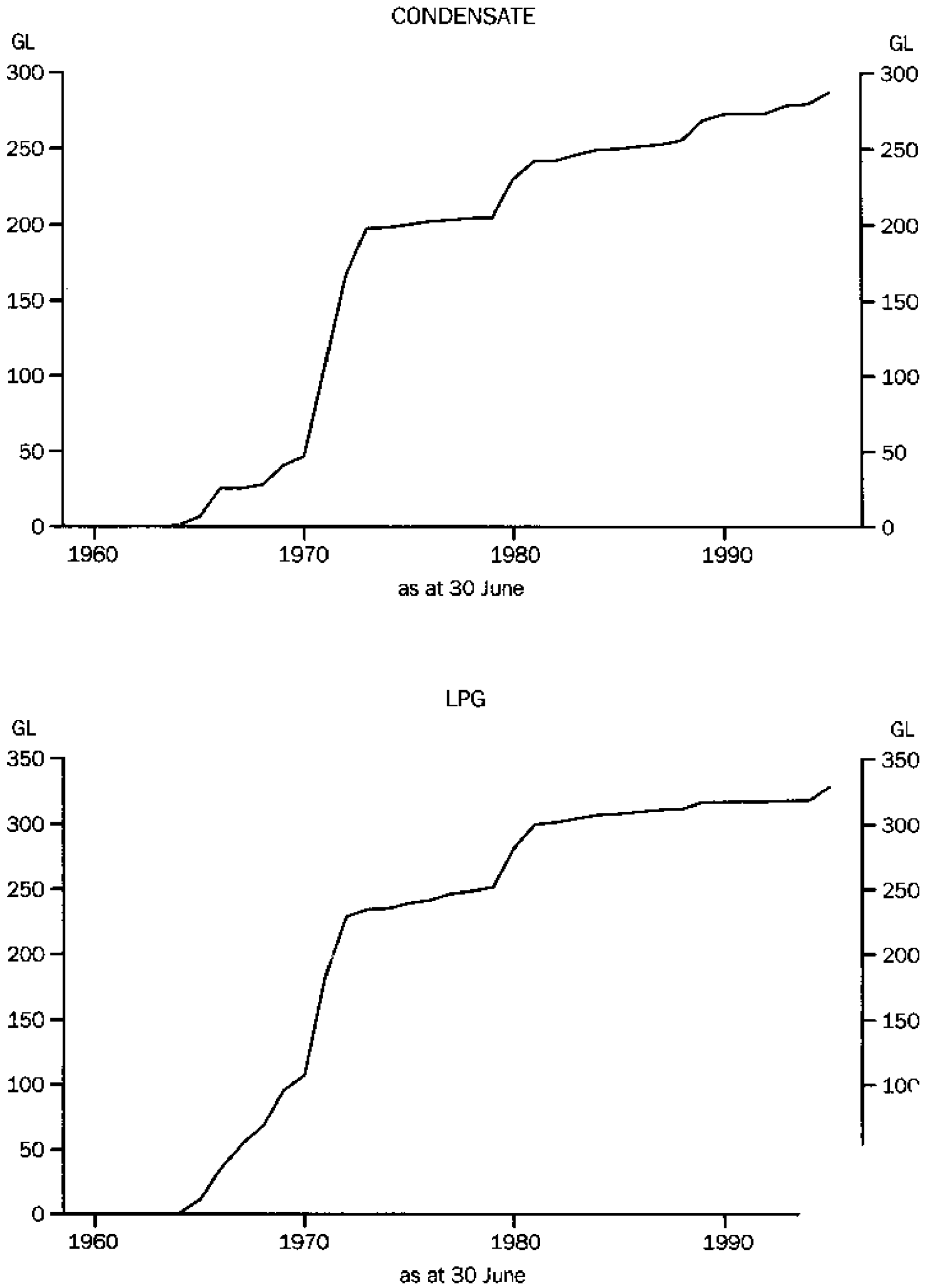
Australia's cumulative initial identified resources of petroleum are shown plotted by year of discovery in graph 4.4. The estimates of initial identified resources have been made by BRS using estimates of initial demonstrated resources (usually as at December 1994) plus an estimates of inferred resources where available. They include preliminary estimates of identified resources within Area A of the Zone of Cooperation which are subject to a production sharing agreement between the permit holders and the (Australia–Indonesia) Joint Authority. These plots show that the major oil discoveries were made before 1970 and the major sales gas, condensate and LPG discoveries were made before 1980. About 950 gigalitres (6,000 million barrels) of crude oil and 3,490 billion cubic metres (123 trillion cubic feet) of sales gas had been identified by the end of 1994.

4.4 CUMULATIVE INITIAL IDENTIFIED RESOURCES BY YEAR OF DISCOVERY





4.4 CUMULATIVE INITIAL IDENTIFIED RESOURCES BY YEAR OF DISCOVERY — *continued*



Source: BRS 1996.

On the basis of figures for the world's identified
beginning of 1993 (Masters, Attanasi & Root,
identified resources of crude oil make up
and natural gas makes up 1.8%.

Undiscovered resources

Australia's undiscovered resources
BRS in early 1993 (BRS 1994, 1
petroleum remains to be disc
probability distributions which s

date there is an estimated 95% probability that at least 140 gigalitres (900 million barrels) of crude oil remain to be discovered and a 5% probability that at least 500 gigalitres (3,200 million barrels) remain to be discovered. There is, therefore, a 10% probability that the amount could even lie outside of this range. The average of the assessment, of 290 gigalitres (1,800 million barrels), gives a more or less central tendency to the range, but has no better chance than any other value of being the final outcome.

At 95% probability, the assessment of undiscovered resources to be discovered are at least 200 giga cubic metres for sales gas, 25 gigalitres for condensate and 25 gigalitres for LPG. There are at least 1,000 giga cubic metres of undiscovered resources remaining for sales gas, 120 gigalitres for condensate and 80 gigalitres for LPG, at 5% probability, respectively. The undiscovered resources are averaged to be 470 giga cubic metres for sales gas, 60 gigalitres for condensate and 46 gigalitres for LPG. Note that the assessed undiscovered resources include undiscovered resources within Area A of the Zone of Cooperation, which are subject to a production sharing agreement between the permit holders and the (Australia–Indonesia) Joint Authority.

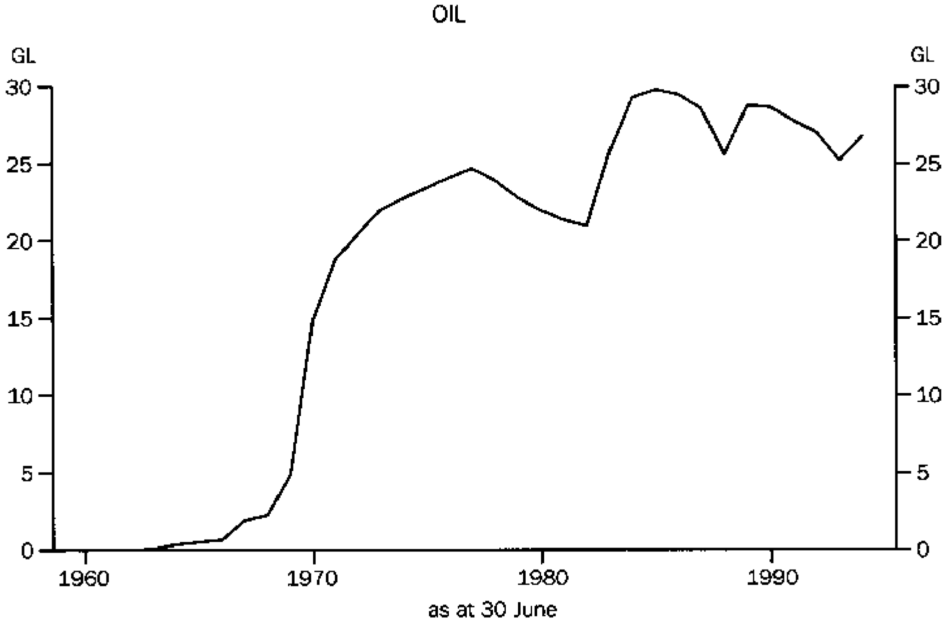
Australia's petroleum production and resource sufficiency

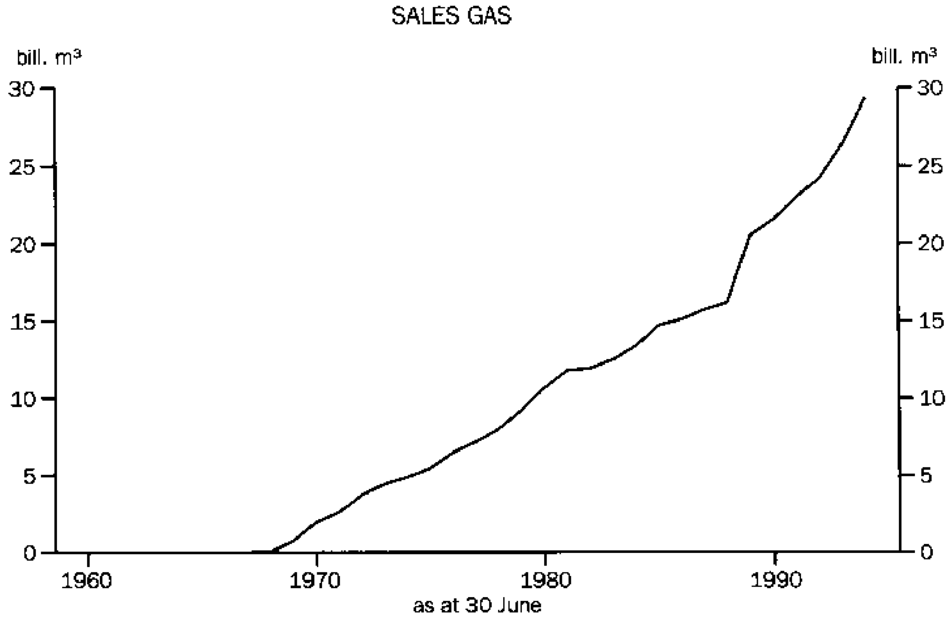
Oil production began from the Moonie field in 1964 and increased significantly as Barrow Island was brought into production in 1967 and the Gippsland Basin in 1970. Production of crude oil reached 20 gigalitres a day in 1973 and has fluctuated between about 20 and 30 gigalitres a day since then. About 625 gigalitres (3,930 million barrels) of crude oil had been produced by the end of June 1995.

Gas production also commenced in the 1960s and pipelines were built to connect gas fields in the Moomba area to Adelaide (1969), Gippsland to Melbourne (1969), Roma to Brisbane (1969), Dongara to Perth (1971) and Moomba to Sydney (1976). Since then, a 1,500 kilometre gas pipeline has been built from Palm Valley (central Australia) to Darwin, a 1,600 kilometre pipeline has been built from North Rankin and Goodwyn platforms (Northwest Australia) to Perth and a 1,400 kilometre pipeline is presently under construction from Yarraloola (Northwest Australia) to Kalgoorlie (southwest Australia). Currently, more than 64 million cubic metres of natural gas is produced per day, 10% of the total energy production of primary fuels. About 320 billion cubic metres (11.35 trillion cubic feet) of sales gas had been produced by the end of June 1995.

Oil or gas are now produced from 12 sedimentary basins. Graph 4.5 shows the amounts of crude oil, sales gas, condensate and LPG that were produced in each financial year up to the end of June 1995. Reported LPG production declined during the late 1980s and early 1990s partly because of a decrease in LPG production from the Gippsland Basin and partly because a part of the LPG resource in Western Australia was delivered to market as part of the sales gas stream. This had the effect of decreasing apparent production of LPG while increasing apparent production of sales gas.

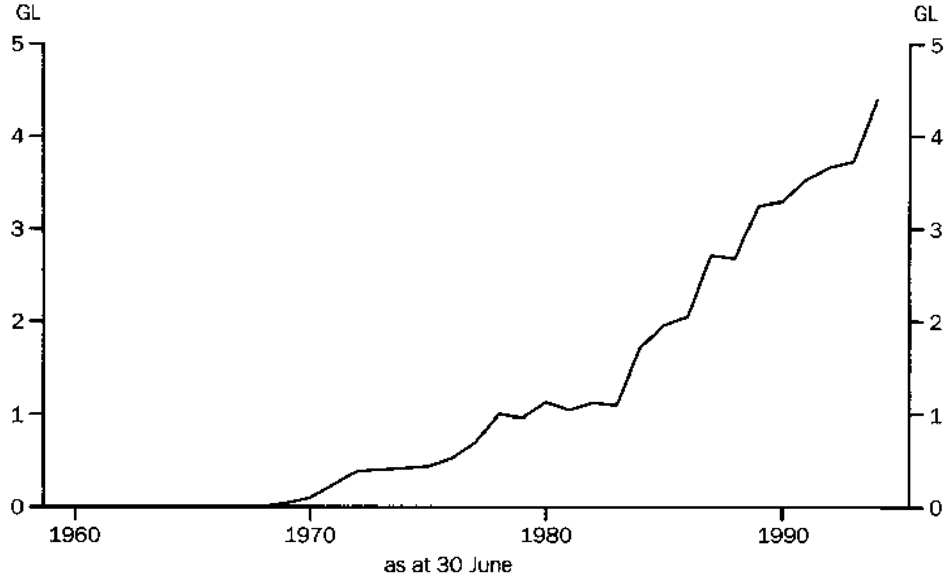
4.5 PETROLEUM PRODUCTION BY FINANCIAL YEAR





4.5 PETROLEUM PRODUCTION BY FINANCIAL YEAR — *continued*

CONDENSATE



LPG

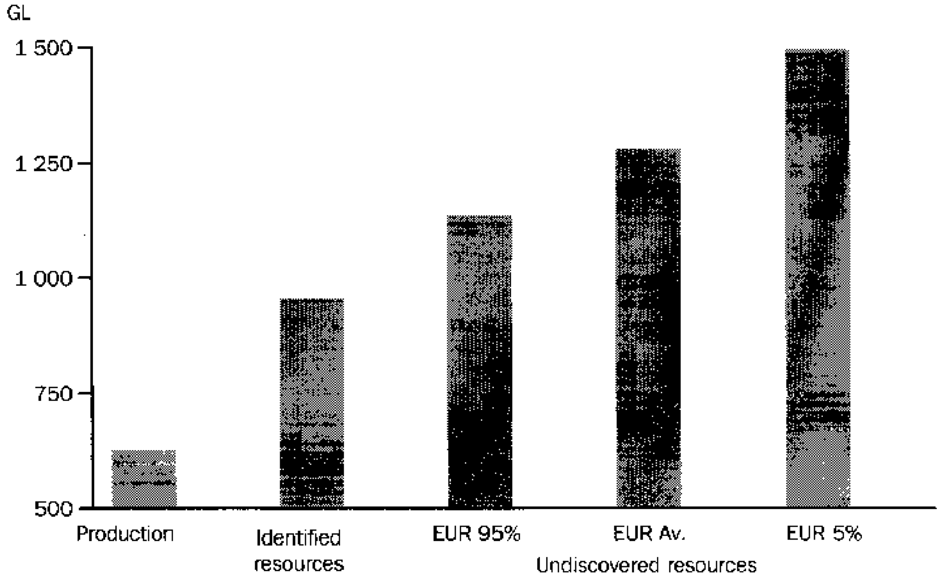
Source: DPIE 1988.

Australia's total oil and gas resources and total production

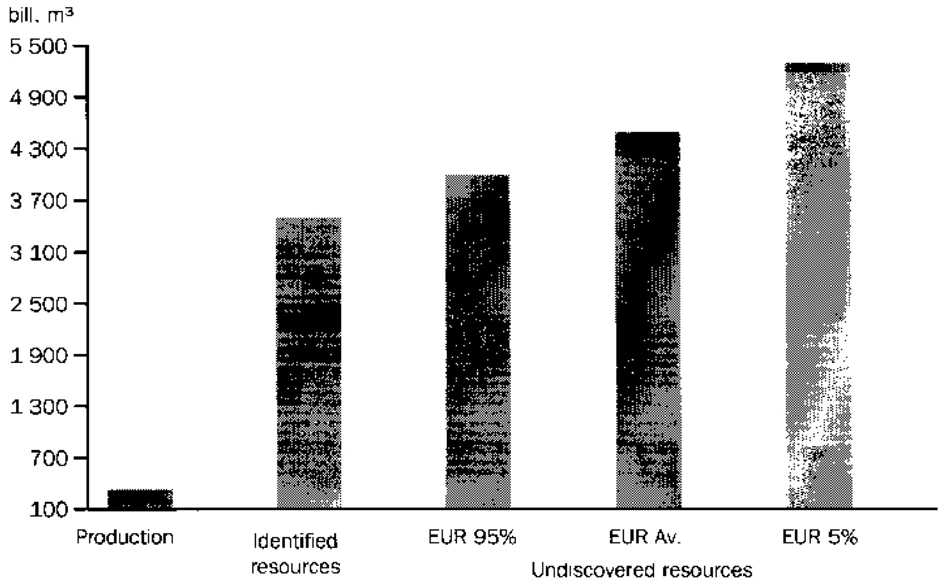
Graph 4.6 shows two separate graphs. Estimates of cumulative identified resources of crude oil and sales gas for each financial year are plotted against each other in the main graph, and the 95%, average (Av.) and 5% estimates of undiscovered resources have been added to them, to obtain an estimate of the amounts of oil and gas that may be produced eventually, called the estimated ultimate recovery (EUR). The EUR includes identified and undiscovered resources within Area A of the Zone of Cooperation, which are subject to a production sharing agreement between the permit holders and the (Australia–Indonesia) Joint Authority.

4.6 INITIAL IDENTIFIED AND UNDISCOVERED GAS RESOURCES VERSUS OIL RESOURCES AND SALES GAS PRODUCTION VERSUS OIL PRODUCTION

OIL RESOURCES, AS AT 30 JUNE 1995



GAS RESOURCES, AS AT 30 JUNE 1995



Source: BRS 1996.

According to whether the 95% or 5% estimates are used, the EUR ranges between 1,100 and 1,450 gigalitres of crude oil and 3,700 and 4,500 billion cubic metres of sales gas. Australia's average estimated ultimate petroleum resources make up about 0.3% of the world's crude oil and 1% of gas as reported in 1993 (Masters, Attanasi & Root 1994).

The average EUR for gas divided by the average EUR for oil gives a ratio of about 3,200 cubic metres of gas for every kilolitre of oil. This compares with about 2,100 for the former Soviet Union, 2,000 for Canada, 1,000 for the United States of America, 950 for the world, 600 for the United Kingdom and 300 for Saudi Arabia, as given by Masters, Attanasi & Root (1994).

Indicators of resource sufficiency

An indicator of resource sufficiency is percentage of self-sufficiency, last published by the Department of Primary Industry and Energy (DPIE) (1987). Self sufficiency was defined as:

$$\text{Self sufficiency} = \frac{\text{Crude oil and condensate production plus demand for naturally occurring LPG}}{\text{Net domestic demand for petroleum products}}$$

Since 1970, self-sufficiency has fluctuated between 60 and 90% with levels above 70% since mid-1984. It would have been difficult to achieve levels of self-sufficiency much above 90%, however, because it was necessary to import a proportion of heavy crude oil suitable for fuel oil, lubricant and bitumen production. The indicator shows how well domestic production meets demand.

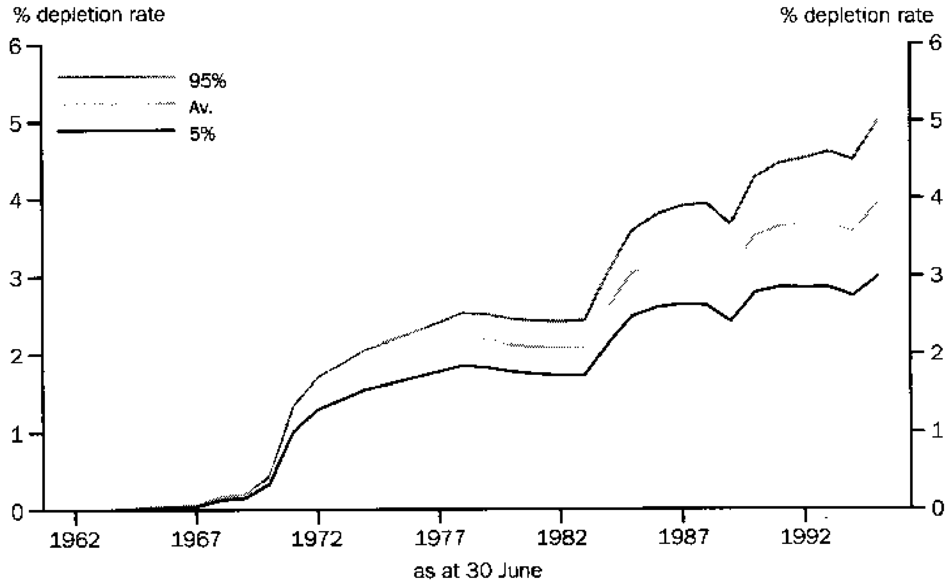
Another group of indicators that can be used show the relationships between resources and production. As shown later in this chapter, the ratio of remaining Economic Demonstrated Resources (EDR) to production for each year (graph 4.7) indicates how many years production the resource would support. The ratio of identified resources to production might be a better indicator but, company assessments of inferred petroleum resources are not uniformly available to government and a national assessment of this category of resources is not maintained. Even the ratio of remaining ultimate resource to production is an unsatisfactory measure of resource 'life', because it is normal for production to decline towards the end.

There is a suggestion that the inverse ratio called 'depletion rate', which is annual production as a percentage of remaining petroleum at the end of the preceding year, is a better measure of supply security. Remaining petroleum equals the amount that will ultimately be produced minus the amount that has already been produced. The amount of petroleum that will ultimately be produced is the sum of the initial identified and undiscovered resources (EUR).

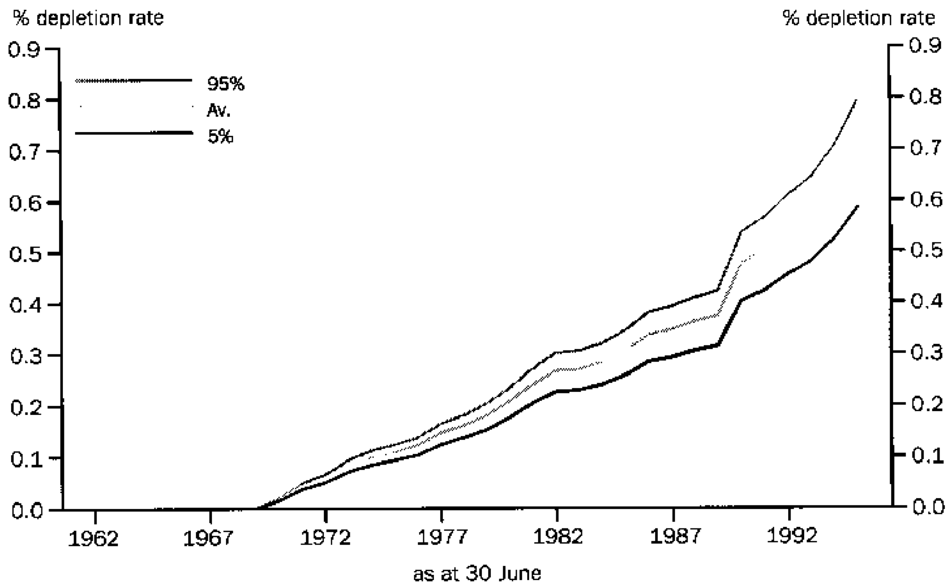
Graph 4.7 shows crude oil depletion rates calculated for Australia, based on the 5%, 95% and average estimates of EUR. Australia's depletion rate has increased steadily to an average of 4.1% at 30 June 1995. This compares with crude oil depletion rates of 1.4% for Saudi Arabia, 2.6% for the former Soviet Union, 5.2% for the United Kingdom, 5.7% for the United States of America, 5.9% for Canada and 2.2% for the world. Annual production during 1992 as a percentage of average remaining petroleum at the end of 1992 is 0.9% for Saudi Arabia, 1.3% for Canada, 1.3% for the former Soviet Union, 2.5% for the United Kingdom, 2.7% for the United States of America and 1.3% for the world. Australia's sales gas depletion rate averages 0.8% (graph 4.7) as at 30 June 1995.

4.7 DEPLETION RATES FOR CRUDE OIL AND SALES GAS

OIL



GAS

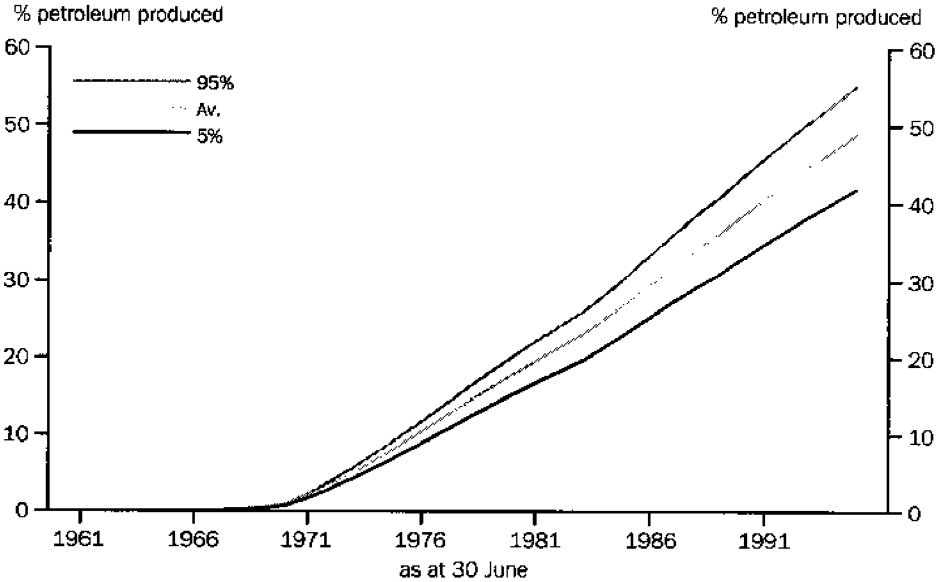


Source: BRS 1996.

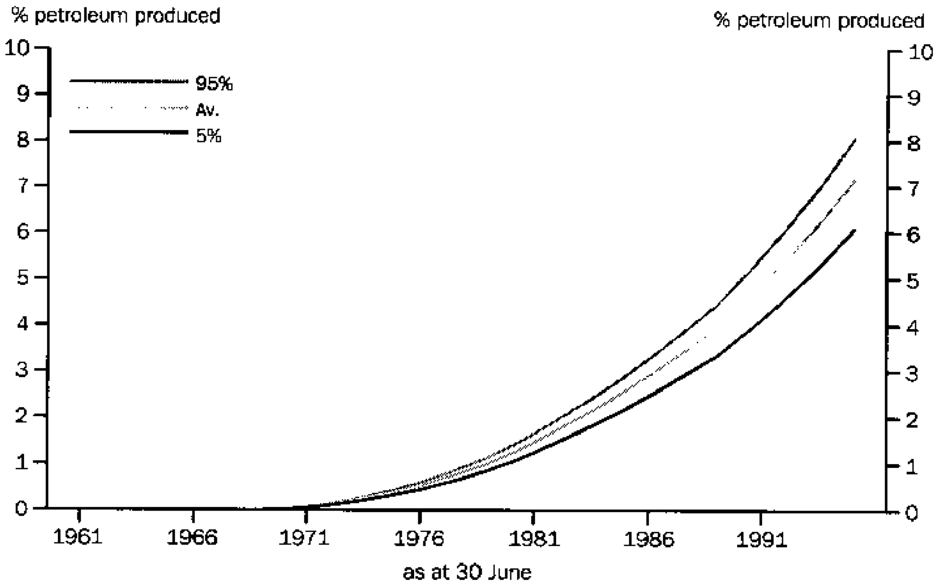
Another indicator that can be calculated is the cumulative amount of petroleum produced as a percentage of ultimate production (EUR). Graph 4.8 shows that Australia has produced an average of 50% of its ultimate crude oil resources and 8% of its sales gas resources (including those within Area A of the Zone of Cooperation which are subject to production sharing agreements between the permit holders and the (Australia–Indonesia) Joint Authority). As at 1 January 1993 Saudi Arabia had produced 17% of its crude oil, the United Kingdom 29%, Canada 29%, the former Soviet Union 32%, the United States of America 63% and the world 29% (Masters, Attanasi & Root 1994).

4.8 CUMULATIVE OIL AND GAS PRODUCED AS A PERCENTAGE OF ULTIMATE RECOVERY

OIL



GAS



Source: BRS 1996.

STOCK ACCOUNTS FOR PETROLEUM

This section deals with Australia's stock of petroleum resources remaining underground at a given time, and the changes in historical estimates. Major causes of changes in stock are production, upgrading of reserves in identified accumulations and new discoveries. Upgrading of reserves may be caused by:

- increases in the known volume of existing pools (from drilling and geophysical data);
- new pool discoveries (often by development wells);
- improved development technology, allowing a greater proportion of in-place oil to be produced; and
- revised assessments of reservoir and fluid properties, leading to higher recovery factors than those originally calculated.

In addition, EDR and sub-EDR of petroleum are reported by sedimentary basin. Note that the petroleum resources and production reported by State authorities may not necessarily be the same as the figures reported here, because data sources differ and the reporting of LPG and flared gas differs from State to State.

Crude oil

Table 4.9 shows the stock accounts for Australia's EDR of crude oil. In 1982–83 the opening stock was 261 gigalitres of crude oil. At the beginning of 1994–95, the remaining resources were 12 gigalitres higher, being at an estimated 273 gigalitres. Australia's domestic production of crude oil during this period totalled 351 gigalitres. Production during the period was outweighed by upgrading of estimates of resources in previously discovered fields and by new discoveries.

4.9 STOCK ACCOUNT FOR CRUDE OIL: EDR

	Opening stock	*Adjustment*	*Production*	*Closing stock*	*Net change*
Year	GL	GL	GL	GL	GL
1982–83	261	9	–21	249	–12
1983–84	249	8	–26	231	–18
1984–85	231	29	–29	231	0
1985–86	231	23	–30	224	–7
1986–87	224	36	–29	231	7
1987–88	231	38	–29	240	9
1988–89	240	38	–26	252	12
1989–90	252	55	–29	278	26
1990–91	278	9	–29	258	–20
1991–92	258	21	–28	251	–7
1992–93	251	30	–23	247	7
1993–94	247	51	–25	273	26
1994–95	273	n.a.	–27	n.a.	n.a.

Note: Stocks for 1991–92 onwards have been calculated by interpolation of calendar year data.

Source: BRS 1996.

Sub-economic demonstrated resources are considered to be potentially economic in the future, when technological or economic conditions change. As shown in table 4.10, the initial stock of sub-economic resources of crude oil in Australia was 34 gigalitres in 1982–83, and 31 gigalitres in 1994–95.

4.10 STOCK ACCOUNT FOR CRUDE OIL: SUB-ECONOMIC DEMONSTRATED RESOURCES

	Opening stock	*Adjustment*	*Closing stock*
Year	GL	GL	GL
1982–83	34	12	46
1983–84	46	11	57
1984–85	57	-15	42
1985–86	42	12	54
1986–87	54	–23	31
1987–88	31	-3	28
1988–89	28	–1	27
1989–90	27	4	31
1990–91	31	51	82
1991–92	82	–43	39
1992–93	39	–4	35
1993–94	35	–4	31
1994–95	31	n.a.	n.a.

Note: Stocks for 1991–92 onwards have been calculated by interpolation of calendar year data.

Source: BRS 1996.

Condensate

Australia's condensate resources are comparable to crude oil resources. Table 4.11 presents the economic demonstrated condensate resources in Australia. In 1982–83 the opening stock was 78 gigalitres and in 1994–95 the stock of condensate increased to 147 gigalitres. A significant revision of condensate stocks occurred in 1986–87 when 40 gigalitres of condensate resources were added.

4.11 STOCK ACCOUNT FOR CONDENSATE: ECONOMIC DEMONSTRATED RESOURCES

Year	Opening stock GL	Adjustment GL	Production GL	Closing stock GL	Net change GL
1982–83	78	–7	–1	71	–8
1983–84	71	12	–1	82	11
1984–85	82	1	–2	81	–1
1985–86	81	1	–2	80	–1
1986–87	80	40	–2	118	38
1987–88	118	3	–3	118	0
1988–89	118	6	–3	121	3
1989–90	121	–11	–3	107	–14
1990–91	107	20	–3	124	17
1991–92	124	9	–4	129	5
1992–93	129	10	–4	135	6
1993–94	135	16	–4	147	12
1994–95	147	n.a.	–4	n.a.	n.a.

Note: Stocks for 1991–92 onwards have been calculated by interpolation of calendar year data.

Source: BRS 1996.

Sub-economic condensate resources in Australia are shown in table 4.12. The opening stock in 1982–83 was 27 gigalitres, and the closing stock in 1994–95 was 59 gigalitres, a doubling during this period.

4.12 STOCK ACCOUNT FOR CONDENSATE: SUB-ECONOMIC DEMONSTRATED RESOURCES

Year	Opening stock GL	Adjustment GL	Closing stock GL
1982–83	27	–3	24
1983–84	24	5	29
1984–85	29	–1	28
1985–86	28	9	37
1986–87	37	27	64
1987–88	64	–16	48
1988–89	48	–2	46
1989–90	46	20	66
1990–91	66	–10	71
1991–92	71	–16	55
1992–93	55	–1	54
1993–94	54	5	59
1994–95	59	n.a.	n.a.

Note: Stocks for 1991–92 onwards have been calcualted by interpolation of calendar year data.

Source: BRS 1996.

Natural (sales) gas

Australia has large EDR of natural (sales) gas given in table 4.13. In 1982–83 the opening stock of EDR was 624 billion cubic metres. Despite a doubling of production, the reserves of natural gas increased to 1,147 billion cubic metres, in 1994–95.

4.13 STOCK ACCOUNT FOR NATURAL GAS: ECONOMIC DEMONSTRATED RESOURCES

Year	Opening stock bill. m³	Adjustment bill. m³	Production bill. m³	Closing stock bill. m³	Net change mill. m³
1982–83	624	17	–12	629	5
1983–84	629	–1	–12	616	–13
1984–85	616	88	–13	691	75
1985–86	691	14	–14	691	0
1986–87	691	156	–15	832	141
1987–88	832	226	–15	1 043	211
1988–89	1 043	3	–16	1 030	–13
1989–90	1 030	–69	–20	941	–89
1990–91	941	30	–21	950	9
1991–92	950	51	–23	978	28
1992–93	978	45	–24	999	21
1993–94	999	174	–26	1 147	148
1994–95	1 147	n.a.	–29	n.a.	n.a.

Note: Stocks for 1991–92 onwards have been calculated by interpolation of calendar year data.

Source: BRS 1996.

Australia has large sub-economic resources of natural (sales) gas available as listed in table 4.14. At the beginning of 1994–95, sub-EDR of natural gas were 1,196 billion cubic metres, about the same as EDR.

4.14 STOCK ACCOUNT FOR NATURAL GAS, AUSTRALIA: SUB-ECONOMIC DEMONSTRATED RESOURCES

Year	Opening stock bill. m³	Adjustment bill. m³	Closing stock bill. m³
1982–83	284	114	398
1983–84	398	442	840
1984–85	840	–10	830
1985–86	830	–27	803
1986–87	803	603	1 406
1987–88	1 406	–422	984
1988–89	984	68	1 052
1989–90	1 052	111	1 163
1990–91	1 163	–75	1 293
1991–92	1 293	–184	1 109
1992–93	1 109	27	1 136
1993–94	1 136	60	1 196
1994–95	1 196	n.a.	n.a.

Note: Stocks for 1991–92 onwards have been calculated by interpolation of calendar year data.

Source: BRS 1996.

LPG The opening stock of EDR of LPG in 1982–83 was 123 gigalitres and this increased to 144 gigalitres at the beginning of 1994–95 as shown in table 4.15. LPG production in Australia was steady at about 4 gigalitres a year during the last 10 years.

4.15 STOCK ACCOUNT FOR LPG: ECONOMIC DEMONSTRATED RESOURCES

	Opening stock	*Adjustment*	*Production*	*Closing stock*	*Net change*
Year	GL	GL	GL	GL	GL
1982–83	123	–8	–3	112	–11
1983–84	112	–24	–3	85	–27
1984–85	85	4	–4	85	0
1985–86	85	7	–4	88	3
1986–87	88	13	–4	97	9
1987–88	97	–8	–4	85	–12
1988–89	85	47	–4	128	43
1989–90	128	–18	–4	106	–22
1990–91	106	6	–4	108	2
1991–92	108	29	–4	133	25
1992–93	133	5	–4	134	1
1993–94	134	14	–4	144	10
1994–95	144	n.a.	–4	n.a.	n.a.

Note: Stocks for 1991–92 onwards have been calculated by interpolation of calendar year data.

Source: BRS 1996.

Table 4.16 lists sub-EDR of LPG. The stock has increased from 33 gigalitres to 89 gigalitres during the period 1982–83 to 1994–95.

4.16 STOCK ACCOUNT FOR NATURAL LPG: SUB-ECONOMIC DEMONSTRATED RESOURCES

	Opening stock	*Adjustment*	*Closing stock*
Year	GL	GL	GL
1982–83	33	–8	25
1983–84	25	–14	11
1984–85	11	0	11
1985–86	11	9	20
1986–87	20	–8	12
1987–88	12	1	13
1988–89	13	24	37
1989–90	37	21	58
1990–91	58	25	94
1991–92	94	–8	86
1992–93	86	2	88
1993–94	88	1	89
1994–95	89	n.a.	n.a.

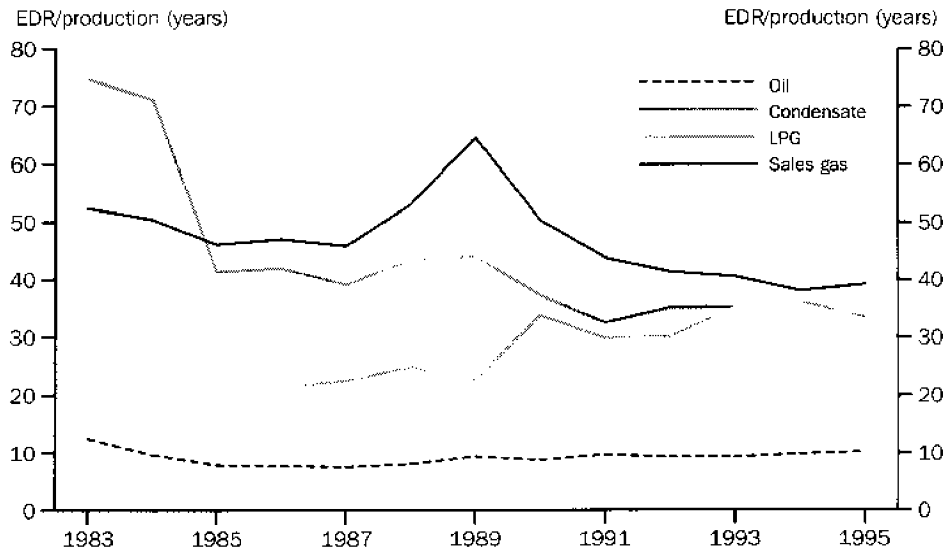
Note: Stocks for 1991–92 onwards have been calculated by interpolation of calendar year data.

Source: BRS 1996.

'Life' of petroleum resources

The ratios of Australia's remaining EDR of petroleum, as estimated at the beginning of each financial year, and the production for that year are presented in graph 4.17. The ratios supposedly indicate how many years production the resource would support assuming that present production rates could be maintained. For instance, remaining economic resources of crude oil (which includes oil within Area A of the Zone of Cooperation which is subject to a production sharing agreement between the permit holders and the Australia–Indonesia Joint Authority) indicates a 'life' which has stayed fairly steady at about 10 years since 30 June 1983. Natural (sales) gas has a current life of 39 years, but has ranged between about 38 and 64 years.

4.17 REMAINING EDR TO PRODUCTION RATIOS FOR CRUDE OIL, SALES GAS, CONDENSATE AND LPG



Source: BRS 1996.

The fairly constant 'life' of about 10 years for crude oil over the last 13 years gas indicates that EDR to production ratios are not a reliable indicator of resource 'life'. The ratio has remained fairly steady because both remaining EDR and production have been steady. Remaining EDR have been maintained ; t a near constant level, despite considerable production, mainly as a result of revisions (additions) to the estimates of the demonstrated resources within the producing fields and partly as a result of new discoveries. The estimates of demonstrated resources in each field commonly have high probability of occurrence and will therefore be, on average, conservative. Additional resources are often demonstrated at the identified fields as a result of new-pool discoveries and extensions to known pools and also with improved technology, improved understanding of reservoirs during production and any improvements of prices relative to costs. Thus, the estimates of initial demonstrated resources in each accumulation tend to grow over time as resources move from the inferred to the demonstrated category.

Production fields of petroleum in sedimentary basins

The producing fields for crude oil and condensate are located in 12 sedimentary basins, listed in table 4.18. Of the 297 gigalitres of economic demonstrated crude oil remaining at the end of 1994, 41% occurs in the Carnarvon Basin, 38% in the Gippsland Basin and 15% in the Bonaparte Basin (which includes oil within Area A of the Zone of Cooperation which is subject to a production sharing agreement between the permit holders and the Australia–Indonesia Joint Authority).

4.18 DEMONSTRATED RESOURCES BY SEDIMENTARY BASIN, AS AT 31 DECEMBER 1994

	EDR				*Sub-EDR*			
	Oil	*Cond.*	*LPG*	*Sales gas*	*Oil*	*Cond.*	*LPG*	*Sales gas*
	GL	GL	GL	bill. m^3	GL	GL	GL	bill. m^3
Adavale	—	—	—	1	—	—	—	—
Bass	2	1	1	3	1	5	7	7
Amadeus	—	—	—	—	—	—	—	7
Amadeus and Bonaparte	37	3	—	23	—	—	—	—
Bonaparte	8	1	—	1	4	4	4	161
Bowen	—	—	—	5	—	—	—	1
Browse	—	—	—	—	—	49	74	625
Carnarvon	123	123	105	958	6	—	—	373
Cooper/Eromanga	10	7	12	83	—	3	4	34
Gippsland	114	20	36	206	18	3	—	36
Otway	—	—	—	9	—	—	—	4
Perth	2	—	—	4	—	—	—	—
Surat	—	—	—	1	—	—	—	—
Total	**297**	**156**	**154**	**1 292**	**29**	**65**	**90**	**1 249**

Source: BRS 1996.

The Carnarvon Basin holds 79% of the demonstrated economic resources of condensate, the Gippsland Basin 13%, and the Cooper and Eromanga Basins 4%.

Most of the sub-EDR of crude oil are also located in the Carnarvon, Gippsland and Bonaparte Basins, with 20, 62 and 14% respectively. Sub-EDR of condensate are distributed in a number of basins, including 75% in Browse, 8% in Bass, 6% in Bonaparte, 5% in Cooper/Eromanga and 5% in Gippsland.

FLOW ACCOUNTS FOR PETROLEUM

This section deals with the physical flow accounts of petroleum and shows the flows from supply to conversion, and then to the end use for liquid and gaseous petroleum such as crude oils, feedstocks, petroleum products, natural gas and town gas.

Crude oil and other refinery feedstock

From table 4.19 it can be seen that the domestic production of crude oil and other refinery feedstock (1,060.8 petajoules) was approximately 70% of the total supply in 1993–94. Imported primary oil in the same year accounted for 787.1 petajoules and exported primary oil was

364.6 petajoules, so that the net liquid petroleum trade added a net 422.5 petajoules of liquid petroleum to meet domestic demand. In the conversion process, some other sources such as oil recycling have also contributed slight amounts of refinery feedstock. The majority of crude oil and refinery feedstock is used as input for petroleum refining. Prior to 1991–92, very small quantities were used for electricity generation.

Liquid products of petroleum

'Liquid products of petroleum' refers here to the final marketable products produced from petroleum, except crude oil and refinery feedstock, and natural gas and town gas. 'Production' is defined as primary production before refinery, and here only LPG is a liquid form of petroleum from primary oil production which is considered to be a final product. Most liquid products of petroleum used domestically are mainly produced from the Australian petroleum refining industry, which is listed separately with primary production, see 'Petroleum refining' in table 4.20. In 1993–94, production of LPG was about 100 petajoules and the total of petroleum refining was 1,513 petajoules. Considered with the imports and exports, the domestic supply of liquid products of petroleum totalled 1,524 petajoules in 1993–94.

In conversion which convert liquid products of petroleum to other energy forms, 130 petajoules of liquid products of petroleum were used in 1993–94. 'Own fuel use' used 91 petajoules of liquid products of petroleum in 1993–94, about 70% of total consumption in conversion. Electricity generation used 28 petajoules, taking about 22% of this amount. The transport sector is the major end user of liquid products of petroleum, particularly road transport, used 849 petajoules in 1993–94 which was about 61% of the total. Air transport has continued to increase in the demand for liquid products of petroleum, reaching about 10% of the total final consumption in 1993–94. Non-transport sectors used about 24% of liquid products of petroleum, with the 'other industry' (mainly manufacturing industry) being the highest consumer with about 4%. Residential use of liquid products of petroleum, such as home heating and mowing, used only 17 petajoules in this period.

Natural gas

The production of natural gas has more than doubled during the period 1982–94 with about 30% of current production in 1993–94 being exported. In the conversion processes, electricity generation takes a large share of natural gas consumption. However, the majority of natural gas was used directly by end users. Table 4.21 shows that industries are major consumers of natural gas, taking about 75% of the total final supply. Manufacturing industry has the largest share of consumption, with residential use being significant.

Town gas

Town gas production and consumption are listed in table 4.22. Use of town gas has been in decline for some time, from 9.8 petajoules in 1982–83 to 2.3 petajoules in 1993–94.

4.19 FLOW ACCOUNT FOR CRUDE OIL AND OTHER REFINERY FEEDSTOCK

	1982–83	1983–84	1984–85	1985–86	1986–87	1987–88	1988–89	1989–90	1990–91	1991–92	1992–93	1993–94
	PJ	PJ	PJ	PJ	PJ	PJ	PJ	PJ	PJ	PJ	PJ	PJ
SUPPLY												
Production	816.6	992.6	1 145.4	1 174.1	1 165.6	1 156.9	1 045.4	1 183.8	1 182.3	1 158.4	1 136.0	1 060.8
From conversion	7.1	8.1	8.2	8.6	8.8	8.7	8.3	8.2	8.6	8.5	9.2	8.8
Imports	455.9	331.0	282.3	239.4	298.9	370.6	466.6	449.0	518.2	593.3	751.6	787.1
Exports	–2.3	–39.1	–215.3	–186.9	–211.0	–238.8	–181.9	–266.5	–326.4	–332.0	–373.6	–364.6
Other[1]	–41.5	–31.1	48.1	12.5	–28.6	24.0	7.4	12.2	39.1	12.2	–27.8	21.5
Total supply	*1 235.8*	*1 261.5*	*1 268.7*	*1 247.7*	*1 233.7*	*1 321.4*	*1 345.8*	*1 386.7*	*1 421.8*	*1 440.4*	*1 495.4*	*1 513.6*
CONVERSION												
Petroleum refining	1 235.6	1 260.9	1 267.6	1 247.3	1 233.3	1 321.2	1 345.6	1 386.3	1 421.4	1 440.0	1 494.8	1 513.0
Electricity generation	0.1	0.1	0.1	0.1	0.1	0.0	0.0	0.1	0.1	..		..
Total conversion	*1 235.7*	*1 261.0*	*1 267.7*	*1 247.4*	*1 233.4*	*1 321.2*	*1 345.6*	*1 386.4*	*1 421.5*	*1 440.0*	*1 494.8*	*1 513.0*
Net supply	0.1	0.5	1.0	0.3	0.3	0.2	0.2	0.3	0.3	0.4	0.6	0.6
END USE												
Mining	0.0	0.4	0.9	0.2	0.2	0.2	0.2	0.3	0.3	0.4	0.6	0.6
Other	0.1	0.1	0.1	0.1	0.1	..	—	—	—	—	—	—
Total	*0.1*	*0.5*	*1.0*	*0.3*	*0.3*	*0.2*	*0.2*	*0.3*	*0.3*	*0.4*	*0.6*	*0.6*

1 Stock changes and discrepancies.

Source: ABARE 1995.

4.20 FLOW ACCOUNT FOR LIQUID PRODUCTS OF PETROLEUM

	1982–83	1983–84	1984–85	1985–86	1986–87	1987–88	1988–89	1989–90	1990–91	1991–92	1992–93	1993–94
	PJ	PJ	PJ	PJ	PJ	PJ	PJ	PJ	PJ	PJ	PJ	PJ
SUPPLY												
Production	77.1	83.0	102.4	106.4	104.1	104.0	99.7	100.3	94.0	95.1	100.1	99.9
Petroleum refining	1 235.6	1 260.9	1 267.6	1 247.3	1 233.3	1 321.2	1 345.6	1 386.3	1 421.4	1 440.0	1 494.8	1 513.0
Imports	101.7	97.5	107.4	105.6	152.3	124.8	153.1	176.6	107.0	83.6	108.8	103.8
Exports	–153.9	–186.3	–152.5	–169.0	–157.1	–167.7	–162.6	–150.0	–154.1	–187.0	–179.9	–168.7
Other[1]	1.8	50.9	-19.6	13.9	–17.7	-14.7	–4.3	-60.7	–27.7	12.9	–33.2	–24.0
Total supply	*1 262.3*	*1 306.0*	*1 305.3*	*1 304.2*	*1 314.9*	*1 367.6*	*1 431.5*	*1 452.5*	*1 440.6*	*1 444.6*	*1 490.6*	*1 524.0*
CONVERSION												
Coke ovens	0.9	0.9	0.9	0.4	0.4	0.4	1.1	0.8	0.9	1.1	0.9	0.6
Gas manufacturing	3.2	3.0	1.9	1.8	1.6	1.4	1.5	1.5	1.3	1.3	1.3	1.2
Electricity generation	46.8	45.6	40.4	35.1	26.5	21.3	28.5	38.0	38.9	27.3	27.4	28.4
Other conversion	7.1	8.1	8.2	8.6	8.8	8.7	8.3	8.2	8.6	8.5	9.2	8.8
Own fuel use	79.4	83.0	80.3	79.4	83.1	84.5	86.8	84.5	89.0	87.1	92.8	91.2
Total conversion	137.4	140.6	131.7	125.3	120.4	116.3	126.2	133.0	138.7	125.3	131.6	130.2
Net supply	*1 124.9*	*1 165.4*	*1 173.6*	*1 178.9*	*1 194.5*	*1 251.3*	*1 305.3*	*1 319.5*	*1 301.9*	*1 319.3*	*1 359.0*	*1 393.8*
END USE												
Agriculture	43.5	49.6	48.2	47.2	49.3	47.7	50.7	48.6	49.0	49.7	51.5	53.1
Mining	23.1	22.6	23.6	24.8	27.4	27.9	32.8	37.6	38.5	38.6	41.7	43.0
Iron and steel	2.3	1.5	1.7	2.3	1.6	1.6	1.6	1.0	1.5	1.3	1.4	1.6
Chemical	33.8	37.9	39.5	41.3	37.7	44.3	45.6	46.0	47.7	43.8	48.5	47.3
Other industry	79.2	90.6	73.2	61.9	60.6	65.5	68.3	67.4	62.8	60.1	60.1	60.9
Construction	34.7	33.0	30.9	34.4	34.6	39.1	41.2	40.7	36.9	38.9	41.3	42.5

For footnotes see end of table.

4.20 FLOW ACCOUNT FOR LIQUID PRODUCTS OF PETROLEUM — *continued*

	1982–83	1983–84	1984–85	1985–86	1986–87	1987–88	1988–89	1989–90	1990–91	1991–92	1992–93	1993–94
	PJ	PJ	PJ	PJ	PJ	PJ	PJ	PJ	PJ	PJ	PJ	PJ
					END USE — *continued*							
Road transport	646.3	676.8	700.7	719.4	728.6	760.1	792.8	811.3	796.3	809.5	827.9	848.7
Rail transport	25.3	27.2	28.7	27.5	28.5	27.9	25.7	25.0	24.8	24.0	23.4	23.3
Air transport	83.3	83.1	88.9	92.9	97.0	106.5	113.4	108.6	122.0	130.6	139.3	144.5
Water transport	73.8	64.7	61.2	51.6	54.0	55.6	55.6	52.3	44.8	44.1	40.8	43.1
Commercial	13.5	11.3	10.7	10.6	10.3	10.6	11.0	11.7	12.0	12.4	13.0	13.1
Residential	21.4	20.1	19.8	18.0	17.9	16.5	16.1	16.6	16.4	16.9	18.0	16.5
Others[2]	44.8	47.0	46.6	47.0	47.0	48.0	50.4	52.7	49.3	48.3	52.1	56.0
Total	*1 124.9*	*1 165.4*	*1 173.6*	*1 178.9*	*1 194.5*	*1 251.3*	*1 305.3*	*1 319.5*	*1 301.9*	*1 319.3*	*1 359.0*	*1 393.8*

1 Stock changes and discrepancies.
2 Others include lubricants, greases, bitumen and solvents.

Source: ABARE 1995.

4.21 FLOW ACCOUNT FOR NATURAL GAS

	1982–83	1983–84	1984–85	1985–86	1986–87	1987–88	1988–89	1989–90	1990–91	1991–92	1992–93	1993–94
	PJ	PJ	PJ	PJ	PJ	PJ	PJ	PJ	PJ	PJ	PJ	PJ
SUPPLY												
Production	466.2	490.0	523.3	570.7	588.4	610.6	627.8	797.3	840.7	914.1	983.1	1 054.1
Exports	—	—	—	—	—	—	—	–109.3	–185.0	–235.4	–276.6	–320.7
Total supply	*466.2*	*490.0*	*523.3*	*570.7*	*588.4*	*610.6*	*627.8*	*688.0*	*655.7*	*678.7*	*706.5*	*733.4*
CONVERSION												
Coke ovens	0.3	1.8	2.6	1.8	1.9	—	—	—	—	—	—	—
Petroleum refining	13.2	12.1	10.6	10.0	8.1	9.1	8.2	10.4	9.5	9.5	9.1	9.2
Gas manufacturing	8.7	7.9	8.1	6.0	5.3	4.5	3.1	2.4	1.6	2.0	1.8	1.6
Elec. generation	117.8	124.1	111.0	134.4	129.1	139.8	143.8	161.5	121.5	131.9	136.4	147.9
Own fuel use	17.0	18.6	19.1	23.0	20.6	19.6	19.9	21.2	19.5	19.8	20.4	20.9
Total conversion	157.0	164.5	151.4	175.2	165.0	173.0	175.0	195.5	152.1	163.2	167.7	179.6
Net supply	*309.2*	*325.4*	*372.0*	*396.6*	*423.3*	*437.3*	*452.7*	*492.6*	*503.8*	*515.4*	*538.9*	*553.8*
END USE												
Agriculture	—	—	—	—	—	—	—	—	—	0.1	0.1	0.1
Mining	31.2	38.9	49.0	47.7	50.1	59.0	61.6	81.6	85.6	91.5	103.6	106.1
Iron and steel	15.8	16.9	17.7	24.2	29.6	25.0	24.3	26.5	23.8	21.7	22.7	23.1
Chemical	47.5	48.3	47.1	48.9	49.6	54.3	52.8	55.7	57.1	54.5	52.8	55.7
Other industry	136.2	137.1	168.1	179.9	189.7	196.3	205.9	206.2	211.7	215.6	221.5	228.5
Construction	0.2	0.2	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Road transport	—	—	—	—	—	—	—	—	0.3	0.6	0.9	1.2
Rail transport	—	—	—	—	—	—	—	—	—	0.1	—	—
Air transport	0.3	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
Water transport	—	—	—	—	—	—	—	—	—	0.1	0.1	0.1
Commercial	20.9	23.0	24.8	26.5	28.9	29.4	31.1	33.9	35.2	37.4	38.8	39.7
Residential	57.2	60.6	64.4	68.7	74.8	72.7	76.1	87.9	89.4	93.3	97.8	98.7
Consumption	*309.2*	*325.4*	*372.0*	*396.6*	*423.3*	*437.3*	*452.7*	*492.6*	*503.8*	*515.4*	*538.9*	*553.8*

Source: ABARE 1995.

4.22 FLOW ACCOUNT FOR TOWN GAS

	1982–83	1983–84	1984–85	1985–86	1986–87	1987–88	1988–89	1989–90	1990–91	1991–92	1992–93	1993–94
	PJ	PJ	PJ	PJ	PJ	PJ	PJ	PJ	PJ	PJ	PJ	PJ
SUPPLY												
Production	11.5	10.2	9.4	7.7	6.5	5.6	4.4	3.6	2.7	2.7	2.7	2.5
Total supply	*11.5*	*10.2*	*9.4*	*7.7*	*6.5*	*5.6*	*4.4*	*3.6*	*2.7*	*2.7*	*2.7*	*2.5*
CONVERSION												
Own fuel use	–1.7	–1.4	–1.2	–1.0	–0.8	–0.7	–0.4	–0.3	–0.2	–0.2	–0.2	–0.2
Net supply	*9.8*	*8.8*	*8.1*	*6.7*	*5.8*	*4.9*	*3.9*	*3.2*	*2.4*	*2.5*	*2.5*	*2.3*
END USE												
Other industry	1.0	0.7	0.6	0.5	0.5	0.3	0.2	0.2	0.1	0.1	—	—
Commercial	2.7	2.6	2.4	2.0	1.7	1.6	1.3	1.0	0.7	0.7	0.8	0.7
Residential	6.1	5.4	5.0	4.3	3.6	3.0	2.5	2.1	1.6	1.7	1.7	1.5
Consumption	*9.8*	*8.8*	*8.1*	*6.7*	*5.8*	*4.9*	*3.9*	*3.2*	*2.4*	*2.5*	*2.5*	*2.3*

Source: ABARE 1995

Petroleum production by field

Australia's major areas for primary oil and gas production are Bass Strait, the Timor Sea, North West Shelf, Barrow Island and small onshore fields located in the Cooper–Eromanga Basin, see table 4.23.

Over the past 20 years, Bass Strait oil fields have produced 445 million litres of oil, 3.5 trillion cubic feet of gas, 52 million litres of LPG and 445 million litres of ethane, making it the largest oil production region in Australia. The Carnarvon Basin is Australia's second largest oil and gas producing region.

Australia's largest gas producing fields are located in the North West Shelf off-shore region. Gas is brought from the North Rankin field via a 134 kilometre pipeline to the onshore facilities. The gas fields began production in 1984 and expanded in 1989.

4.23 PETROLEUM PRODUCTION

	Units	1986–87	1987–88	1988–89	1989–90	1990–91	1991–92	1992–93	1993–94
Crude oil									
Amadeus	ML	164	141	107	94	82	93	117	152
Bonaparte	ML	771	1 337	2 430	3 775	4 078	3 3796	3 304	1 969
Bowen–Surat	ML	80	80	122	128	105	84	73	60
Canning	ML	50	35	27	20	20	19	17	19
Carnarvon									
Barrow Island	ML	1 080	979	900	844	819	828	813	845
North West Shelf	ML	—	—	—	—	—	—	—	—
Other	ML	535	898	1 125	3 313	4 178	4 481	3 666	4 172
Cooper–Eromanga									
Queensland	ML	1 702	1 516	1 374	1 276	1 143	1 085	990	878
South Australia	ML	1 365	1 337	1 569	1 473	1 452	1 340	1 062	963
Gippsland	ML	23 701	22 215	17 902	17 789	16 747	16 021	16 956	15 846
Otway	ML	—	—	—	—	—	—	—	—
Perth	ML	9	13	17	31	38	33	40	38
Total	*ML*	*29 457*	*28 551*	*25 574*	*28 744*	*28 661*	*27 780*	*27 037*	*24 942*
Condensate									
Amadeus	ML	—	—	5	6	4	4	5	1
Bonaparte	ML	—	—	—	—	—	—	—	—
Bowen–Surat	ML	70	73	65	58	58	59	58	69
Canning	ML	—	—	—	—	—	—	—	—
Carnavon									
Barrow Island	ML	—	—	—	—	—	—	—	—
North West Shelf	ML	498	1 174	1 134	1 631	1 841	1 988	2 121	2 252
Other	ML	—	—	—	—	—	—	29	35
Cooper–Eromanga									
Queensland	ML	—	—	—	—	—	—		77
South Australia	ML	731	725	679	665	654	625	599	533
Gippsland	ML	745	740	796	888	735	851	849	756
Otway	ML	—	—	—	—	—	—	2	3
Perth	ML	2	1	1	1	2	2	3	4
Total	*ML*	*2 047*	*2 713*	*2 681*	*3 250*	*3 294*	*3 529*	*3 666*	*3 731*
Liquefied petroleum gas									
Amadeus	ML	—	—	—	—	—	—	—	—
Bonaparte	ML	—	—	—	—	—	—	—	—
Bowen–Surat	ML	85	101	99	103	101	100	99	108
Canning	ML	—	—	—	—	—	—	—	—
Carnarvon									
Barrow Island	ML	1	1	—	—	—	—	—	—
North West Shelf	ML	—	—	—	—	—	—	—	—
Other	ML	—	—	—	—	—	—	—	—
Cooper–Eromanga									
Queensland	ML	—	—	—	—	—	—	—	—
South Australia	ML	964	981	974	999	947	30	935	931
Gippsland	ML	2 877	2 841	2 689	2 684	2 500	2 558	2 744	2 662
Otway	ML	—	—	—	—	—	—		—
Perth	ML	—	—	—	—	—	—	—	
Total	*ML*	*3 927*	*3 923*	*3 763*	*3 785*	*3 547*	*3 589*	*3 778*	*3 701*

... continued

4.23 PETROLEUM PRODUCTION — *continued*

	Units	1986–87	1987–88	1988–89	1989–90	1990–91	1991–92	1992–93	1993–94
Naturally occurring ethane and natural gas									
Amadeus	GL	127	276	259	308	325	334	334	339
Bonaparte	GL	—	—	—	—	—	—	—	—
Bowen–Surat	GL	524	602	541	589	977	1 103	1 005	1 151
Canning	GL	—	—	—	—	—	—	—	—
Carnavon									
Barrow Island	GL	18	18	18	18	17	18	15	13
North West Shelf	GL	2 929	3 611	3 905	7 254	9 126	10 143	11 133	12 857
Other	GL	1	1	1	2	4	158	443	403
Cooper–Eromanga									
Queensland	GL	—	—	—	—	—	—	—	—
South Australia	GL	5 392	5 298	5 435	5 463	4 943	5 005	5 149	5 328
Gippsland	GL	5 433	5 362	5 635	6 404	5 677	5 790	5 690	5 733
Otway	GL	10	13	14	18	23	38	52	95
Perth	GL	429	257	148 226	204	178	333	385	385
Total	*GL*	*14 863*	*15 438*	*15 956*	*20 282*	*21 296*	*22 677*	*24 154*	*26 304*

Source: ABARE 1994.

Refinery products by type

During the period of 1980–92, the outputs of Australian refinery products have shown significant changes. Production of aviation turbine fuel has increased about 67% and aviation gasoline about 38%. Automotive diesel fuel rose 42%. Petrol production increased 20%. However, many petroleum products have declined. Industrial diesel fuel production fell 81%, and kerosine fell 70%. The total output of petroleum products during this period rose about 19%. Table 4.24 provides the details of Australian refinery production.

4.24 REFINERY PRODUCTION

	1980–81	1981–82	1982–83	1983–84	1984–85	1985–86	1986–87	1987–88	1988–89	1989–90	1990–91	1991–92
	ML	ML	ML	ML	ML	ML	ML	ML	ML	ML	ML	ML
REFINERY INPUT												
Total refinery input	33 284	34 236	34 330	33 024	34 026	33 395	32 515	33 830	35 540	36 064	36 741	38 644
PERCENTAGE INDIGENOUS												
Total percentage indigenous	67	65	65	69	75	80	78	77	68	65	67	61
PRODUCTION OF MARKETABLE PRODUCTS												
Aviation gasoline	111	144	161	163	204	187	171	228	192	209	215	153
Petrol	14 170	14 656	15 164	14 979	15 365	15 851	15 335	15 523	15 983	16 075	16 439	16 944
Aviation turbine	2 214	2 395	2 459	2 359	2 616	2 603	2 739	2 923	3 279	3 184	3 469	3 704
Lighting and power kerosine	167	160	176	121	130	97	95	61	74	57	135	50
Heating oil	334	322	276	268	234	197	197	205	169	198	221	201
Automotive diesel	7 467	7 433	8 022	7 803	8 196	8 104	8 111	8 785	9 577	9 933	10 373	10 582
Industrial diesel	885	762	568	376	358	391	261	248	179	142	142	165
Fuel oil	3 544	3 466	3 328	3 163	2 875	2 865	2 093	2 231	2 105	2 401	2 492	2 762
Lubricating oil basestock	600	528	592	528	595	587	534	616	620	631	669	672
Bitumen	484	457	528	440	504	512	542	502	536	601	565	523
LPG	631	708	684	640	731	965	771	770	786	811	771	898
Others	1 004	1 318	1 185	1 730	1 579	1 189	909	1 115	1 125	1 006	883	1 075
Total	**31 610**	**32 348**	**33 144**	**32 570**	**33 386**	**33 548**	**31 757**	**33 207**	**34 625**	**35 248**	**36 373**	**37 728**

Note: Any discrepancies between totals and sums of components are due to rounding.

Source: DPIE 1992.

Petroleum import and export by country

Tables 4.25 and 4.26 provide detailed information on Australian imports and exports of petroleum in 1993–94. Most of the imported primary oil came from the United Arab Emirates (22%), Saudi Arabia (20%), Papua New Guinea (18%) and Indonesia (14%).

Singapore is the largest supplier of refined products to Australia. Petrol, automotive diesel and aviation turbine were the main products supplied. The second largest supplier of refined petroleum products was the United States of America.

Japan is the major export market for Australia's primary oil. In 1993–94, Australia exported 3,366 mega litres (38%) of primary oil to Japan. While Indonesia sold a large quantity of oil to Australia, it also imported 1,601 mega litres Australia's primary oil.

4.25 PETROLEUM IMPORTS BY SOURCE, 1993–94

Country	*Crude Oil and other feedstock*	*Petrol*	*Aviation fuels*	*Automotive diesel*	*Industrial diesel*	*Fuel[1] oil*	*Lubricating oil*
	ML	ML	ML	ML	ML	ML	ML
Bahrain	55.9	—	—	—	—	—	—
Brunei	94.9	—	—	—	—	—	—
Indonesia	2 804.9	—	—	—	0.3	—	—
Korea	52.1	—	—	—	11.9	—	—
Kuwait	273.2	—	—	—	—	—	—
Malaysia	196.7	—	—	—	—	—	—
New Zealand	1 152.0	13.6	—	17.3	0.3	—	—
Papua New Guinea	3 692.4	—	—	—	0.2	—	—
Qatar	1 062.0	—	—	—	—	—	—
Saudi Arabia	3 958.2	39.7	—	—	—	—	—
Singapore	717.6	178.4	186.7	555.6	12.5	—	15.6
United Arab Emirates	4 360.1	41.3	—	—	0.3	—	—
United States of America	1.6	100.6	—	142.9	—	—	0.9
Vietnam	1 576.4	—	—	—	—	—	—
All countries	**20 189.4**	**447.2**	**188.9**	**737.2**	**26.4**	**944.4**	**24.2**

[1] No country details available.

Source: ABS Trade Fastraccs.

4.26 PETROLEUM EXPORTS BY DESTINATION, 1993–94

Country	Crude	Petrol	Avgas	Avtur	Kerosine	Automotive diesel	Industrial diesel	Fuel oil	Lubricating oils
	ML	ML	ML	ML	ML	ML	ML	ML	ML
Fiji	—	61.3	1.9	52.3	9.6	85.5	29.2	34.7	15.4
Indonesia	1 601.4	—	—	0.5	—	—	1.8	—	17.6
Japan	3 366.1	0.9	—	37.2	—	—	—	—	0.4
Korea	241.9	—	4.0	—	—	—	0.5	—	—
New Caledonia	—	77.6	0.4	23.5	—	111.8	—	29.2	7.8
New Zealand	385.1	425.2	25.7	7.8	—	58.1	—	—	64.0
Papua New Guinea	0.3	104.7	9.3	22.3	43.4	340.9	1.2	19.5	27.3
Singapore	1 591.4	168.3	12.9	116.3	—	22.3	10.6	607.3	101.2
Taiwan	457.0	—	—	—	—	—	—	—	8.2
United States of America	1 104.8	1.4	—	26.8	—	3.6	—	12.6	—
Ships and Aircraft	—	—	—	1 191.5	—	92.3	51.8	669.5	5.8
All countries	**8 904.5**	**891.5**	**58.9**	**1 579.0**	**53.2**	**844.0**	**109.0**	**1 382.3**	**396.8**

Source: ABS Trade Fastraccs.

Petroleum consumption

Table 4.27 provides information on liquid petroleum consumption in Australia by industry. Note that the total marketable petroleum products are not necessarily equal to the sum of the individual products due to netting off the double counting which can occur in the case of some petroleum product produced by the conversion of other products.

The liquid petroleum consumption varied greatly across industries in terms of the type and quantity of fuel used, as shown in table 4.27. As might be expected, transport was one of the sectors with the largest consumption of liquid petroleum fuel. Automotive gasoline, both leaded and unleaded, was the dominant fuel used in road transport (70% of the total in 1993–94), with automotive diesel 25%. Despite rapid growth in LPG consumption, it accounted for only about 5% of total fuel.

In air transport, aviation turbine fuel was the predominant fuel used (98%). Automotive diesel oil accounted for 95% of energy usage in railway transport. About 78% of total energy used in the shipping industry was in the form of fuel oil.

The basic chemicals industry was the highest consumer of liquid petroleum in manufacturing, since miscellaneous petroleum products, such as olefins and aromatics, and LPG are major input materials.

Automotive diesel oil is the major form of liquid petroleum used in many other sectors, such as agriculture, forestry, fishing, mining, construction and private electricity generation, due to the use of internal combustion engines. In residential, commercial and services sectors, LPG has increased rapidly.

4.27 LIQUID PETROLEUM CONSUMPTION, BY INDUSTRY AND FUEL TYPE

	1982–83	1983–84	1984–85	1985–86	1986–87	1987–88	1988–89	1989–90	1990–91	1991–92	1992–93	1993–94
Fuel Type	PJ	PJ	PJ	PJ	PJ	PJ	PJ	PJ	PJ	PJ	PJ	PJ
AGRICULTURE, FORESTRY AND FISHING												
LPG	0.3	0.3	0.3	0.4	0.4	0.4	0.5	0.5	0.5	0.5	0.5	0.6
Power kerosene	0.4	0.4	0.4	0.3	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Heating oil	0.2	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
ADO	42.5	48.7	47.3	46.5	48.6	47.2	50.1	48.1	48.4	49.1	50.8	52.4
Subtotal	*43.5*	*49.6*	*48.2*	*47.2*	*49.3*	*47.8*	*50.7*	*49.1*	*49.4*	*49.2*	*51.4*	*53.1*
MINING												
LPG	0.2	0.2	0.2	0.4	0.4	0.4	0.4	0.4	0.3	0.2	0.2	0.2
Aviation turbine	—	—	—	—	0.3	0.4	0.2	0.3	0.4	—	—	—
ADO	19.3	19.4	20.4	21.7	24.1	24.9	29.9	34.5	36.1	37.9	39.8	41.1
IDF	0.1	0.1	—	—	—	—	—	—	—	—	—	—
Fuel oil	3.5	2.9	3.0	2.6	2.7	2.2	2.4	2.3	1.8	1.5	1.6	1.6
Others	0.1	0.3	0.8	0.3	0.2	0.3	0.3	0.5	0.5	0.5	0.7	0.7
Subtotal	*23.2*	*22.9*	*24.4*	*24.9*	*27.6*	*28.1*	*33.1*	*37.9*	*38.9*	*40.4*	*42.3*	*43.6*
MANUFACTURING												
Food, beverages, tobacco												
LPG	1.4	1.8	2.0	2.3	2.5	2.7	2.9	3.0	3.2	3.0	3.4	3.6
ADO	1.6	1.3	1.2	1.1	1.1	1.1	1.2	1.1	1.0	1.0	1.0	1.0
IDF	0.7	0.5	0.4	0.3	0.2	0.1	0.1	0.0	0.0	0.0	0.0	0.0
Fuel oil	5.8	4.9	4.2	3.7	3.1	2.8	2.7	2.3	2.3	2.1	2.1	2.1
Subtotal	*8.6*	*7.7*	*7.2*	*6.7*	*6.5*	*6.7*	*6.4*	*6.4*	*6.5*	*6.6*	*6.5*	*6.7*
Textiles, clothing, footwear												
LPG	0.1	0.1	0.2	0.2	0.2	0.3	0.3	0.4	0.4	0.4	0.4	0.4
ADO	0.2	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Fuel oil	0.6	0.7	0.7	0.7	0.5	0.4	0.3	0.3	0.2	0.2	0.2	0.2
Subtotal	*0.9*	*1.0*	*1.0*	*1.1*	*0.9*	*0.7*	*0.6*	*0.8*	*0.7*	*0.7*	*0.7*	*0.7*

... *continued*

4.27 LIQUID PETROLEUM CONSUMPTION, BY INDUSTRY AND FUEL TYPE — *continued*

Fuel Type	*1982–83* PJ	*1983–84* PJ	*1984–85* PJ	*1985–86* PJ	*1986–87* PJ	*1987–88* PJ	*1988–89* PJ	*1989–90* PJ	*1990–91* PJ	*1991–92* PJ	*1992–93* PJ	*1993–94* PJ
					MANUFACTURING — *continued*							
Wood and wood products												
LPG	0.1	0.1	0.1	0.1	0.1	0.2	0.2	0.2	0.2	0.2	0.2	0.2
ADO	0.8	0.8	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9
IDF	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Fuel oil	1.1	1.2	1.2	1.1	1.0	0.9	1.0	0.8	0.7	0.7	0.7	0.7
Subtotal	*2.1*	*2.2*	*2.3*	*2.2*	*2.0*	*2.0*	*2.1*	*1.9*	*1.8*	*1.7*	*1.8*	*1.8*
Paper and paper products												
LPG	0.2	0.2	0.4	0.7	0.7	0.8	0.8	0.8	0.8	0.5	0.5	0.5
ADO	0.4	0.2	0.2	0.2	0.1	0.0	0.0	0.0	0.0	0.1	0.0	0.1
IDF	0.4	0.4	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Fuel oil	2.3	0.9	0.9	0.9	0.9	0.9	0.9	0.0	0.9	0.8	0.8	0.8
Subtotal	*3.1*	*1.8*	*1.7*	*1.8*	*1.7*	*1.7*	*1.8*	*1.8*	*1.7*	*1.6*	*1.3*	*1.4*
Chemicals, petroleum, coal products												
Refinery feedstock	1 235.6	1 260.9	1 267.5	1 247.2	1 233.4	1 321.6	1 345.7	1 386.3	1 421.4	1 440.0	1 494.8	1 513.1
LPG	8.5	12.0	20.3	22.1	20.5	23.0	23.9	29.1	26.5	27.2	29.9	31.9
ADO	0.4	0.3	0.4	0.3	0.3	0.1	0.1	0.2	0.1	0.2	0.1	0.1
IDF	0.3	0.1	0.1	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0
Fuel oil	3.2	2.6	2.2	1.2	0.8	0.6	0.7	0.7	0.5	0.5	0.4	0.5
Others	126.2	136.1	130.0	129.1	131.5	139.0	142.0	133.1	143.5	140.4	152.1	150.2
Subtotal	*1 374.2*	*1 412.0*	*1 420.5*	*1 400.0*	*1 386.7*	*1 485.4*	*1 512.4*	*1 558.3*	*1 601.3*	*1 628.9*	*1 677.3*	*1 695.8*
Non-metallic products												
LPG	0.9	1.1	1.2	1.2	1.4	1.4	1.7	1.6	1.6	1.5	1.6	1.7
ADO	1.3	1.1	1.0	1.0	1.0	1.0	1.0	1.1	1.0	1.0	1.0	1.1
IDF	0.5	0.2	0.2	0.2	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0
Fuel oil	2.9	2.7	2.3	1.9	1.3	1.0	1.1	1.2	1.1	0.8	0.8	0.8
Others	0.1	0.2	0.2	0.3	0.3	0.4	1.4	0.7	0.9	1.2	0.8	1.0
Solvents	—	—		—	—	—	—	—	—	—	0.0	0.1
Subtotal	*5.7*	*5.4*	*5.0*	*4.6*	*4.0*	*4.0*	*5.3*	*4.7*	*4.9*	*3.8*	*4.2*	*4.7*

... *continued*

4.27 LIQUID PETROLEUM CONSUMPTION, BY INDUSTRY AND FUEL TYPE — *continued*

Fuel Type	*1982–83*	*1983–84*	*1984–85*	*1985–86*	*1986–87*	*1987–88*	*1988–89*	*1989–90*	*1990–91*	*1991–92*	*1992–93*	*1993–94*
	PJ	PJ	PJ	PJ	PJ	PJ	PJ	PJ	PJ	PJ	PJ	PJ
					MANUFACTURING — *continued*							
Basic metal products												
LPG	0.9	1.0	1.0	1.3	1.6	1.9	2.3	2.3	2.6	2.9	3.1	2.6
Power kerosene	..		—	—	—	..	..	0.0	0.1	0.1	0.1	0.1
ADO	3.0	2.9	2.7	2.2	2.3	2.6	2.7	2.7	3.0	2.8	3.0	3.1
IDF	1.0	0.8	0.7	0.2	0.1	0.0	0.0	0.0	0.0	0.2	0.1	0.0
Fuel oil	50.5	63.6	46.4	35.5	34.8	38.5	38.8	37.7	32.5	31.2	29.7	30.3
Others	3.4	4.1	5.4	6.6	6.9	7.4	8.7	9.1	9.3	9.0	9.3	9.4
Subtotal	*59.0*	*72.4*	*56.0*	*45.9*	*45.6*	*50.5*	*52.6*	*52.1*	*47.7*	*45.8*	*45.3*	*45.5*
Fabricated metal products												
LPG	0.5	0.5	0.5	0.6	0.6	0.6	0.6	0.7	0.7	0.7	0.9	0.9
ADO	0.1	0.1	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
IDF	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	—	—
Fuel oil	0.1	0.0	0.0	—	—	—		—	..	—	—	—
Subtotal	*0.7*	*0.6*	*0.6*	*0.6*	*0.6*	*0.6*	*0.7*	*0.8*	*0.8*	*0.9*	*1.0*	*1.0*
Transport equipment												
LPG	0.2	0.3	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
ADO	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
IDF	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	—	—	—
Fuel oil	0.2	0.2	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Subtotal	*0.7*	*0.7*	*0.6*	*0.5*	*0.4*	*0.4*	*0.4*	*0.4*	*0.4*	*0.3*	*0.3*	*0.3*
Other machinery and equipment												
LPG	0.2	0.2	0.3	0.3	0.3	0.4	0.4	0.5	0.5	0.5	0.6	0.7
ADO	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Fuel oil	0.1	0.1	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Subtotal	*0.4*	*0.4*	*0.4*	*0.4*	*0.4*	*0.4*	*0.4*	*0.5*	*0.5*	*0.5*	*0.6*	*0.7*
Miscellaneous manufacturing												
LPG	—	0.1	0.2	0.2	0.2	0.3	0.3	0.3	0.3	0.3	0.3	0.3
ADO	0.1	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	—
Fuel oil	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.1	0.0	0.1	0.1	0.2
Subtotal	*0.4*	*0.3*	*0.3*	*0.3*	*0.3*	*0.3*	*0.3*	*0.3*	*0.3*	*0.3*	*0.4*	*0.5*

... continued

4.27 LIQUID PETROLEUM CONSUMPTION, BY INDUSTRY AND FUEL TYPE — *continued*

Fuel Type	*1982-83*	*1983-84*	*1984-85*	*1985-86*	*1986-87*	*1987-88*	*1988-89*	*1989-90*	*1990-91*	*1991-92*	*1992-93*	*1993-94*
	PJ	PJ	PJ	PJ	PJ	PJ	PJ	PJ	PJ	PJ	PJ	PJ
					MANUFACTURING — *continued*							
Total manufacturing												
Refinery feedstock	1 235.6	1 260.9	1 267.5	1 247.2	1 233.4	1 321.6	1 345.7	1 386.3	1 421.4	1 440.0	1 494.8	1 513.1
LPG	13.1	17.5	26.4	29.2	28.3	32.5	33.5	38.9	37.0	37.3	41.2	43.0
Power kerosene	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.1
Heating oil	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ADO	8.2	7.0	6.7	5.9	5.9	6.1	6.2	6.2	6.4	6.2	6.4	6.5
IDF	3.3	2.4	1.8	0.9	0.4	0.3	0.3	0.1	0.1	0.2	0.2	0.1
Fuel oil	66.8	77.0	58.2	45.2	42.4	45.3	45.6	44.0	38.3	36.4	34.9	35.4
Others	129.7	140.3	135.6	136.0	138.8	146.8	152.1	142.9	153.7	150.6	162.2	160.6
Subtotal	*1 456.7*	*1 505.1*	*1 496.2*	*1 464.7*	*1 449.4*	*1 552.8*	*1 583.5*	*1 627.8*	*1 666.5*	*1 691.4*	*1 739.8*	*1 758.8*
					ELECTRICITY, GAS AND WATER							
Public electricity generation												
ADO	9.3	8.7	8.1	7.9	7.7	6.1	4.5	3.5	3.5	3.0	2.9	3.3
IDF	0.3	0.3	0.2	0.0	0.0	0.0	0.0	0.0	0.0	—	—	..
Fuel oil	17.6	15.5	14.3	11.8	7.7	3.3	5.7	12.3	13.8	3.9	4.2	3.4
Subtotal	*27.1*	*24.4*	*22.7*	*19.6*	*15.5*	*9.5*	*10.2*	*15.8*	*17.4*	*6.9*	*7.1*	*6.7*
Private electricity generation												
ADO	11.4	11.4	8.8	8.3	7.6	10.8	17.5	22.2	21.4	20.3	20.3	21.7
IDF	0.8	0.0	0.0	0.0	0.0	..		—	—	—		—
Fuel oil	7.1	9.8	8.9	6.6	3.4	0.4	0.7	0.0	0.2	0.1	0.1	0.0
Others	0.1	0.1	0.1	0.1	0.1	0.0	0.0	0.1	0.1	0.1	0.1	0.0
Subtotal	*19.9*	*21.3*	*17.8*	*15.6*	*11.1*	*11.8*	*18.3*	*23.0*	*22.4*	*22.4*	*20.5*	*21.7*
Total electricity, gas and water												
LPG	1.9	2.0	2.0	1.8	1.6	1.4	1.5	1.5	1.3	1.3	1.3	1.2
ADO	21.2	20.7	17.4	16.6	15.8	17.5	22.6	26.2	25.4	23.8	23.7	25.5
IDF	1.0	0.3	0.2	0.0	0.0	0.0	0.0	0.0	0.0	—		—
Fuel oil	24.7	25.2	23.2	18.4	11.1	3.7	6.5	12.3	14.0	4.0	4.3	3.5
Others	1.5	1.3	0.1	0.1	0.1	0.0	0.0	0.1	0.1	0.1	0.1	0.0
Subtotal	*50.7*	*49.4*	*43.0*	*37.5*	*28.6*	*23.2*	*30.5*	*40.8*	*41.5*	*31.2*	*29.4*	*29.2*

... continued

4.27 LIQUID PETROLEUM CONSUMPTION, BY INDUSTRY AND FUEL TYPE — *continued*

	1982–83	1983–84	1984–85	1985–86	1986–87	1987–88	1988–89	1989–90	1990–91	1991 92	1992–93	1993–94
Fuel Type	PJ	PJ	PJ	PJ	PJ	PJ	PJ	PJ	PJ	PJ	PJ	PJ
CONSTRUCTION												
Lighting kerosene	0.1	0.2	0.2	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
ADO	34.2	32.5	30.6	33.9	34.2	38.8	40.9	40.3	36.5	38.6	40.9	42.1
IDF	0.3	0.2	0.1	0.1	—	—	—	—	—	. .	—	—
Fuel oil	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1
Subtotal	*34.7*	*33.0*	*30.9*	*34.4*	*34.6*	*39.1*	*41.2*	*40.7*	*36.9*	*38.4*	*41.3*	*42.5*
TRANSPORT AND STORAGE												
Road transport												
LPG	7.4	8.7	10.0	12.4	13.7	17.6	20.0	22.4	27.6	33.3	37.7	41.8
Auto gasoline-leaded	515.4	527.3	533.8	527.6	497.9	482.6	461.7	427.6	383.4	359.5	337.0	304.2
Auto gasoline-unleaded		—	—	18.4	47.8	82.3	120.7	161.3	192.2	219.5	247.6	290.9
ADO	123.4	140.8	154.8	161.3	169.3	179.3	192.3	200.1	193.0	197.5	205.6	211.7
Subtotal	*646.3*	*676.8*	*700.7*	*719.4*	*728.6*	*760.1*	*792.8*	*811.4*	*796.6*	*810.1*	*818.8*	*849.9*
Railway transport												
ADO	25.1	25.1	25.9	24.8	25.8	25.2	22.8	23.0	23.0	22.0	21.1	21.9
IDF	—	2.0	2.7	2.6	2.6	2.6	2.6	1.7	1.5	1.7	2.1	1.1
Subtotal	*25.1*	*27.1*	*28.6*	*27.4*	*28.4*	*27.8*	*25.4*	*24.7*	*24.5*	*23.7*	*23.2*	*23.0*
Total water transport												
ADO	6.1	5.0	4.9	4.2	7.0	7.1	7.0	6.2	4.8	5.7	5.6	7.1
IDF	9.5	6.7	7.0	5.8	5.5	5.0	4.3	4.2	3.1	3.1	2.7	2.3
Fuel oil	58.1	52.8	49.1	41.4	41.4	43.3	44.2	41.7	36.7	35.1	32.4	33.6
Subtotal	*73.8*	*64.5*	*61.0*	*51.4*	*53.9*	*55.4*	*55.5*	*52.1*	*44.6*	*44.0*	*40.7*	*43.0*
Air transport												
Aviation gasoline	3.5	3.6	3.7	3.6	3.7	3.9	3.9	4.3	3.5	3.3	3.3	3.4
Aviation turbine	79.7	79.4	85.1	89.3	93.2	102.5	109.4	104.3	118.4	127.3	135.9	141.1
Subtotal	*83.2*	*83.0*	*88.8*	*92.8*	*96.9*	*106.4*	*113.4*	*108.6*	*121.9*	*130.2*	*139.2*	*144.5*
Other transport, services and storage												
ADO	0.4	0.4	0.4	0.4	0.4	0.4	0.5	0.5	0.5	0.5	0.5	0.5
IDF	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Others	—	—	—	0.1	—		—	—	—	—	—	—
Subtotal	*0.4*	*0.5*	*0.5*	*0.6*	*0.4*	*0.5*	*0.5*	*0.5*	*0.5*	*0.5*	*0.5*	*0.5*

... *continued*

4.27 LIQUID PETROLEUM CONSUMPTION, BY INDUSTRY AND FUEL TYPE — *continued*

Fuel Type	1982–83 PJ	1983–84 PJ	1984–85 PJ	1985–86 PJ	1986–87 PJ	1987–88 PJ	1988–89 PJ	1989–90 PJ	1990–91 PJ	1991–92 PJ	1992–93 PJ	1993–94 PJ
SOLVENTS, LUBRICANTS, GREASES AND BITUMEN												
Solvents	5.6	4.6	3.2	3.2	3.6	4.1	3.9	4.0	3.2	3.2	3.8	4.9
Lubricants and greases	17.0	17.4	17.5	17.8	17.9	18.8	19.8	20.1	18.6	18.5	19.1	19.5
Bitumen	21.5	24.4	25.3	25.6	25.0	24.6	26.0	28.3	27.4	26.3	29.1	31.5
Others	0.6	0.6	0.6	0.4	0.5	0.5	0.7	0.3	0.1	0.1	0.0	0.1
Subtotal	*44.8*	*47.0*	*46.6*	*47.0*	*47.0*	*48.0*	*50.4*	*52.7*	*49.3*	*48.3*	*42.0*	*56.0*
TOTAL												
Refinery feedstock	1 235.6	1 260.9	1 267.5	1 247.2	1 233.4	1 321.6	1 345.7	1 386.3	1 421.4	1 440.0	1 494.8	1 513.1
LPG	32.5	39.0	50.2	56.5	57.3	65.8	65.4	78.6	82.5	88.8	98.2	104.4
Auto gasoline-leaded	515.4	527.3	533.8	527.6	497.9	482.6	461.7	427.6	383.4	359.3	337.0	304.2
Auto gasoline-unleaded	—	—	2.1	18.4	47.8	82.3	120.7	161.3	192.2	219.5	247.6	290.9
Aviation gasoline	3.5	3.6	3.7	3.6	3.7	3.9	4.0	4.3	3.5	3.3	3.4	3.4
Aviation turbine	79.7	79.5	85.2	89.3	93.5	102.9	109.7	104.6	118.8	127.3	136.0	141.1
Lighting kerosene	5.1	4.6	4.5	3.7	3.5	2.8	2.6	2.5	2.2	1.6	1.7	1.5
Power kerosene	0.5	0.4	0.4	0.3	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Heating oil	9.0	8.0	7.4	5.9	5.7	4.8	4.4	4.8	4.8	5.6	6.1	4.7
ADO	287.0	305.1	313.6	320.2	335.7	351.0	376.7	389.6	378.3	385.6	398.6	413.0
IDF	17.3	13.3	12.9	10.4	9.0	8.2	7.4	6.1	4.9	5.2	5.1	3.6
Fuel oil	155.1	159.3	134.5	109.1	98.6	95.9	99.4	101.9	92.3	78.5	74.7	75.5
Others	131.9	142.5	137.2	136.9	139.6	147.7	153.1	143.7	154.4	151.2	163.0	161.5
Solvents	5.6	4.6	3.2	3.2	3.6	4.1	3.9	4.0	3.2	3.2	3.8	5.1
Lubricants and greases	17.0	17.4	17.5	17.8	17.9	18.8	19.8	20.1	18.6	18.5	19.1	19.5
Bitumen	21.5	24.4	25.3	25.6	25.0	24.6	26.0	28.3	27.4	26.3	29.1	31.5
Total	**2 516.7**	**2 589.9**	**2 596.9**	**2 575.7**	**2 572.4**	**2 717.1**	**2 800.6**	**2 863.8**	**2 888.0**	**2 914.0**	**3 018.3**	**3 072.9**

Source: ABARE 1995.

RESIDUAL ACCOUNTS FOR PETROLEUM

Economic activity to do with petroleum resources has a significant impact on the natural environment. Petroleum exploration, transport, conversion and end use, release pollutants to the environment in various ways, for example:

- spoilage from chemicals and fuel used in exploration drilling;
- oil pollution to the oceans resulting from spills during extraction of oil from off-shore wells or from accidents involving oil transport carriers;
- oil or gas leakage through pipelines and storage;
- waste water released from petroleum refineries and petrochemical plants; and
- air pollution emitted from end use, such as petroleum production processes and combustion engines.

Of the environmental impacts listed above, air pollution and greenhouse gas emissions are regarded as amongst the most severe consequences of petroleum production and consumption. Other forms of environmental impact, such as waste water discharge and oil pollution in the sea, are also important but there is generally a lack of data in these areas.

Petroleum production and consumption are responsible for many of the air pollutants discharged to the atmosphere, such as carbon monoxide; sulphur dioxide; oxides of nitrogen, lead, suspended particulates, tropospheric ozone, and volatile organic compounds (VOC); and greenhouse gas emissions such as carbon dioxide and methane. Most of the emissions in Australia comes from transport, electricity generation and industrial operations in which petroleum is used as energy through fuel combustion. In this section, emissions from production and end use of petroleum are considered from the two major sources, mobile and stationary.

Based on international practice, air pollutants and greenhouse gas emissions are estimated by applying emission factors to estimates of the volume of energy consumption. An exception is carbon dioxide where an 'oxidation' factor must also be included. An emission factor is expressed in terms of the mass emitted per unit of energy used. The unit of energy used is the gross calorific value. The oxidation factor describes the proportion of carbon in the energy products being oxidised during combustion and is estimated on a mass basis. After combustion, the remaining carbon is stored in solid products such as ash, soot and chimney build up.

Emission factors

Table 4.28 lists the carbon dioxide emission and oxidation factors for major liquid and gas fuels used in Australia. It can be seen that for liquid fuel the oxidation factor is generally 99% of the total carbon content of fuels, and for gases, it is considered as 100%. Natural gas has the lowest carbon dioxide emissions with 51.3 gigagrams per peta joule. LPG is the lowest emitter of carbon dioxide of the liquid fuels (59.4 gigagrams per petajoule), followed by automotive gasoline (66.0 gigagrams per petajoule). Detailed information on emission factors of air pollutants and greenhouse gas for the transport sector is given in table 4.29.

4.28 LIST OF FUELS AND CO_2 EMISSION AND OXIDATION FACTORS

Fuel type	*Proportion of fuel oxidised* %	*CO_2 emission factor* Gg/PJ
Liquids		
Automotive gasoline	—	66.0
Automotive diesel oil	—	69.7
Aviation gasoline	—	68.0
Aviation turbine	—	69.7
Fuel oil	—	73.3
Refinery fuel	—	68.1
Industrial diesel fuel	—	69.7
Power kerosene	—	69.7
Lighting kerosene	—	69.7
Heating oil	—	69.7
LPG	—	59.4
pnec[1]	—	68.6
Total proportion of fuel oxidised	99	—
Gases		
Natural gas	—	51.3
Total proportion of fuel oxidised	100	—

[1] pnec — liquid products of petroleum which are not elsewhere classified.

Source: NGGIC 1996.

4.29 EMISSION FACTORS FOR MAJOR AIR POLLUTANTS AND GREENHOUSE GASES FOR TRANSPORT

					Emission factor
	CH_4	*N_2O*	*NOx*	*CO*	*NMVOCs*
Source	g/km	g/km	g/km	g/km	g/km
Cars					
Petrol					
Post–1985	0.520	0.048	0.930	5.460	0.258
1981–85	0.058	0.122	0.450	3.850	0.289
1976–80	0.095	0.004	1.400	14.900	1.260
Pre–1976	0.143	0.004	2.460	24.000	2.280
ADO	0.010	0.010	1.030	1.080	0.530
LPG	0.087	0.008	1.940	21.600	1.690
Light trucks					
Petrol	0.140	0.012	1.760	23.580	1.970
ADO	0.010	0.014	1.180	1.110	0.530
LPG	0.089	0.008	1.980	21.990	1.720
Medium trucks					
Petrol	0.174	0.006	4.650	57.800	4.130
ADO	0.020	0.017	3.100	1.820	0.990
LPG	0.130	0.011	2.820	24.000	2.460

... continued

4.29 EMISSION FACTORS FOR MAJOR AIR POLLUTANTS AND GREENHOUSE GASES FOR TRANSPORT — *continued*

	Emission factor				
	CH_4	N_2O	NOx	CO	NMVOCs
Source	g/km	g/km	g/km	g/km	g/km
Heavy trucks					
Petrol	0.210	0.009	4.660	121.300	6.090
ADO	0.070	0.025	15.290	7.860	2.780
LPG	0.220	0.020	4.830	24.000	4.210
Buses					
Petrol	0.150	0.005	3.910	48.610	3.470
ADO	0.030	0.025	4.900	2.880	1.560
LPG	0.120	0.011	2.760	24.000	2.410
Motorcycles					
Petrol	0.150	0.002	0.210	19.270	4.580
	g/MJ	g/MJ	g/MJ	g/MJ	g/MJ
Aircraft					
Domestic					
Avgas	0.057	0.001	0.076	22.800	0.513
Avtur	0.009	0.002	0.531	0.111	0.035
International					
Avtur	0.009	0.002	0.531	0.111	0.035
Railway					
ADO	0.003	0.002	1.530	0.202	0.071
IDF	0.003	0.002	1.530	0.202	0.071
Marine					
Petrol (2-stroke)	0.670	0.001	0.217	32.500	6.040
ADO	0.004	0.002	1.105	0.246	0.075
IDF	0.007	0.002	1.580	0.163	0.046
Fuel oil	0.003	0.002	2.000	0.044	0.063
NG	0.243	0.001	0.243	0.095	0.029
Military (land)					
Petrol	0.026	0.001	0.418	4.240	0.670
ADO	0.010	0.002	0.860	0.600	0.124
Recreation					
Petrol	0.030	0.001	0.370	7.000	1.080
Industrial equipment					
ADO	0.006	0.002	1.006	0.390	0.108
LPG	0.022	0.001	0.437	5.465	0.409
Farm equipment					
ADO	0.010	0.002	1.360	0.541	0.189
Utility engines					
Petrol	0.038	0.001	0.087	13.000	3.450

Source: NGGIC 1996.

The emission factors for stationary sources are given in table 4.30. The worst carbon monoxide emission is from internal combustion diesel and fuel oil electricity generation, at about 349 megagrams per petajoule, followed by oil kilns and gas kilns, at about 75 megagrams per petajoule.

4.30 EMISSION FACTORS FOR STATIONARY SOURCES

	Emission factors				
	CO	CH_4	NOx	N_2O	NMVOC
Source/equipment	Mg/PJ	Mg/PJ	Mg/PJ	Mg/PJ	Mg/PJ
Electricity generation					
Natural gas — boilers	16	0.1	226.0	0.1	0.6
Gas turbine	46	8.0	190.0	0.1	2.4
Residual oil boilers	14	0.8	186.0	0.6	2.1
Distillate boilers	13	0.0	64.0	0.6	1.4
Internal combustion — diesel	349	4.0	1 322.0	0.6	45.0
Internal combustion — fuel oil	349	4.0	1 322.0	0.6	45.0
Internal combustion — natural gas	340	240.0	1 331.0	0.1	80.0
Other energy transformers and industrial equipment					
Residual oil-fired boilers	14	2.8	154.0	0.6	0.8
Natural gas-fired boilers	14	1.2	58.0	0.1	1.1
Natural gas — kilns	75	1.0	1 010.0	0.1	1.1
Oil — kilns	75	1.0	502.0	0.6	0.8
Natural gas — dryer	10	1.0	58.0	0.1	1.1
Oil — dryer	15	1.0	160.0	0.6	0.8
Commercial					
Gas boilers	9	1.1	41.0	0.1	2.2
Residual oil boilers	14	1.3	154.0	0.6	3.2
Distillate oil boilers	13	0.6	53.0	0.6	0.9
Residential					
LPG furnaces	8	0.8	67.0	0.1	1.6
Distillate oil furnaces	13	4.7	48.0	0.6	1.9
Gas heaters	16	1.6	39.0	0.1	3.1

Source: NGGIC 1996.

Transport sector emissions

The air pollutant and greenhouse gas emissions from the transport sector in 1993–94 are given in table 4.31. About 88% of total energy was used for domestic civil transport which was responsible for the majority of emissions. For example, 88% of carbon dioxide, 89% of methane, 97% of nitrous oxide, 80% of oxides of nitrogen, 98% of carbon monoxide, 96% of non-methane volatile organic compounds and 60% of sulphur dioxide were emitted by this sector. International marine transport contributed a significant proportion of sulphur dioxide emissions (38% of the total) from the use of fuel oil.

Within domestic civil transport in 1993–94, road transport contributed 89% of the total fuel consumption, followed by domestic air transport (6%), rail (2%) and marine (2%). Road transport contributed a large proportion of air pollutants and greenhouse gas emissions, with 88% of carbon dioxide, 87% of methane, 98% of nitrous oxide, 77% of oxides of nitrogen, 94% of carbon monoxide, 95% of non-methane volatile organic compounds and 54% of sulphur dioxide. Other transport sectors were relatively minor in the volume of emissions, except domestic marine with sulphur dioxide emissions accounting for 37% of the total.

4.31 AIR POLLUTANTS AND GREENHOUSE GASES EMISSIONS FROM TRANSPORT, 1993–94

		Emission type						
	Energy use	CO_2	CH_4	N_2O	NOx	CO	NMVOCs	SOx
Source	PJ	Gg	Gg	Gg	Gg	Gg	Gg	Gg
		DOMESTIC CIVIL TRANSPORT						
Domestic air								
Avgas	3.3	220.0	0.2	0.0	0.3	74.4	1.7	0.0
Avtur	52.2	3 604.0	0.5	0.1	27.7	5.8	1.8	0.7
Total domestic air	*55.5*	*3 824.0*	*0.7*	*0.1*	*28.0*	*80.2*	*3.5*	*0.7*
Road								
Passenger cars								
Petrol								
Post-1985	290.3	18 969.0	8.0	7.9	75.3	686.4	150.8	3.8
1976–1985	180.6	11 798.0	6.3	0.2	93.0	1 294.4	177.5	2.4
Pre-1976	29.8	1 950.0	1.8	0.0	16.9	344.9	47.3	0.4
Total petrol	*500.7*	*32 716.0*	*16.1*	*8.1*	*185.3*	*2 325.7*	*375.6*	*6.5*
ADO	22.9	1 580.0	0.0	0.0	4.3	4.5	2.2	1.9
LPG	31.2	1 833.0	0.7	0.1	14.9	165.8	13.0	0.3
NG	0.1	7.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	*554.9*	*36 137.0*	*16.8*	*8.2*	*204.5*	*2 496.0*	*390.8*	*8.7*
Light trucks								
Petrol	78.9	5 159.0	2.2	0.2	29.0	316.5	47.0	0.9
ADO	29.4	2 028.0	0.1	0.1	7.3	6.6	3.3	2.1
LPG	10.1	593.0	0.2	0.0	5.5	52.9	4.1	0.0
NG	0.1	8.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	*118.6*	*7 787.0*	*2.5*	*0.3*	*41.8*	*376.1*	*54.4*	*3.0*
Medium trucks								
Petrol	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ADO	23.1	1 592.0	0.6	0.1	35.1	22.5	4.5	1.9
LPG	0.3	16.0	0.0	0.0	0.2	1.2	0.2	0.0
NG	0.1	7.0	0.0	0.0	0.2	0.0	0.0	0.0
Total	*23.5*	*1 615.0*	*0.6*	*0.1*	*35.5*	*23.7*	*4.7*	*1.9*
Heavy trucks								
Petrol	0.2	15.0	0.0	0.0	0.1	0.7	0.1	0.0
ADO	118.5	8 176.0	0.4	0.1	25.8	305.9	16.7	9.8
LPG	0.2	12.0	0.0	0.0	0.1	1.1	0.1	0.0
NG	0.0	3.0	0.0	0.0	0.1	0.0	0.0	0.0
Total	*119.0*	*8 205.0*	*0.4*	*0.1*	*26.0*	*307.6*	*16.9*	*9.8*
Buses								
Petrol	0.4	26.0	0.0	0.0	0.3	3.3	0.4	0.0
ADO	16.8	1 160.0	0.0	0.0	7.1	4.2	2.3	1.4
LPG	0.1	6.0	0.0	0.0	0.1	0.7	0.1	0.0
NG	0.7	40.0	0.1	0.0	0.9	0.2	0.0	0.0
Total	*18.0*	*1 232.0*	*0.1*	*0.0*	*8.3*	*8.3*	*2.7*	*1.4*
Motorcycles								
Petrol	2.9	192.0	0.2	0.0	0.3	29.5	8.2	0.0
Total road	*836.9*	*55 168.0*	*20.7*	*8.7*	*316.3*	*3 241.2*	*477.6*	*25.4*

... continued

4.31 AIR POLLUTANTS AND GREENHOUSE GASES EMISSIONS FROM TRANSPORT, 1993–94 — *continued*

		Emission type						
	Energy use	*CO_2*	*CH_4*	*N_2O*	*NOx*	*CO*	*NMVOCs*	*SOx*
Source	PJ	Gg	Gg	Gg	Gg	Gg	Gg	Gg
DOMESTIC CIVIL TRANSPORT — *continued*								
Rail								
ADO	21.9	1 511.0	0.1	0.0	33.5	4.4	1.6	1.8
IDF	1.1	76.0	0.0	0.0	1.7	0.2	0.1	0.2
Total rail	*23.0*	*1 587.0*	*0.1*	*0.1*	*35.2*	*4.7*	*1.6*	*2.0*
Marine								
Petrol	6.0	389.0	2.1	0.0	1.5	120.8	19.3	0.1
ADO	1.2	83.0	0.0	0.0	1.3	0.3	0.1	0.1
IDF	0.6	43.0	0.0	0.0	1.0	0.1	0.0	0.1
Fuel Oil	12.4	907.0	0.0	0.0	24.9	0.6	0.8	16.8
NG	0.1	3.0	0.0	0.0	0.0	0.0	0.0	0.0
Total marine	*20.2*	*1 425.0*	*2.2*	*0.0*	*28.7*	*121.8*	*20.2*	*17.1*
Total domestic civil	*939.4*	*62 339.0*	*23.8*	*8.9*	*408.9*	*3 448.6*	*503.9*	*46.7*
INTERNATIONAL CIVIL TRANSPORT								
International air[1]								
Avtur	77.6	5 354.0	0.7	0.2	41.2	8.6	2.7	1.0
International sea								
ADO	3.4	233.0	0.0	0.0	5.3	0.6	0.2	0.3
IDF	1.7	115.0	0.0	0.0	2.6	0.3	0.1	0.3
Fuel oil	21.1	1 539.0	0.1	0.0	42.2	0.9	1.3	28.5
Total sea	*26.2*	*1 886.0*	*0.1*	*0.1*	*50.2*	*1.8*	*1.6*	*29.1*
Total International	*103.7*	*7 240.0*	*0.8*	*0.2*	*91.4*	*10.4*	*4.3*	*30.1*
MILITARY TRANSPORT								
Petrol	0.6	39.0	0.0	0.0	0.3	2.5	0.4	0.0
ADO	3.5	244.0	0.0	0.0	4.8	1.0	0.3	0.3
Avgas	0.1	8.0	0.0	0.0	0.0	2.7	0.1	0.0
Avtur	11.3	779.0	0.1	0.0	6.0	1.3	0.4	0.2
Total military	*15.5*	*1 070.0*	*0.2*	*0.0*	*11.1*	*7.5*	*1.1*	*0.5*
OTHER MOBILE ENGINES								
Recreational vehicles								
Petrol	0.6	39.0	0.0	0.0	0.2	4.2	0.6	0.0
Utility engines								
Petrol	4.8	311.0	1.8	0.0	0.4	61.9	16.4	0.1
Total other mobile	*5.4*	*350.0*	*1.8*	*0.0*	*0.6*	*66.1*	*17.1*	*0.1*
Total	**1 064.1**	**70 999.0**	**26.6**	**9.1**	**512.1**	**3 532.5**	**526.4**	**77.3**

[1] Fuels purchased in Australia.

Source: NGGIC 1996.

Fuel combustion emissions

Table 4.32 lists the emissions of air pollutants and greenhouse gases from energy-related fuel combustion sources in 1993–94. The emission data for years back to 1987–88 are available and the reader is referred to the original sources published by NGGIC (1996) for details.

4.32 ENERGY-RELATED AIR POLLUTANTS AND GREENHOUSE GASES FROM FUEL COMBUSTION EMISSION 1993–94 (EXCLUDING TRANSPORT)

Source category	*Energy use* PJ	CO_2 Gg	*CO* Gg	CH_4 Gg	NO_x Gg	N_2O Mg
		ENERGY INDUSTRY				
Electricity generation						
Public						
Petroleum	6.6	471.0	1.5	0.02	5.9	0.0
Gas	124.4	6 360.0	2.6	0.18	19.3	0.0
Private						
Petroleum	21.8	1 502.0	7.2	0.08	27.2	0.0
Gas	21.8	1 114.0	0.6	0.07	4.4	0.0
Subtotal electricity						
Petroleum	*28.4*	*1 972.0*	*8.6*	*0.10*	*33.1*	*0.0*
Gas	*146.2*	*7 474.0*	*3.2*	*0.26*	*23.7*	*0.0*
Petroleum refining						
Petroleum	84.6	5 743	4.3	0.1	29.0	0.1
Gas	10.7	547	0.5	0.01	6.4	0.0
Total	*95.3*	*6 291*	*4.8*	*0.11*	*35.4*	*0.1*
Solid fuel transformation and Other energy						
Petroleum	15.8	1 089.0	3.4	0.05	17.6	0.0
Gas	116.9	5 967.0	3.5	0.50	15.1	0.0
Total energy and transformation						
Petroleum	128.7	8 804.0	16.3	0.3	79.7	0.1
Gas	273.8	13 988.0	7.2	0.8	45.2	0.0
		GENERAL INDUSTRY				
Mining						
Petroleum	28.4	1 965.0	6.0	0.1	31.8	0.0
Gas	1.1	58.0	0.0	0.0	0.1	0.0
Iron and steel						
Petroleum	1.5	98.0	3.9	0.0	0.5	0.0
Gas	23.1	1 180.0	0.8	0.0	6.3	0.0
Food, beverages and tobacco						
Petroleum	6.6	429.0	11.0	0.1	1.6	0.0
Gas	26.0	1 325.0	0.4	0.0	1.1	0.0
Paper and paper products						
Petroleum	1.4	94.0	2.4	0.0	0.4	0.0
Gas	18.3	935.0	0.3	0.0	1.4	0.0
Chemicals						
Petroleum	30.4	1 887.0	3.6	0.1	13.4	0.0
Gas	34.9	1 938.0	2.3	0.1	26.0	0.0

... continued

4.32 ENERGY-RELATED AIR POLLUTANTS AND GREENHOUSE GASES FROM FUEL COMBUSTION EMISSION 1993–94 (EXCLUDING TRANSPORT) — *continued*

	Energy use	CO_2	*CO*	CH_4	*NOx*	N_2O
Source category	PJ	Gg	Gg	Gg	Gg	Mg
	GENERAL INDUSTRY — *continued*					
Non-ferrous metals						
Petroleum	35.2	2 515.0	6.8	0.1	15.1	0.0
Gas	109.3	5 581.0	4.3	0.1	48.8	0.0
Non-metallic mineral products						
Petroleum	4.8	313.0	8.9	0.04	2.3	0.0
Gas	52	2 655.0	3.6	0.05	48.6	0.0
Other manufacturing						
Petroleum	4.9	315.0	11.3	0.1	1.8	0.0
Gas	22.9	1 169.0	0.4	0.0	2.3	0.0
Construction						
Petroleum	42.5	2 933.0	16.6	0.2	42.7	0.0
Gas	0.3	13.0	0.0	0.0	0.0	0.0
Total industry						
Petroleum	155.7	10 547.0	70.5	0.7	109.6	0.1
Gas	287.9	14 854.0	12.1	0.3	134.6	0.0
	OTHER					
Commercial services						
Petroleum	13.7	863.0	0.5	0.0	1.6	0.0
Gas	40.4	2 067.0	0.3	0.0	1.7	0.0
Residential						
Petroleum	16.5	1 048.0	0.2	0.1	0.8	0.0
Gas	100.3	5 130.0	1.6	0.2	3.9	0.0
Agriculture, fishing and forestry						
Petroleum	53.1	3 657.0	25.0	0.5	68.6	0.0
Gas	0.1	3.0	0.0	0.0	0.0	0.0
Other industrial processes						
Petroleum	11.0	802.0	—	—	—	—
	TOTAL EMISSIONS					
Petroleum	**378.7**	**25 721.0**	**112.5**	**1.7**	**260.3**	**0.2**
Gas	**702.5**	**36 042.0**	**21.2**	**1.3**	**185.4**	**0.0**

Note: pnec — liquid products of petroleum which are not elsewhere classified.

Source: NGGIC 1996.

CHAPTER 5 COAL

Coal has been the highest ranking source of energy for some time. Compared with other energy forms, coal is relatively cheap, and easy to transport and use. In many countries, coal is the major fuel used in electricity generation, and is important in iron and steel making and other industrial processes. Australia has abundant coal resources, with many of them located conveniently close to the coast and population centres, and close to the surface so that they can be developed as open cut mines. A large part of Australia's coal production is exported.

BACKGROUND

Categories of coal

Coal is the family name for a variety of solid organic fuels, and refers to a whole range of combustible sedimentary rocks spanning a continuous scale. The classification of coal depends upon its chemical composition and thermal properties such as calorific value, volatile matter content, fixed carbon content, degree of dilution by moisture and ash, caking and coking properties. Two broad categories are internationally recognised (Organisation for Economic Cooperation and Development/International Energy Agency (OECD/IEA) 1992).

Hard coal

Coal having a gross calorific value greater than 23,865 kilojoules per kilogram (5,700 kilocalories per kilogram) on an ash-free but moist basis. Hard coal comprises two sub-categories:

- Coking coal — coal which can be used for the production of coke suitable to support a blast furnace charge (also called metallurgical coal).
- Steaming coal — other bituminous coal and anthracite (not included as coking coal) and used for steam raising and space heating.

Brown coal

Non-agglomerating coal having a gross calorific value less than 23,865 kilojoules per kilogram (5,700 kilocalories per kilogram) containing more than 31% volatile matter on a dry mineral matter-free basis. Brown coal is divided into two sub-categories:

- Sub-bituminous coal — coal with a gross calorific value between 17,435 kilojoules per kilogram (4,165 kilocalories per kilogram) and 23,865 kilojoules per kilogram (5,700 kilocalories per kilogram); and
- Lignite — coal with a gross calorific value less than 17,435 kilojoules per kilogram (4,165 kilocalories per kilogram).

In some countries such as Australia, New Zealand and United States, hard coal includes sub-bituminous coal because the latter has a relatively high calorific value. The other reason is to follow the traditional classification for coal in order to maintain the time series. Hard coal is also called black coal in Australia, and traditionally a majority of coal reserves in the States except Victoria are regarded as black coal. Victoria is the only State producing brown coal, with over 93% of Australia's brown coal reserves. Much smaller brown coal deposits are found in

Tasmania, South Australia and Western Australia, although there is currently no production.

Classification of coal resources and reserves

Coal resources are defined as all of the potentially usable coal in a defined area, which is, or could be processed to give a quality acceptable for commercial usage. Coal reserves are those parts of the coal resources for which sufficient information is available to enable detailed or conceptual mine planning and for which such planning has been undertaken. To assist assessment and calculation of coal resources in Australia, reliability categories are used based on the degree of assurance of the coal occurrence. Coal categories used here are based on the McKelvey Classification adopted by the Bureau of Resource Science. As location, quantity, and quality of the coal deposit become known from specific measurements or estimated from geological evidence, the resources are recognised as identified resources. Identified resources are further subdivided into measured, indicated and inferred resources.

For measured resources, the sites for inspection, drilling, sampling, and measurements are closely spaced. Tonnage is computed from dimensions revealed in outcrops, trenches, workings, and drill holes, and the quality is determined from the results of detailed sampling. The geological information on size, shape, and coal content allow for both a reliable estimate of the resources and the planning of their extraction.

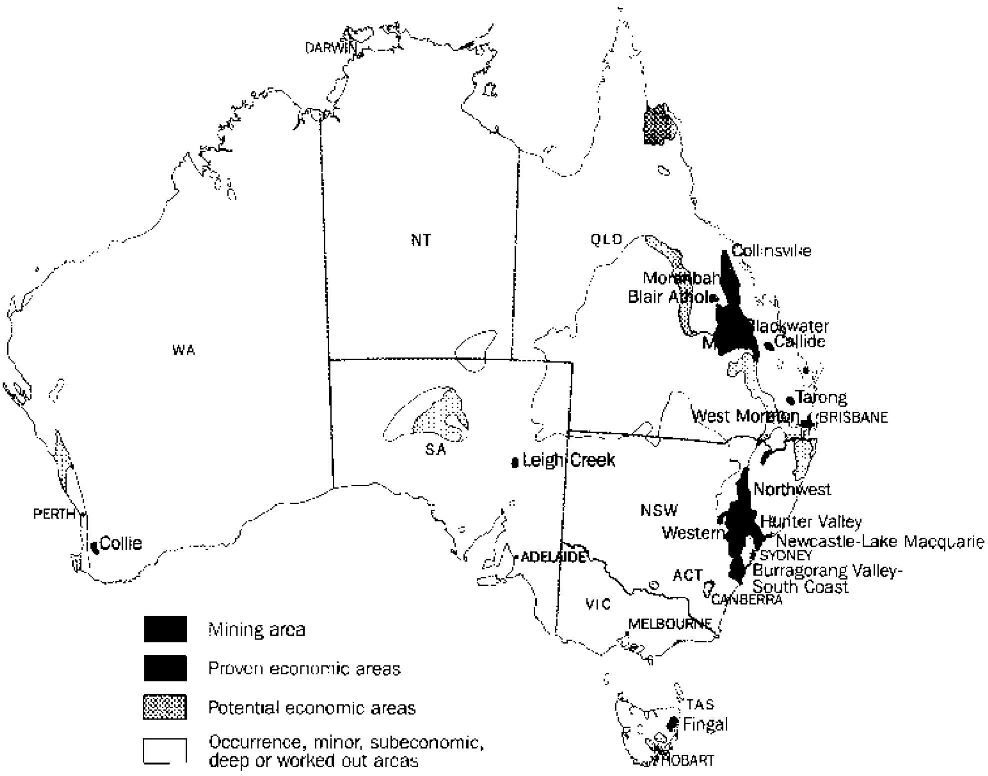
Indicated resources use assessment methods similar to those for measured resources to estimate tonnage and quality of coal but the sites for inspection, sampling and measurement are further apart. Geological information on indicated resources is sufficient to assume continuity between points of observation.

Where quantitative estimates of coal resources are obtained largely from broad knowledge of the geological character of the deposit, and where drilling samples and measurements are few, the coal deposit is regarded as an inferred resource.

The sum of measured and indicated resources is called demonstrated resources. Economic Demonstrated Resources (EDR) are coal resources that can be profitably extracted under defined investment assumptions. Sub-economic resources are coal resources that do not meet the criteria of economic resources. Recoverable coal resources have accounted for mining recovery factors such as rivers, dams, railway lines, lease boundaries, open cut slopes, pillars and geological faults.

Map 5.1 shows the identified black coal basins, producing areas and ports in Australia.

5.1 IDENTIFIED COAL RESOURCES



Source: AUSLIG.

Coal production, conversion and consumption in Australia

Australian coal production was initiated soon after European settlement. The discovery of high quality black coal in the Sydney Basin underpinned industrial development in the new colony. Coal mining was well established in New South Wales by the early 19th century and in Queensland by the 1870s. Other States, such as Tasmania, Western Australia and South Australia had built up a significant production capacity of black coal in the late 19th and early 20th centuries. Victoria's brown coal production had also been established in the same period.

Coal mining in Australia initially adopted traditional underground methods. The depth of underground mining is up to 600 metres which is regarded as the present economic limit. In more recent time, open cut mining technology has enabled modern equipment to operate at open cut depths far greater than previously possible. About 72% of Australian black coal is mined by open cut method. An effective infrastructure for black coal production has been established, particularly transport facilities which connect the coal mines to industrial centres and seaports. Australia is ranked as the sixth largest producer of black coal in the world, behind China, the United States, the former Soviet Union, India and South Africa.

Black coal was Australia's first export mineral product. Since 1965 Australian exports of black coal have expanded steadily due to a growth in world demand for black coal, particularly since the oil crises of the 1970s. At present Australia is the world's largest exporter of black coal, accounting for almost 28% of internationally traded coal in 1992. In recent years, black coal has overtaken wool as the country's most valuable export commodity and represents about 11% of the total merchandise exports.

Domestically, black and brown coal are the main energy forms used for electricity generation, and black coal is important to iron and steel production, metal treatment, and cement and paper manufacture. As in many countries, coal was the initial energy form used to generate electricity, and coal-fired power stations are still dominant in electricity generation, such that in New South Wales, about 94% of electricity is generated from coal, and Queensland and South Australia about 86%. A significant proportion of black coal resources are considered suitable as coking coals which are essential for the iron and steel industry.

STOCK ACCOUNTS FOR COAL

This section presents coal stock accounts for Australia. 'Stock' refers to coal resources remaining in the ground. In terms of the Australian Code for Reporting Identified Coal Resources and Reserves, the stock includes all of the potentially usable coal in a defined area, based on the results of detailed geological and engineering studies. However, it should be noted that a large proportion of coal resources are affected by other land uses, such as national parks, urban development and farming (Coal Resources Development Committee (CDRC) 1994).

Coal resources are reported here in the categories: economic demonstrated and sub-EDR, and inferred resources. Separate tables are also used to distinguish coal resources (in situ) and (recoverable). Coal resources (in situ) cover the total of measured and indicated resources. Recoverable resources are calculated according to recovery factors applied to the coal resources (in situ), and recovery factors depend on the mining method to be used (e.g. 50% for underground resources and 90% for open cut resources). Hence, recoverable resources are the expected proportion of the demonstrated resources to be extracted. Note that inferred black coal resources are not quantified here since the resources are very large in Australia (generally regarded as over 500,000 million tonnes).

The stock of coal changed considerably during the period from 1982–83 to 1993–94. Exploration drilling by government geological surveys and private companies have lead to the increase in recoverable resources. It should be noted that the total of resources reported in State accounts will not necessarily be equivalent to figures estimated on a national basis since the basis of estimation and definition are not exactly the same.

Black coal

The total identified black coal resources (not all of which are currently economic) are extensive. In the last decade, the world's black coal resources increased about 32% compared with the 1981 level. Australia also increased its estimated recoverable coal resources, while its share of world black coal rose from 6% to 8% as shown in table 5.2. Australia's black coal resources are mainly located in New South Wales (49%) and Queensland (48%) with small but locally significant black coal resources in Tasmania, Western Australia and South Australia.

5.2 AUSTRALIAN AND WORLD ECONOMIC DEMONSTRATED BLACK COAL RESOURCES (RECOVERABLE)

	Australia	*World*	*Australian share*
Year	Gt	Gt	%
1982–83	30.4	631	4.82
1983–84	31.0	631	4.91
1984–85	35.0	631	5.55
1985–86	34.0	631	5.39
1986–87	34.0	657	5.18
1987–88	49.5	654	7.57
1988–89	49.7	654	7.60
1989–90	50.8	654	7.77
1990–91	51.1	650	7.86
1991–92	51.4	650	7.91
1992–93	52.0	650	8.00
1993–94	49.0	642	7.63

Note: The data collection period ended at September each year.

Source: BRS 1996.

The estimates for EDR of black coal (in situ) are given in table 5.3. During the period of 1982–94, the stock increased about 30% from 52.9 gigatonnes to 69.0 gigatonnes. The 'adjustment' represents the net changes in stock, resulting both from production and upgrading the reserves. A significant change occurred in 1987 with 15.3 gigatonnes being added to the resources, which was caused by a major reassessment of New South Wales' coal resources.

5.3 STOCK ACCOUNT FOR BLACK COAL: ECONOMIC DEMONSTRATED RESOURCES (IN SITU)

Year	Opening stock Gt	Adjustment Gt	Closing stock Gt
1982–83	52.9	1.1	54.0
1983–84	54.0	0.0	54.0
1984–85	54.0	0.0	54.0
1985–86	54.0	1.0	55.0
1986–87	55.0	15.3	70.3
1987–88	70.3	0.0	70.3
1988–89	70.3	0.9	71.2
1989–90	71.2	-0.3	70.9
1990–91	70.9	0.6	71.5
1991–92	71.5	0.5	72.0
1992–93	72.0	–3.0	69.0
1993–94	69.0	0.0	69.0

Note: The data collection period ended at September each year.

Source: BRS 1996.

The EDR (recoverable) are shown in table 5.4. Recoverable black coal resources increased about 61% in the last twelve years from 30.4 gigatonnes to 49.0 gigatonnes. With total production of 2.2 gigatonnes, between 1982 and 1994, the net change in recoverable black coal resources was about 18.6 gigatonnes.

5.4 STOCK ACCOUNT FOR BLACK COAL: ECONOMIC DEMONSTRATED RESOURCES (RECOVERABLE)

Year	Opening stock Gt	Adjustment Gt	Production[1] Gt	Closing stock Gt	Net change Gt
1982–83	30.4	0.7	–0.1	31.0	0.6
1983–84	31.0	4.1	–0.1	35.0	4.0
1984–85	35.0	–0.9	–0.2	34.0	–1.0
1985–86	34.0	0.2	–0.2	34.0	0.0
1986–87	34.0	15.7	–0.2	49.5	15.5
1987–88	49.5	0.4	–0.2	49.7	0.2
1988–89	49.7	1.3	–0.2	50.8	1.1
1989–90	50.8	0.5	–0.2	51.1	0.3
1990–91	51.1	0.5	–0.2	51.4	0.3
1991–92	51.4	0.8	–0.2	52.0	0.6
1992–93	52.0	0.2	–0.2	52.0	0.0
1993–94	52.0	–2.8	–0.2	49.0	–3.0

[1] Raw coal production.
Note: This data collection period ended at September each year.

Source: BRS 1996.

Tables 5.3 and 5.4 indicate that coal production in Australia has large potential. At the current rate of production of 0.2 gigatonnes a year and with recoverable coal resources of 49.0 gigatonnes, black coal production could last for a further 245 years (if there were no land use constraints), even without further discovery and technological change, assuming prices remain high enough to make recovery economic.

Australia has limited sub-EDR of black coal as shown in tables 5.4 and 5.5. The coal in situ at 30 September 1994 was 7 gigatonnes and the recoverable amount was 5 gigatonnes, (a recovery rate of about 70%).

5.5 STOCK ACCOUNT FOR BLACK COAL: SUB-ECONOMIC DEMONSTRATED RESOURCES (IN SITU)

	Opening stock	*Adjustment*	*Closing stock*
Year	Gt	Gt	Gt
1982–83	0.00	3.00	3.00
1983–84	3.00	–1.00	2.00
1984–85	2.00	1.00	3.00
1985–86	3.00	0.00	3.00
1986–87	3.00	0.34	3.34
1987–88	3.34	0.00	3.34
1988–89	3.34	0.26	3.60
1989–90	3.60	2.70	6.30
1990–91	6.30	0.70	7.00
1991–92	7.00	0.00	7.00
1992–93	7.00	0.00	7.00
1993–94	7.00	0.00	7.00

Note: The data collection period ended at September each year.

Source: BRS 1996.

5.6 STOCK ACCOUNT FOR BLACK COAL: SUB-ECONOMIC DEMONSTRATED RESOURCES (RECOVERABLE)

	Opening stock	*Adjustment*	*Closing stock*
Year	Gt	Gt	Gt
1982–83	0.00	2.50	2.50
1983–84	2.50	–1.50	1.00
1984–85	1.00	0.00	1.00
1985–86	1.00	0.00	1.00
1986–87	1.00	1.02	2.02
1987–88	2.02	0.00	2.02
1988–89	2.02	–0.02	2.00
1989–90	2.00	1.90	3.90
1990–91	3.90	1.10	5.00
1991–92	5.00	0.00	5.00
1992–93	5.00	0.00	5.00
1993–94	5.00	0.00	5.00

Note: The data collection period ended at September each year.

Source: BRS 1996.

Brown coal Australia's brown coal resources are mainly located in Victoria and represent about 15.2% of the world total resources (table 5.7). Among the countries rich in brown coal, Australia is ranked fourth.

5.7 AUSTRALIAN AND WORLD ECONOMIC DEMONSTRATED BROWN COAL RESOURCES (RECOVERABLE)

	Australia	*World*	*Australian share*
Year	Gt	Gt	%
1982–83	36.2	254	14.3
1983–84	37.0	254	14.6
1984–85	41.9	254	16.5
1985–86	41.9	254	16.5
1986–87	41.9	238	17.6
1987–88	41.9	273	15.4
1988–89	41.8	273	15.3
1989–90	41.8	273	15.3
1990–91	41.7	270	15.4
1991–92	41.7	270	15.4
1992–93	41.0	270	15.2
1993–94	41.0	269	15.2

The data collection period ended at September each year.

Source: BRS 1996.

As shown in table 5.8, the stock of brown coal in 1982–83 was 39.3 gigatonnes in situ, and this figure increased to 46.0 gigatonnes in 1993–94. During this period, the significant changes occurred in 1982–83 and 1983–84, with 2.7 and 4.5 gigatonnes respectively being added to the account.

5.8 STOCK ACCOUNT FOR BROWN COAL: ECONOMIC DEMONSTRATED RESOURCES (IN SITU)

	Opening stock	*Adjustment*	*Closing stock*
Year	Gt	Gt	Gt
1982–83	39.3	2.7	42.0
1983–84	42.0	4.5	46.5
1984–85	46.5	0.0	46.5
1985–86	46.5	0.0	46.5
1986–87	46.5	0.0	46.5
1987–88	46.5	0.0	46.5
1988–89	46.5	–0.1	46.4
1989–90	46.4	0.0	46.4
1990–91	46.4	–0.1	46.3
1991–92	46.3	–0.3	46.0
1992–93	46.0	0.0	46.0
1993–94	46.0	0.0	46.0

Note: The data collection period ended at September each year.

Source: BRS 1996.

Table 5.9 presents the stock account for recoverable brown coal. Since 1984, Australian recoverable brown coal stocks have remained steady with only minor decline as a result of production. The remaining stock of brown coal in 1993–94 was 41 gigatonnes. At the current production rate of 50 million tonnes a year, the brown coal resources can support production for about 800 years if there were no land use constraints.

5.9 STOCK ACCOUNT FOR BROWN COAL: ECONOMIC DEMONSTRATED RESOURCES (RECOVERABLE)

	Opening stock	*Adjustment*	*Production*	*Closing stock*	*Net change*
Year	Gt	Gt	Gt	Gt	Gt
1982–83	36.2	0.84	–0.04	37.0	0.8
1983–84	37.0	4.94	–0.03	41.9	4.9
1984–85	41.9	0.04	–0.04	41.9	0.0
1985–86	41.9	0.04	–0.04	41.9	0.0
1986–87	41.9	0.04	–0.04	41.9	0.0
1987–88	41.9	–0.06	–0.04	41.8	–0.1
1988–89	41.8	0.05	–0.05	41.8	0.0
1989–90	41.8	–0.05	–0.05	41.7	–0.1
1990–91	41.7	0.05	–0.05	41.7	0.0
1991–92	41.7	–0.65	–0.05	41.0	–0.7
1992–93	41.0	0.05	–0.05	41.0	0.0
1993–94	41.0	0.05	–0.05	41.0	0.0

Note: The data collection period ended at September each year.

Source: BRS 1996.

As with black coal, Australia's sub-EDR of brown coal are very limited, as shown in tables 5.10 and 5.11. In 1993–94, the sub-economic demonstrated brown coal (in situ) was estimated at about 3.0 gigatonnes. Note that the estimates in 1983–84 reflect significant changes in classification and estimation methods.

5.10 STOCK ACCOUNT FOR BROWN COAL: SUB-ECONOMIC DEMONSTRATED RESOURCES (IN SITU)

	Opening stock	Adjustment	Closing stock
Year	Gt	Gt	Gt
1982–83	0.0	80.0	80.0
1983–84	80.0	-77.1	2.9
1984–85	2.9	0.0	2.9
1985–86	2.9	0.0	2.9
1986–87	2.9	0.0	2.9
1987–88	2.9	0.0	2.9
1988–89	2.9	0.7	3.6
1989–90	3.6	–0.3	3.3
1990–91	3.3	0.0	3.3
1991–92	3.3	–0.3	3.0
1992–93	3.0	0.0	3.0
1993–94	3.0	0.0	3.0

Note: The data collection period ended at September each year.

Source: BRS 1996.

5.11 STOCK ACCOUNT FOR BROWN COAL: SUB-ECONOMIC DEMONSTRATED RESOURCES (RECOVERABLE)

	Opening stock	Adjustment	Closing stock
Year	Gt	Gt	Gt
1982–83	0.0	71.0	71.0
1983–84	71.0	-70.0	1.0
1984–85	1.0	0.0	1.0
1985–86	1.0	0.0	1.0
1986–87	1.0	1.02	2.02
1987–88	2.02	0.0	2.02
1988–89	2.02	-0.02	2.0
1989–90	2.0	1.0	3.0
1990–91	3.0	0.1	3.1
1991–92	3.1	–0.1	3.0
1992–93	3.0	0.0	3.0
1993–94	3.0	0.0	3.0

Note: The data collection period ended at September each year.

Source: BRS 1996.

Australia's (in situ and recoverable) inferred brown coal resources are listed in table 5.12. During the period of 1982–94, the estimates of inferred resources doubled to 184 gigatonnes in situ. The large variations in the beginning of this period reflect changes in classification and estimation methods.

5.12 STOCK ACCOUNT FOR BROWN COAL: INFERRED RESOURCES (IN SITU)

Year	Opening stock Gt	Adjustment Gt	Closing stock Gt
1982–83	87.5	–75.5	12.0
1983–84	12.0	191.0	203.0
1984–85	203.0	0.0	203.0
1985–86	203.0	1.0	204.0
1986–87	204.0	0.0	204.0
1987–88	204.0	0.0	204.0
1988–89	204.0	0.0	204.0
1989–90	204.0	0.0	204.0
1990–91	204.0	–20.0	184.0
1991–92	184.0	0.0	184.0
1992–93	184.0	0.0	184.0
1993–94	184.0	0.0	184.0

Note: The data collection period ended at September each year.

Source: BRS 1996.

Effects of other land uses on coal resources

Australia has vast economic black and brown coal resources, sufficient to support coal production for hundreds of years. However, no account is taken of constraints in accessing these resources and their consequent availability for production.

In fact, a large proportion of coal resources are affected by other land uses, such as national parks, dams and water catchments, urban areas and farming. In New South Wales, the results of a recent investigation by CRDC (1994) show that many of the coal resources of high quality occur in areas which are under or near national parks, or where urban development is likely to take place. The coal mines affected by other land uses in New South Wales are given in table 5.13, and a summary of the coal resources in New South Wales is given in table 5.14.

5.13 COAL AFFECTED BY OTHER LAND USES IN NEW SOUTH WALES

Land use	Major seam mill. t	Minor seam mill. t	Total mill. t
	NEWCASTLE COALFIELD		
National park	190	100	290
Urban development	1 100	650	1 750
National features			
Infrastructure	160	30	190
Lake foreshores	675	450	1 125
Flood-prone land	300	550	850
Total	*2 425*	*1 780*	*4 205*
	HUNTER COALFIELD		
National park	12 000	6 700	18 700
Urban development	245	—	245
Infrastructure	185	—	185
Water storage	85	—	85
Prime agricultural land	3 500	—	3 500
Commonwealth land	3 200	—	3 200
Natural features	25	—	25
Total	*19 240*	*6 700*	*25 940*
	GUNNEDAH COALFIELD		
National park	1 000	1 000	2 000
Prime agricultural land	7 500	8 500	16 000
Total	*8 500*	*9 500*	*18 000*
	SOUTHERN COALFIELD		
National park	935	520	1 455
Infrastructure	550	210	760
Water storage	1 075	255	1 330
Commonwealth land	75	300	375
Natural features	140	25	165
Total	*2 775*	*1 310*	*4 085*
	WESTERN COALFIELD		
National park	11 410	11 230	22 640
	NEW SOUTH WALES		
National park	—	—	45 085
Urban development	—	—	1 995
Infrastructure	—	—	1 135
Water storage	—	—	2 165
Prime agricultural land	—	—	1 415
Commonwealth land	—	—	19 500
Natural features	—	—	3 575
Total	—	—	**74 870**

Source: CRDC 1994.

5.14 SUMMARY OF COAL IN NEW SOUTH WALES

Field	Total resource mill. t	Resource affected mill. t	Resource affected %
Newcastle	10 700	4 205	39
Hunter	61 100	25 940	42
Gunnedah	38 000	18 000	47
Southern	17 045	4 085	24
Western	29 963	22 640	76
Total	**156 808**	**74 870**	**48**

Source: CRDC 1994.

FLOW ACCOUNTS FOR COAL

Black coal

Table 5.15 presents the flow account for black coal (in petajoules) for the period 1982 to 1994. Since the early 1980s, more than half of the output of black coal produced in Australia each year has been exported. With the growth of coal production, the proportion of coal exported rose from 61% to 77%. Australia exports black coal to many countries (see table 5.16).

During the period 1982–94, domestic consumption of black coal increased by 30%. The major part of black coal used domestically was for energy conversion (about 89% to 90%).

Electricity generation is the largest consumer of black coal. In the early 1980s, 71% of black coal used domestically was converted into electricity. The consumption increased to 76% of the total in 1993–94 (914 petajoules). Black coal was also used for coke production. In 1994, an amount equivalent to 164 petajoules of black coal was used in coke ovens, representing about 14% of total domestic black coal uses.

The direct use of black coal as fuel in Australia is very limited, taking about 10% of the total domestic consumption, mainly in the cement and paper industries, (about 80% of the total in directly using black coal as fuel). Table 5.17 lists the details of consumption of black coal by industry.

5.15 FLOW ACCOUNT FOR BLACK COAL

	1982–83	1983–84	1984–85	1985–86	1986–87	1987–88	1988–89	1989–90	1990–91	1991–92	1992–93	1993–94
	PJ	PJ	PJ	PJ	PJ	PJ	PJ	PJ	PJ	PJ	PJ	PJ
SUPPLY												
Production	2 658.5	2 826.6	3 203.5	3 596.7	3 955.1	3 610.5	3 951.1	4 234.0	4 396.0	4 680.1	4 778.0	4 786.6
Export	–1 608.4	–1 913.9	–2 398.0	–2 558.7	–2 718.2	–2 910.4	–2 834.4	–2 965.6	–3 217.0	–3 502.2	–3 660.6	–3 668.1
Other[1]	–180.3	1.0	162.8	–56.6	–228.3	335.8	–9.2	–136.3	–37.7	–9.7	78.2	78.9
Total	*869.8*	*913.7*	*968.3*	*981.4*	*1 008.6*	*1 035.9*	*1 107.5*	*1 132.1*	*1 141.3*	*1 168.2*	*1 195.6*	*1 197.4*
CONVERSION												
Coke ovens	159.1	160.6	164.3	160.3	165.2	171.2	192.3	177.9	174.5	175.1	170.4	164.3
Gas manufacturing	0.2	0.1	—	—	—	—	—	—	—	—	—	—
Elec. generation	619.1	659.0	695.0	709.5	731.4	753.5	799.3	836.0	848.7	872.4	905.6	913.9
Total conversion	778.4	819.7	859.3	869.8	896.6	924.7	991.6	1 013.9	1 023.2	1 047.5	1 075.0	1 078.2
Net supply	*91.5*	*93.9*	*109.0*	*111.7*	*112.1*	*111.2*	*115.9*	*118.2*	*118.2*	*120.7*	*119.6*	*119.2*
END USE												
Mining	1.0	1.4	1.7	1.9	3.0	3.9	4.3	6.5	6.0	6.6	6.4	6.0
Iron and steel	5.6	6.9	10.0	8.3	9.3	8.8	8.8	8.2	9.3	10.7	9.5	8.2
Chemical	3.3	3.4	3.5	3.7	3.5	3.5	3.3	3.1	3.1	3.4	3.0	3.1
Other industry	75.7	73.8	85.6	89.8	87.9	87.0	91.3	92.9	92.3	93.2	94.2	95.6
Rail transport	0.1	—	—	—	—	0.1	0.1	—	—	—	—	—
Water transport	0.7	3.6	3.3	3.3	3.8	3.5	3.9	3.5	3.7	4.0	4.1	3.8
Commercial	4.3	4.3	4.3	4.2	4.1	3.9	3.9	3.8	3.4	2.7	2.3	2.3
Residential	0.7	0.6	0.6	0.5	0.5	0.4	0.3	0.3	0.3	0.1	0.1	0.1
Consumption	*91.5*	*93.9*	*109.0*	*111.7*	*112.1*	*111.2*	*115.9*	*118.2*	*118.1*	*120.7*	*119.6*	*119.2*

[1] Stock changes and discrepancies.

Source: ABARE 1995.

5.16 COAL EXPORTS, SELECTED COUNTRIES

	1993–94			1994–95		
	Quantity	*Value*	*Av. value*	*Quantity*	*Value*	*Av. value*
Country	'000 t	$A'000	$A/t	'000 t	$A'000	$A/t
Japan	61 391	3 385 266	55.14	65 057	3 225 103	49.57
China	558	37 285	66.82	1 357	56 449	41.60
Korea, Republic of	16 496	929 554	56.35	17 339	880 008	50.75
India	7 693	486 797	63.28	8 907	537 316	60.33
Taiwan	8 314	433 364	52.12	8 356	399 548	47.82
Belgium/Luxembourg	2 398	133 491	55.67	3 025	156 645	51.78
Brazil	4 239	243 081	57.34	3 654	198 103	54.22
France	2 816	170 062	60.39	2 978	161 669	54.29
Italy	2 862	168 478	58.87	2 807	143 776	51.22
United Kingdom	3 798	230 679	60.74	3 469	197 103	56.82
Turkey	1 694	105 767	62.44	2 039	112 816	55.33
Total	**129 055**	**7 161 907**	**55.49**	**136 236**	**6 871 968**	**50.44**

Source: ABS Trade Fastraccs.

Brown coal

Brown coal product is mostly used in the domestic market due to storage and transport difficulties. When exposed to the atmosphere brown coal can deteriorate rapidly and may even ignite spontaneously. Therefore brown coal is not suitable to be stored or transported over long distances. However, after industrial processing to make briquettes, brown coal can be transported and shipped.

Table 5.18 presents the flow account for brown coal. In the past 12 years, brown coal production rose by 48%. Most brown coal was used for electricity generation in Victoria. In 1982–83, 94% of the total brown coal produced was converted into electricity. By 1993–94, this proportion increased to 97% whilst the use of brown coal for briquette production fell in the period from 5% of the total brown coal produced to about 3%.

5.17 BLACK COAL CONSUMPTION (INCLUDING CONVERSION) BY INDUSTRY

	1982–83	1983–84	1984–85	1985–86	1986–87	1987–88	1988–89	1989–90	1990–91	1991–92	1992–93	1993–94
	PJ	PJ	PJ	PJ	PJ	PJ	PJ	PJ	PJ	PJ	PJ	PJ
Mining												
Total	*1.0*	*1.4*	*1.7*	*1.9*	*3.0*	*4.0*	*4.3*	*6.5*	*6.0*	*6.5*	*6.6*	*6.0*
Manufacturing												
Food, beverages and tobacco	8.1	9.0	9.0	10.0	9.7	9.8	9.9	9.9	11.3	10.9	10.0	10.1
Textiles, clothing, footwear	0.5	0.5	0.7	0.7	0.7	0.7	0.6	0.7	0.7	0.6	0.6	0.6
Wood and wood products included in total	—	—		—	—	—		—	—	—	—	—
Paper and paper products	8.3	7.9	8.0	8.3	8.5	8.7	8.6	8.3	8.3	7.5	7.2	7.3
Chemicals, petroleum, coal products	3.3	3.4	3.5	3.7	3.5	3.5	3.3	3.1	3.1	3.4	3.0	3.1
Non-metallic mineral products	24.0	20.4	23.7	23.7	18.1	17.4	20.6	23.0	21.1	20.4	21.1	22.4
Basic metal products	198.1	202.0	217.1	214.5	224.1	229.1	251.3	235.9	233.9	239.0	234.5	227.2
Fabricated metal products	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	—	—		—
Transport equipment included in total	—	—	—	—	—	—	—		—	—	—	—
Other machinery and equipment	0.4	0.3	0.3	0.2	0.2	0.2	0.1	0.1	0.0	—	—	—
Miscellaneous manufacturing	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.2	0.2	0.1	0.1
Total	*243.7*	*244.7*	*263.5*	*262.1*	*264.0*	*270.5*	*295.7*	*282.1*	*279.2*	*282.5*	*277.1*	*271.3*
Electricity, gas and water												
Public electricity generation	608.3	648.7	684.6	698.9	720.0	742.0	787.5	824.4	835.1	859.1	892.1	902.0
Private electricity generation	10.8	10.3	10.4	10.6	11.4	11.5	11.8	11.9	13.6	12.9	13.5	11.9
Gas production and distribution	0.2	0.1	—	—		—	—	—		—	—	—
Total	*619.3*	*659.1*	*695.0*	*709.5*	*731.4*	*753.5*	*799.3*	*836.3*	*848.7*	*872.4*	*905.6*	*913.9*
Transport and storage												
Railway transport	0.1		—	—	—	0.1	0.1	—	—	—	—	—
Water transport	3.3	3.3	3.8	3.5	3.9	3.5	3.7	4.0	4.1	3.8	—	—
Total	*0.8*	*3.6*	*3.3*	*3.3*	*3.8*	*3.6*	*4.0*	*3.5*	*3.7*	*4.0*	*4.1*	*3.8*
Commercial services												
Total	*4.4*	*4.3*	*4.4*	*4.2*	*4.1*	*4.0*	*3.9*	*3.8*	*3.4*	*2.7*	*2.3*	*2.4*
Residential												
Total	*0.7*	*0.6*	*0.6*	*0.5*	*0.5*	*0.4*	*0.3*	*0.3*	*0.3*	*0.1*	*0.1*	*0.1*
Total	**869.8**	**913.7**	**968.4**	**981.4**	**1 008.7**	**1 035.9**	**1 107.6**	**1 132.4**	**1 141.3**	**1 168.2**	**1 195.6**	**1 197.4**

Source: ABARE 1995.

5.18 FLOW ACCOUNT FOR BROWN COAL

	Supply		Conversion to				End use		
	Production	Total	Briquetting	Electricity generation	Total consumption	Net supply	Chemical	Other industry	Consumption
Year	PJ	PJ	PJ	PJ	PJ	PJ	PJ	PJ	PJ
1982–83	329.4	329.4	17.0	308.7	325.7	3.8	—	3.8	3.8
1983–84	316.5	316.5	17.2	295.7	312.9	3.6	—	3.6	3.6
1984–85	369.2	369.2	18.5	347.3	365.8	3.4	—	3.4	3.4
1985–86	350.1	350.1	18.8	327.8	346.6	3.5	—	3.5	3.5
1986–87	405.0	405.0	18.3	383.6	401.9	3.2	—	3.2	3.2
1987–88	424.9	424.9	18.0	403.3	421.3	3.6	0.2	3.4	3.6
1988–89	474.8	474.8	15.8	457.0	472.8	2.1	0.1	2.0	2.1
1989–90	450.7	450.7	15.8	434.1	449.9	0.8	0.3	0.5	0.8
1990–91	484.1	484.1	16.0	467.6	483.6	0.5	0.1	0.4	0.5
1991–92	497.3	497.3	17.9	478.9	496.8	0.5	—	0.5	0.5
1992–93	466.8	466.8	11.4	455.0	466.4	0.5	—	0.5	0.5
1993–94	486.8	486.8	13.1	473.2	486.3	0.5	—	0.5	0.5

Source: ABARE 1995.

Coke

Coke is a product of black coal and is produced by a conversion process. In 1993–94, 164 petajoules equivalent of black coal was used for coking production (see table 5.15). The produced coke was about 108 petajoules as shown in table 5.19, about a 66% conversion rate. Between 1982–94, the export of coke increased from 0.1 petajoules to 14.3 petajoules.

A large amount of coke was used in blast furnaces in conversion process, accounting for over 92% of domestic consumption in 1993–94 as shown in table 5.19. The iron and steel industry used a small amount of coke as fuel and this is shown in the end use category.

5.19 FLOW ACCOUNTS FOR COKE

	Supply				Conversion			End use				
Year	Production	Exports	Other[1]	Total	Other conversion	Total	Net supply	Mining	Iron and steel	Chemical	Other industry	Consumption
	PJ	PJ	PJ	PJ	PJ	PJ	PJ	PJ	PJ	PJ	PJ	PJ
1982–83	99.3	–0.1	–2.3	96.9	88.3	88.3	8.6	0.5	2.0	1.1	5.1	8.6
1983–84	97.8	–0.4	–1.9	95.5	85.9	85.9	9.6	0.1	3.2	1.1	5.1	9.6
1984–85	97.3	–0.3	–2.0	95.0	84.8	84.8	10.2	0.1	4.0	0.9	5.1	10.2
1985–86	101.9	–5.9	–6.5	89.5	80.0	80.0	9.5	0.2	3.7	0.8	4.7	9.5
1986–87	97.2	–4.6	–6.2	86.4	76.9	76.9	9.5	0.4	2.6	0.8	5.7	9.5
1987–88	110.2	–22.1	–5.6	82.5	73.3	73.3	9.2	0.2	3.3	0.8	4.9	9.2
1988–89	119.3	–26.5	–6.5	86.3	77.2	77.2	9.1	0.3	3.2	0.8	4.8	9.1
1989–90	121.4	–15.5	7.9	113.8	105.8	105.8	8.0	0.3	2.6	—	5.1	8.1
1990–91	114.3	–22.6	21.3	113.0	105.5	105.5	7.6	0.2	2.3	—	5.0	7.6
1991–92	114.8	–19.6	0.8	96.0	87.1	87.1	8.9	0.2	3.1	—	5.5	8.9
1992–93	110.7	–16.2	–0.9	93.6	85.5	85.5	8.1	0.2	2.7	—	5.2	8.1
1993–94	107.8	–14.3	2.9	96.4	88.3	88.3	8.1	0.2	2.4	—	5.5	8.1

[1] Stock changes and discrepancies.

Source: ABARE 1995.

Briquettes Briquettes are produced from brown coal. Unlike coke, briquette production maintains over 98% of the energy component from brown coal. In 1993–94, 13.1 petajoules of brown coal was used (see table 5.18) and 12.8 petajoules briquettes were produced (see table 5.20).

Domestic demand for briquettes for electricity generation fell markedly during the period such that in 1993–94 only 1.3 petajoules was used (12% of the total). Manufacturing was the major consumer of briquettes (consumed 4.1 petajoules in 1993–94). Residential use was 0.2 petajoules of briquettes this year, only 29% of the use in 1982–83.

Coal by-products Coal by-products arise from different sources, such as coke ovens, blast furnaces, and other conversion processes. Following the decline of the demand for coke production, the supply of coal by-products has also been decreased (see table 5.21).

RESIDUAL ACCOUNTS FOR COAL

Historically, smog from coal combustion has caused severe problems. Although there have been significant improvements in technology, coal burning is still regarded as one of the major sources of environmental pollution. A range of pollutants can be identified from the smoke, such as carbon monoxide; sulphur dioxide; oxides of nitrogen, suspended particulates and dust. Some major greenhouse gases such as carbon dioxide and methane are associated with the combustion of coal.

Air pollutant emissions from coal burning depend upon the chemical content and physical status of the coal, and the burning conditions. Estimates of air pollutants and greenhouse gas emissions are generally based on emission factors and the tonnage of coal used. Table 5.22 lists the emissions of major air pollutants and greenhouse gases in 1993–94. The focus is on carbon dioxide, methane, nitrous oxide, oxide of nitrogen and carbon monoxide, for energy use in most sectors other than transport. For information regarding methodological issues, the reader should refer to the Workbooks 1.1–8.1, National Greenhouse Inventory Committee, 1996.

Examining the impact of use of coal, emissions of carbon dioxide rose 4% during 1989–90 to 1993–94, from 143 million tonnes to 149 million tonnes, in line with the rise in coal consumption of 4.8%. Carbon monoxide emissions decreased from 47,400 tonnes to 44,800 tonnes (5%), methane rose 7%, nitrous oxide rose 7% and oxides of nitrogen rose 4%. Most emissions came from the energy industry, particularly from electricity generation.

During the mining process, some greenhouse gases and air pollutants can also escape, (termed 'fugitive emissions'). Methane gas escapes during coal mining. Fugitive emissions are given in table 5.23. Methane emissions remained about 758 kilotonnes during the period 1989–90 to 1993–94.

5.20 FLOW ACCOUNT FOR BRIQUETTES

	Supply				Conversion				End use				
	Production	Exports	Other[1]	Total	Electricity generation	Other conversion	Total conversion	Net supply	Chemical	Other industry	Commercial	Residential	Consumption
Year	PJ	PJ	PJ	PJ	PJ	PJ	PJ	PJ	PJ	PJ	PJ	PJ	PJ
1982–83	16.6	–1.0	–0.5	15.1	4.7	0.1	4.8	10.3	2.9	4.9	1.8	0.7	10.3
1983–84	16.9	–1.2	1.2	16.9	6.6	0.1	6.7	10.2	2.5	5.1	1.9	0.6	10.2
1984–85	17.9	–1.0	–0.8	16.1	4.9	0.1	5.0	11.1	3.6	5.2	1.8	0.5	11.1
1985–86	18.8	–1.4	–0.7	16.7	3.9	0.1	4.0	12.7	4.6	5.8	1.8	0.4	12.7
1986 87	18.3	–1.2	0.5	17.6	5.3	0.1	5.4	12.2	4.1	5.8	1.8	0.4	12.2
1987 88	18.0	–1.7	–0.3	16	3.8	0.1	3.9	12.1	4.1	5.8	1.9	0.3	12.1
1988 89	15.7	0.5	0.00	15.2	3.3	0.1	3.4	11.8	3.7	5.9	1.9	0.3	11.8
1989–90	15.6	–0.7	0.9	15.8	3	0.1	3.1	12.7	4.2	6.4	1.9	0.3	12.7
1990–91	15.8	–1.0	–0.5	14.3	1.9	0.1	2.0	10.3	4.1	6.1	1.9	0.2	12.3
1991–92	15.9	–1.8	–3.6	10.5	2.0	—	2.0	10.3	3.3	5.0	1.8	0.2	10.3
1992–93	11.4	–1.3	1.0	11.1	1.4	—	1.4	9.7	3.0	4.9	1.7	0.2	9.7
1993–94	12.8	1.5	0.6	10.7	1.3	—	1.3	9.4	3.4	4.1	1.7	0.2	9.4

[1] Stock changes and discrepancies.

Source: ABARE 1995.

5.21 FLOW ACCOUNTS FOR COAL BY-PRODUCTS

	Supply			Conversion		End use				
Year	Coke ovens	Others[1]	Total	Electricity generation	Net supply	Mining	Iron and steel	Chemical	Other industry	Consumption
	PJ	PJ	PJ	PJ	PJ	PJ	PJ	PJ	PJ	PJ
1982–83	22.2	30.9	53.1	—	53.0	0.2	43.9	8.9	—	53.0
1983–84	20.4	31.0	51.4	—	51.4	0.7	42.7	8.0	—	51.4
1984–85	20.5	30.4	50.9	—	51.0	1.1	41.5	8.4	—	51.0
1985–86	19.5	32.6	52.1	0.4	51.8	1.0	44.3	6.5	—	51.8
1986–87	19.7	32.6	52.3	0.3	51.9	1.0	44.5	6.6	0.1	51.9
1987–88	22.3	28.6	50.9	0.5	50.4	1.3	41.4	7.7	—	50.4
1988–89	23.3	30.0	53.3	0.5	52.8	1.5	43.2	8.1	—	52.8
1989–90	27.6	25.0	52.6	0.5	52.2	1.6	42.7	7.9	—	52.2
1990–91	25.2	26.4	51.6	0.5	51.1	1.8	41.6	7.8	0.1	51.1
1991–92	28.1	22.1	50.2	0.5	49.7	1.8	40.5	7.4	0.1	49.7
1992–93	28.8	22.6	51.4	0.5	50.9	1.9	40.5	8.5	—	50.9
1993–94	28.3	23.2	51.5	0.5	51.1	2.0	42.0	7.1	—	51.1

[1] Include conversion of coke in blast furnace, blast furnace gas manufacture.

Source: ABARE 1995.

5.22 ENERGY-RELATED AIR POLLUTANTS AND GREENHOUSE GASES FROM FUEL COMBUSTION EMISSIONS

Source category	Energy use PJ	CO_2 '000 t	CO '000 t	CH_4 t	NO_x '000 t	N_2O t
Energy						
Electricity generation						
Public						
Black coal	886.8	80 494	9.9	790.0	286.6	720.0
Brown coal incl. briquettes	457.5	43 293	8.2	220.0	58.9	630.0
Private						
Black coal	12.4	1 064	0.1	10.0	3.7	10.0
Brown coal incl. briquettes	16.9	1 461	0.2	20.0	5.2	20.0
Total	*1 373.6*	*126 312*	*18.3*	*1 040.0*	*354.5*	*1 390.0*
Coke Ovens						
Coal	28.2	1 724	2.0	20.0	9.7	10.0
Briquetting						
Coal	0.3	22	0.0	37.0	100.0	0.0
Total	*1 402.0*	*128 058*	*20.4*	*1 060.0*	*364.2*	*1 400.0*
Industry						
Mining						
Coal	8.3	634	0.7	10.0	2.2	10.0
Iron and steel						
Coal	117.1	9 135	8.9	100.0	41.5	60.0
Food, beverages and tobacco						
Coal	13.5	1 239	1.4	20.0	2.4	10.0
Paper and paper products						
Coal	7.3	647	0.8	10.0	1.7	10.0
Chemicals						
Coal	7.1	621	1.4	20.0	2.5	10.0
Non-ferrous metals						
Coal	60.1	5 453	6.2	70.0	19.3	50.0
Other manufacturing						
Coal	24.9	2 211	2.0	20.0	11.2	20.0
Transport						
Coal	3.8	335	12.8	100	0.7	0.0
Commercial and services						
Coal	4.1	386	0.5	10.0	0.9	0.0
Residential						
Coal	0.3	28	1.7	30.0	0.1	0.0
Total	*246.5*	*20 691*	*24.4*	*400.0*	*82.6*	*200.0*
Total emissions	**1 648.5**	**148 749**	**44.8**	**1 500.0**	**446.8**	**1 600.0**

Source: NGGIC 1996.

5.23 ENERGY-RELATED AIR POLLUTANTS AND GREENHOUSE GASES FROM FUGITIVE EMISSIONS IN COAL MINING, 1993–94

	Energy use	CH_4
Source category	mill. t	t
Surface mining		
Surface activities	153.3	199.1
Underground mines		
Class A	33.2	546.2
Class B	24.5	13.2
Total	57.7	559.4
Total	**211.0**	**758.6**

Source: NGGIC 1996.

CHAPTER 6 ELECTRICITY

Electricity is a derived energy source obtained by converting other energy forms such as fossil and nuclear fuels, hydro, solar, and wind sources. However, electricity provides the major form of energy actually used in industrial and domestic applications. In energy accounting, it represents a large part of end use of energy produced.

The sections of the chapter provide general information on electricity generation and distribution in Australia; the stock accounts, which cover the hydro-electricity potential, and thermal and hydro plants installed; the flow accounts cover the total electricity supply and consumption; and a short discussion of the environmental aspects.

BACKGROUND

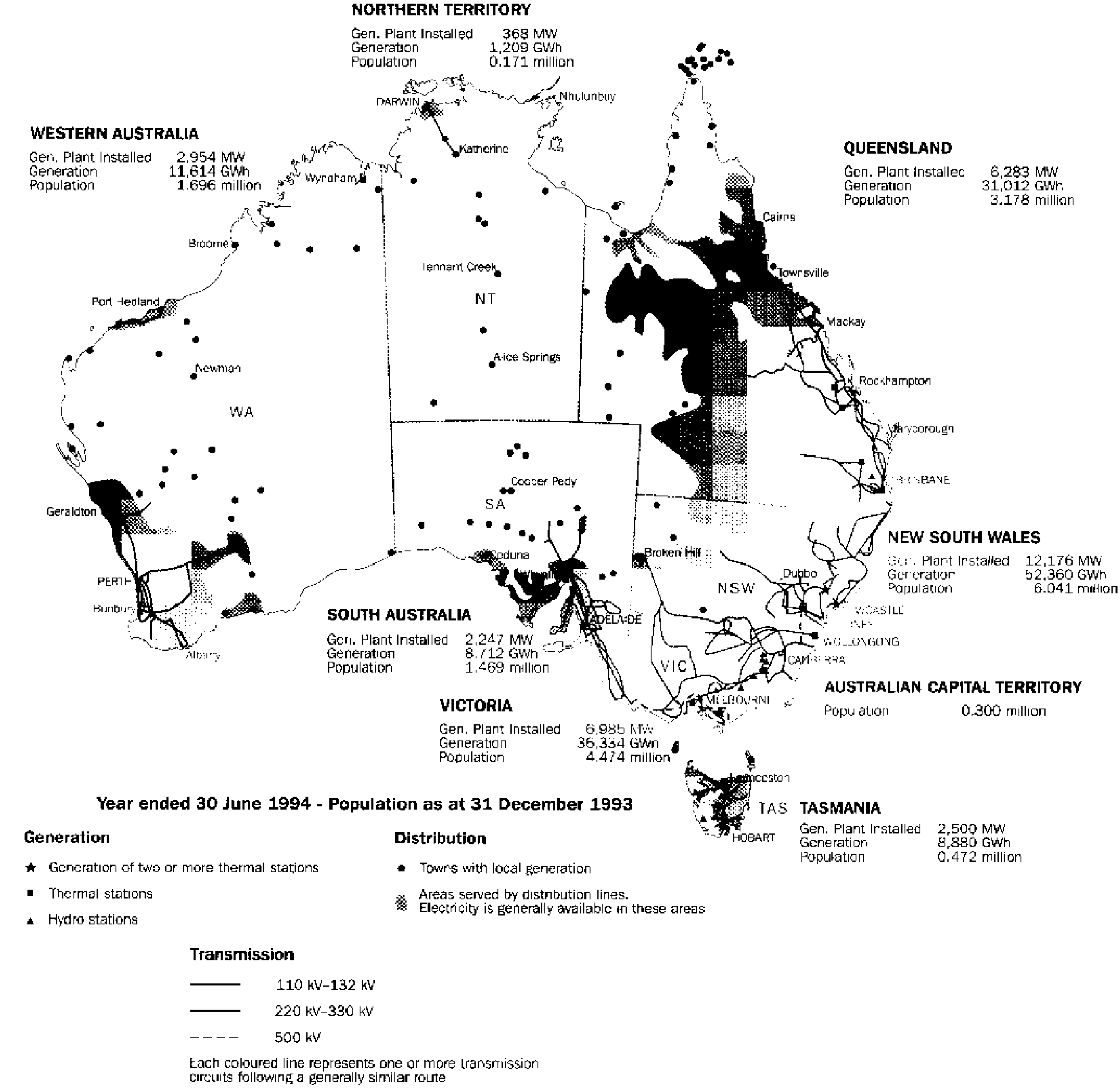
Electricity generation uses a great diversity of technology depending on the primary energy form used. The type of power station installed in a country is subject to the available energy resources, economic viability, and environmental consideration. In Australia, for public electricity supply in 1994–95, about 90% of electricity is generated from fossil fuels with about 10% being produced by hydro power stations. Wind farm electrical generation which is still very minor, produced 4.2 million kilowatt hours. Coal-fired power stations contribute the major part of electricity generation since Australia has vast coal resources available and the price of coal gives this fuel source a competitive advantage.

At 30 June 1994, the total installed generating capacity of plants was 39.8 gigawatts, of which 94% (37.3 gigawatts) was installed for the public supply of electricity and about 6% (2.5 gigawatts) was installed by private organisations for their own use. (The statistics exclude some mining and business private electricity generation due to data limitations.) In public electricity supply, New South Wales has about 33% of the installed capacity, Victoria about 19%, Queensland about 17%, South Australia about 6%, Western Australia about 8%, Tasmania about 7% and Northern Territory less than 1%. The remaining 10% was located in the Snowy Mountains Scheme.

For public thermal electricity stations, in 1993–94 black coal accounted for about 62% of fuels consumed (in energy units) and brown coal 28%. Natural gas accounted for about 9% of fuel used in public electricity generation and oil was less than 1%. There was very minor use of brown coal briquettes to generate electricity.

Map 6.1 shows the distribution of public electricity supply in Australia. The public electricity supply is provided by five grouped thermal stations (two or more), 12 thermal and 14 hydro power stations with capacity of 100 megawatts or more. The figure also indicates the location of towns with local generation facilities.

6.1 PUBLIC ELECTRICITY SUPPLY DISTRIBUTION, YEAR ENDED 30 JUNE 1994



Source: ESAA 1995.

STOCK (POTENTIAL) ACCOUNTS FOR ELECTRICITY

This section provides the accounts for electricity generation potential by both hydro and thermal power stations. The former depends upon water resources and climatic conditions, and the latter is mainly subject to electricity demand and economics, as well as environmental considerations.

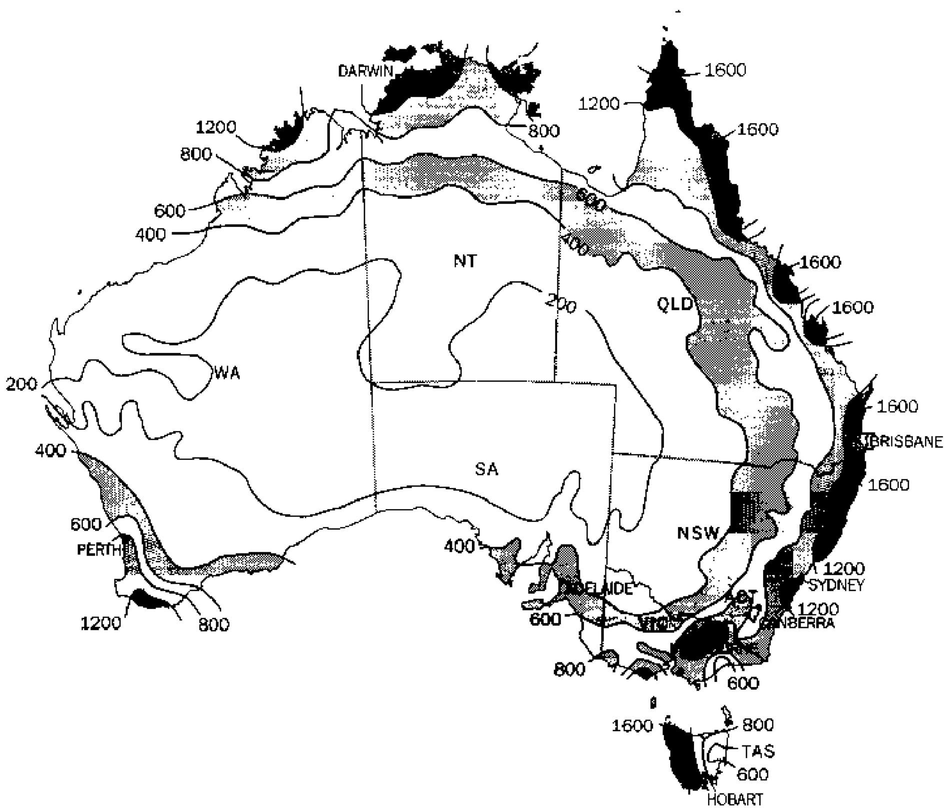
Water resources for electricity generation

There is a long history of harnessing water power for various purposes. Water power has been used for centuries to drive grinding mills, pumps and other machinery.

Hydro-electricity generation requires rivers and lakes with adequate flow of water so that dams can be constructed for storing water. When the water is released down tunnels or pipes, the stored energy drives turbines which are coupled to generators to produce electricity.

Adequate water resources depend on a reliable rainfall. Map 6.2 shows the median annual rainfall in Australia, and it indicates that large parts of Western Australia, South Australia and Northern Territory have less than 300 millimetres annual median rainfall. By contrast, most coastal areas have a great deal of rainfall. Table 6.3 presents the distribution of median annual rainfall as a percentage of total area.

6.2 ANNUAL MEDIAN RAINFALL



Source: AUSLIG.

6.3 DISTRIBUTION OF MEDIAN ANNUAL RAINFALL

							Proportion of total area	
	NSW[1]	*Vic.*	*Qld*	*SA*	*WA*	*Tas.*	*NT*	*Aust.*
Median annual rainfall	%	%	%	%	%	%	%	%
Under 200 mm	8.0	. .	10.2	74.2	43.5	. .	15.5	29.6
200–300 mm	20.3	6.3	13.0	13.5	29.6	. .	35.6	22.9
300–400 mm	19.0	19.2	12.3	6.8	10.5	. .	9.0	11.2
400–500 mm	12.4	11.8	13.5	3.2	4.3	. .	6.6	7.6
500 600 mm	11.3	14.1	11.6	1.8	3.1	12.2	5.8	6.6
600–800 mm	15.1	24.5	20.5	0.5	4.6	18.2	11.6	10.7
800–1,200 mm	11.3	17.7	12.6	. .	3.7	25.0	9.6	7.7
Above 1,200 mm	2.6	6.4	6.3	. .	0.7	44.6	6.3	3.7
Total	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**

[1] Includes Australian Capital Territory.

Source: ABS 1992.

To illustrate hydro energy potential for electricity generation in Australia, an example is selected from the Snowy Mountains hydro-electric stations. In 1993, there were 671 gigalitres of water (net diversion) taken from Lake Eucumbene to the Tumut River, and 424 gigalitres of water were taken from Lake Jindabyne to Geehi Reservoir. Water taken back from the Murray Development to Lake Eucumbene was 105 gigalitres (net diversion). Total usable water storage of the main reservoirs at 30 June 1993 was 3,453 gigalitres (Snowy Mountains Hydro-Electricity Authority (SMHEA) 1993) which was 65% of the active stage capacity of the scheme. Table 6.4 lists the main water storages in 1993. Water releases and inflows are given in tables 6.5 and 6.6 respectively. The average equivalent power generated by water resources in gigalitres is shown in table 6.7. The electricity generated from the Snowy Mountains hydro power stations is given in table 6.8.

6.4 MAIN RESERVOIR WATER STORAGES IN 1993

	Active capacity	*Active storage*	*Change over the year*
Reservoir	GL	GL	GL
Eucumbene	4 367	3 187	7
Jindabyne	389	60	–10
Tantangara	239	6	–20
Talbingo	190	155	2
Blowering	1 607	1 174	76

Source: SMHEA 1993.

6.5 WATER RELEASES

	1990–91	1991–92	1992–93
	GL	GL	GL
WATER RELEASES FROM HEADWORKS STORAGES			
To Murray River from Murray 1	1 278	1 340	1 611
To Murrumbidgee River from Tumut 1	1 412	1 134	1 539
WATER RELEASES FROM THE SNOWY MOUNTAINS HYDRO-ELECTRIC SCHEME			
To Murray River from Khancoban Pondage	1 851	1 726	2 124
To Murrumbidgee River from Jounama Pondage	1 945	1 595	2 257

Source: SMHEA 1993.

6.6 INFLOWS

	Proportion of the long-term average inflow					
	1987–88	*1988–89*	*1989–90*	*1990–91*	*1991–92*	*1992–93*
	%	%	%	%	%	%
Murray Development	65	118	87	102	107	120
Tumut Development	66	117	81	107	108	137
Total	65	117	84	105	107	130

Source: SMHEA 1993.

6.7 WATER UTILISATION

	1990–91	1991–92	1992–93
	GWh/GL	GWh/GL	GWh/GL
Murray Development	1.85	1.85	1.86
Tumut Development	1.92	1.94	1.95

Note: Water utilisation is power station generation divided by releases from headworks storages. Murray Development comprises the Murray 1 and Murray 2 Power Stations. The Tumut Development comprises Tumut 1, Tumut 2, Tumut 3 and Blowering Power Stations.

Source: SMHEA 1993.

6.8 ELECTRICITY GENERATED FROM SNOWY MOUNTAINS HYDRO POWER STATIONS

	1989–90	1990–91	1991–92	1992–93	1993–94
Mill. kW/h	4 366	5 870	5 151	6 451	5 539

Source: ESAA 1995.

In Australia, the 14 hydro power stations generated 16,296 megawatts of electricity in 1993–94. The total energy converted from water flow to electricity generation during 1982–94 is given in table 6.9.

6.9 HYDRO ENERGY USED FOR ELECTRICITY GENERATION

Year	*Water supply* PJ	*Other*[1] PJ	***Total*** **PJ**
1982–83	46.5	–0.9	**45.6**
1983–84	46.3	0.7	**47.0**
1984–85	53.9	1.6	**55.5**
1985–86	55.8	–2.3	**53.5**
1986–87	52.4	0.8	**53.2**
1987–88	53.9	–0.4	**53.5**
1988–89	54.1	0.5	**54.6**
1989–90	53.6	–1.4	**52.2**
1990–91	58.0	0.7	**58.7**
1991–92	56.8	0.9	**57.7**
1992–93	61.0	0.6	**61.6**
1993–94	60.5	0.3	**60.8**

[1] 'Other' represents statistica. discrepancies. The details refer to original sources.

Source: ABARE 1995.

The installed capacity of hydro-electric power stations by State is shown in table 6.10. It shows that the Snowy Mountains hydro-electricity scheme is the largest with 3,740 megawatts capacity, about 50% of the total. Note that in the table, the figures for New South Wales and Victoria do not include their entitlements to the capacity of the Snowy Mountains Scheme. The shares of the capacity of the SMEHA are approximately 79% to New South Wales and 21% to Victoria.

6.10 HYDRO-ELECTRICITY STATIONS INSTALLED, 1993–94

	MW
New South Wales	345
Victoria	469
Queensland	632
Western Australia	2
Tasmania	2 254
Snowy Mountains Scheme	3 740
Total	**7 441**

Source: ESAA 1995.

As Australia is the world's driest continent the potential for hydro development is limited. From the results of investigations by State electricity utilities, the gross theoretical hydro-electric potential of Australia is 264,000 gigawatt hours annually, if all natural flows were turbined down to sea level with 100% efficiency. The economically feasible hydro-electric potential is only 30,000 gigawatt hours. However, when environmental considerations are taken into account, it is suggested that the figures on hydro-electricity potential in Australia paints an over-optimistic picture (ESAA 1994).

Several potential sites have been identified for developing relatively large hydro-electric stations. These sites include Mitta, Mitchell and Macalister Rivers in Victoria; Clarence, Nymboida and Styx Rivers in New South Wales, and Burdekin Falls and Tully Millstream in Queensland. It is also recognised that there is still a considerable potential to install small-scale hydro-electric power stations (1–20 megawatts) in many States. In Victoria, 30 megawatts of economically and environmentally sound small hydro-schemes are being considered, with a 5.6 megawatt hydro generator installed at Thomson Dam, and 2.6 megawatt at Blue Rock Dam proceeding to construction. A study has shown that the small hydro potential at a number of existing dams could be about 200–250 megawatts, producing 1,300 gigawatt hours per year. Augmentation and modification of existing hydro-electric schemes are also options to increase hydro-electric capacity in Australia.

Thermal electricity generation

Thermal electricity generation uses fossil fuels as the major energy source. As reported in previous chapters, extensive coal resources, several large gas fields and some other petroleum deposits are available in Australia. Installation of thermal electricity stations depends upon the demand for electricity and economic as well as environmental considerations.

Thermal power generation capacity installed in States is given in table 6.11. It should be noted that the table only covers the public supply of electricity. Generation of electricity from private organisations, such as mining and manufacturing businesses, is excluded due to data limitations.

6.11 THERMAL GENERATING INSTALLED CAPACITY

Year	NSW	Vic.	Qld	SA	WA	Tas.	NT	Total
	MW	MW	MW	MW	MW	MW	MW	MW
STEAM TURBINE								
1986–87	11 459	5 460	3 752	2 355	2 040	240	141	25 447
1987–88	11 496	5 460	4 042	2 355	2 040	240	0	25 633
1988–89	11 336	5 720	4 242	2 265	2 040	240	0	25 843
1989–90	10 775	5 720	4 242	2 025	2 040	240	0	25 042
1990–91	10 175	5 720	4 242	2 025	2 040	240	0	24 442
1991–92	10 215	5 720	4 428	2 025	2 040	240	0	24 668
1992–93	10 875	5 720	4 910	2 025	2 040	240	0	25 810
1993–94	11 535	6 050	5 435	1 905	2 040	240	0	27 205
INTERNAL COMBUSTION TURBINE								
1986–87	41	0	59	18	170	5	81	372
1987–88	37	0	46	19	172	5	72	350
1988–89	38	0	41	19	180	5	69	352
1989–90	28	0	46	22	184	5	[1]92	354
1990–91	1	0	41	21	193	5	94	355
1991–92	1	0	48	21	181	5	99	354
1992–93	1	0	29	15	175	6	99	325
1993–94	1	0	29	15	175	6	85	339
GAS TURBINE								
1986–87	269	465	178	321	60	0	190	1 483
1987–88	295	465	178	321	60	0	162	1 481
1988–89	295	465	178	321	60	0	175	1 494
1989–90	295	465	178	321	240	0	175	1 674
1990–91	295	465	178	321	312	0	179	1 750
1991–92	295	465	178	321	596	0	184	2 039
1992–93	295	465	178	321	596	0	186	2 041
1993–94	295	466	188	321	712	0	188	2 170
COMBINED CYCLE								
1986–87	0	0	0	0	0	0	95	95
1987–88	0	0	0	0	0	0	95	95
1988–89	0	0	0	0	0	0	95	95
1989–90	0	0	0	0	0	0	95	95
1990–91	0	0	0	0	0	0	95	95
1991–92	0	0	0	0	0	0	95	95
1992–93	0	0	0	0	0	0	95	95
1993–94	0	0	0	0	0	0	95	95
TOTAL								
1986–87	11 769	5 925	3 989	2 694	2 270	245	507	27 397
1987–88	11 828	5 925	4 266	2 695	2 272	245	329	27 559
1988–89	11 669	6 185	4 461	2 605	2 280	245	339	27 784
1989–90	11 098	6 185	4 466	2 368	2 464	245	[1]362	27 165
1990–91	10 471	6 185	4 461	2 367	2 545	245	368	26 642
1991–92	10 511	6 185	4 654	2 367	2 817	245	378	27 156
1992–93	11 171	6 185	5 117	2 361	2 811	246	380	28 271
1993–94	11 831	6 516	5 652	2 241	2 927	246	368	29 809

[1] Generation capacity in remote areas and Aborigines Service Centre is included after 1989–90.

Source: ESAA 1995.

Of the various types of turbines used in electricity generation, the steam turbine is still dominant in power supply, providing 91% of the total thermal power installed capacity in public electricity supply.

FLOW ACCOUNTS FOR ELECTRICITY

The flow account for electricity supply and consumption is given in table 6.12. The supply category lists the electricity generated from power stations, as well as other conversion processes in which electricity was only a by-product. In the conversion category, electricity was used in conversion processes to form other energy products such as coke, briquettes and petroleum products. The end use category provides electricity consumed by various sectors as end users.

Table 6.12 shows that during the period 1982–83 to 1993–94, electricity generation increased steadily from 371 petajoules to 580 petajoules.

The residential sector was the highest electricity consumer until about the mid-1980s. With the rapid expansion of manufacturing production, electricity consumption in the manufacturing sector has risen quickly to become the largest consumer at 33% of the total electricity consumption in 1993–94. The residential sector is second (28%), followed by the commercial sector (21%).

RESIDUAL ACCOUNTS FOR ELECTRICITY

It has been recognised that the use of electricity does not produce residuals. However, as shown in early chapters, generation of electricity from other fuels results in residuals. In this sense, the use of electricity is indirectly associated with the creation of pollutants. For convenience, these are repeated in table 6.13 from early chapters (principally Chapter 5, Coal).

Most air pollutants and greenhouse gases can be found in the residuals discharged from thermal power stations. Table 6.13 is an account of residuals from thermal electricity generation in 1993–94. Note that the table includes only some of the major air pollutants and greenhouse gases from the electricity generation sector.

In 1993–94, the fossil fuel used for thermal electricity generation has increased by about 5% compared with 1989–90. The emissions of carbon dioxide and methane have also gone up by about 5%.

Hydro-electric power plants are generally considered as environmentally friendly. They convert hydro energy into electricity without combustion of fossil fuels. Hence hydro power stations utilise a renewable resource and at the same time there are no pollutants discharged into the atmosphere. In general, hydro power stations have a longer working life with low running and maintenance costs.

A controversial issue has risen about hydro-electric plants concerning their greenhouse impact. Recent studies suggest that if the fate of the carbon on the land flooded by a hydro-scheme lake is considered, then the carbon dioxide coefficient of hydro-electricity may be higher than those of wind or solar electricity generation. The analysis indicated that the amount of carbon dioxide equivalent emissions associated with a hydro-electric scheme increases in proportion to the area of the lake, the amount of biological material on the flooded land and that the proportion of carbon that is converted to methane increases. The amount of carbon dioxide equivalent emissions is inversely proportional with the annual energy output of the dam and the lifetime of the dam (IPCC 1990 & DASETT 1991a).

As an exploratory example, the calculation of carbon dioxide coefficients for the Snowy Mountains Scheme in New South Wales, the proposed Tully Millstream Scheme in Queensland and the Gordon River Dam in Tasmania using a 100 year time horizon is given in table 6.14. (Note that the calculations are only to illustrate the point that further research is required.) It shows that the Snowy Mountains Scheme in New South Wales has large lake areas but less amount of biological material on the flooded land and high power output. Hence it has much low carbon dioxide equivalent emissions than other two schemes.

6.12 FLOW ACCOUNT FOR ELECTRICITY

	1982–83	1983–84	1984–85	1985–86	1986–87	1987–88	1988–89	1989–90	1990–91	1991–92	1992–93	1993–94
	PJ	PJ	PJ	PJ	PJ	PJ	PJ	PJ	PJ	PJ	PJ	PJ
SUPPLY												
Electricity generation	371.2	391.8	419.2	440.0	459.9	482.8	513.6	539.0	545.9	552.7	556.8	579.9
Other conversion	12.6	14.1	16.3	17.0	17.8	17.9	18.5	19.3	18.9	20.2	21.7	22.1
Total supply	*383.8*	*405.9*	*435.5*	*457.0*	*477.7*	*500.7*	*532.1*	*558.3*	*564.8*	*572.9*	*578.5*	*602.0*
CONVERSION												
Coke ovens	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Briquetting	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.1	0.1	0.2	0.2	0.2
Petro refining	3.7	3.5	3.6	3.3	3.4	3.3	3.4	3.5	3.8	4.2	4.1	4.4
Electricity in conversion	56.0	59.0	66.9	67.3	69.7	68.6	74.4	75.4	72.3	74.2	76.6	75.9
Total conversion	60.0	62.8	70.8	70.9	73.4	72.2	78.1	79.1	76.3	78.7	81.0	80.6
Net supply	*323.7*	*343.1*	*364.8*	*386.2*	*404.3*	*428.5*	*453.9*	*479.1*	*488.4*	*494.3*	*508.5*	*520.9*
END USE												
Agriculture	6.2	5.9	6.4	6.6	6.9	7.4	7.4	8.5	9.0	9.2	8.0	9.1
Mining	19.3	19.4	20.9	23.3	24.2	25.5	30.0	35.0	35.4	36.6	37.9	38.2
Iron and steel	12.4	13.5	14.0	14.4	14.6	16.1	16.2	17.9	17.0	17.5	18.8	19.0
Chemical	9.5	9.5	9.9	10.7	10.8	11.1	11.7	12.3	12.7	13.1	12.8	13.5
Other industry	90.5	106.7	119.6	127.2	134.8	146.5	158.7	161.6	163.1	165.3	169.7	174.5
Construction	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Rail transport	3.0	3.4	3.7	4.0	4.2	4.7	5.4	5.7	5.7	5.9	5.9	6.2
Air transport	0.5	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.4
Water transport	0.2	0.3	0.3	0.4	0.4	0.5	0.5	0.5	0.5	0.6	0.6	0.6
Commercial	65.4	66.3	69.8	75.2	79.9	86.0	91.8	98.3	103.2	103.9	107.3	111.0
Residential	116.4	117.5	119.9	124.1	128.0	130.2	131.9	138.8	141.3	141.8	146.3	148.3
Consumption	*323.7*	*343.1*	*364.8*	*386.2*	*404.3*	*428.5*	*453.9*	*479.1*	*488.4*	*494.3*	*508.5*	*520.9*

Source: ABARE 1995.

6.13 AIR POLLUTANTS AND GREENHOUSE GASES FROM ELECTRICITY GENERATION, 1993–94

	Energy use	CO_2	*CO*	CH_4	NO_x	N_2O
	PJ	Gg	Gg	Mg	Gg	Mg
			PUBLIC ELECTRICITY GENERATION			
Black coal	886.8	80 494.0	9.9	790.0	287.0	720.0
Brown coal including briquettes	457.5	43 293.0	8.0	220.0	59.0	630.0
Petroleum	6.6	471.0	1.5	20.0	6.0	0.0
Gas	124.4	6 360.0	2.6	180.0	19.0	10.0
Total	*1 475.3*	*130 617.0*	*22.0*	*1 220.0*	*371.0*	*1 370.0*
			PRIVATE ELECTRICITY GENERATION			
Black coal	12.4	1 064.0	0.1	10.0	3.7	10.0
Brown coal including briquettes	16.9	1 461.0	0.2	20.0	5.2	20.0
Petroleum	21.8	1 502.0	7.2	80.0	27.2	10.0
Gas	21.8	1 114.0	0.6	70.0	4.4	0.0
Total	*72.8*	*5 140.0*	*8.1*	*180.0*	*40.4*	*50.0*
			TOTAL			
Black coal	899.2	81 558.0	10.0	800.0	290.4	730.0
Brown coal including briquettes	474.4	44 754.0	8.3	240.0	64.1	660.0
Petroleum	28.4	1 972.0	8.6	100.0	33.1	20.0
Gas	146.2	7 474.0	3.2	260.0	23.7	10.0
Total	**1 548.2**	**135 758.0**	**30.2**	**1 400.0**	**411.2**	**1 420.0**

Source: NGGIC 1996.

6.14 HYDRO CO_2 COEFFICIENTS

		Scheme	
	Gordon River	*Snowy Mountains*	*Tully Millstream*
Lake area (km²)	133	273	45
Average output (MW)	172	490	118
Ecosystem carbon (t/h)	250	150	250
CO_2 coefficient			
Carbon forms CO_2 ('000 t/PJ)	27	14	18
Carbon forms methane ('000 t/PJ)	176	77	92

Source: DASETT 1991a.

CHAPTER 7 URANIUM

Nuclear power which mainly uses uranium as the fuel is an important energy source brought about by modern science and technology. More than 30 countries have established nuclear power stations for electricity generation, and world uranium requirements to fuel nuclear power stations is currently around 57,000 tonnes uranium per year. Nuclear power stations are particularly important for those countries which lack sufficient fossil fuel resources. However, nuclear power generation, as well as uranium mining and milling, are a matter of considerable public debate, arising from political, economical, social and environmental concerns.

Although Australia has the world's largest resources of low-cost uranium, current legislation does not allow nuclear power stations. Domestic consumption is limited to minor use in medical, industrial and scientific applications. Uranium produced in Australia is exported to countries which use uranium for generation of electricity, or for other peaceful purposes. There are stringent nuclear safeguard conditions applied to exports, and subsequent use of Australian uranium is bound by international legal obligations in bilateral nuclear safeguards agreements. These conditions include an undertaking not to use Australian nuclear material for any military or explosive purpose, and acceptance of the International Atomic Energy Agency safeguards in order to verify that undertaking. Australia has concluded 15 bilateral nuclear safeguards agreements covering 24 countries and two international bodies. The *Nuclear Non-Proliferation (Safeguards) Act (1987)* provides for safeguards concerning the possession and transport of nuclear material and other physical items related to nuclear reactors in Australia.

BACKGROUND

Forms of nuclear energy

Uranium and nuclear fuels differ from other fuels such as oil, gas, coal and wood because uranium is a fissionable metal whose atom, when spilt, releases a large amount of energy, whereas the other fuels are carbon compounds which react with oxygen releasing energy.

When burning, carbon-based fuels react with oxygen to produce heat and carbon dioxide as well as other gases. Combustion of these fuels is a chemical process and atoms of fuel elements in reaction remain unchanged with no resultant loss of mass. Nuclear energy is produced from an atomic fission process where atoms of uranium split and are transferred into other elements, in the process releasing very large amounts of energy which appear as heat and radiation, and there is a resultant loss of mass.

In nuclear power stations, the fission process is controlled so that a steady rate of fission with continuing energy release is achieved. For currently available commercial power reactors, the heat produced is carried away by circulating liquid or gaseous coolants, with the hot coolant passing through a heat exchanger to produce steam, or coolant water boils to produce steam. The steam drives a conventional turbine-generator system to produce electricity.

Naturally-occurring uranium consists of a mixture of three isotopes in the following proportion: uranium-238 (99.28%), uranium-235 (0.71%) and uranium-234 (0.01%). Uranium-235 is the only naturally-occurring fissionable element. Heat-producing fuel rods in nuclear reactors usually contain about 3% of Uranium-235.

After mining, the uranium ore must undergo treatment, called milling, to produce uranium oxide. The uranium oxide contains about 84.8% of the metal by weight, and is the principal form of Australia's uranium for export. Customer countries need to provide for further treatment to upgrade the uranium-235 component of the uranium oxide into a usable fuel suitable for nuclear power stations.

Uranium is as abundant as industrial metals such as tin, mercury, antimony or silver. It has an average concentration of about two grams a tonne in the earth's crust. Uranium has also been found in sea water at about three parts of uranium per billion parts, a total of some four billion tonnes of uranium in the oceans. However, it is rare to discover rich uranium deposits that are economically viable for mining. Economic viability is a crucial factor for resources assessment and this depends, to an extent, on the price that users are prepared to pay.

System of uranium resource classification

International Scheme for Uranium Resource Classification

The Organisation for Economic Cooperation and Development/Nuclear Energy Agency (OECD/NEA) and the International Atomic Energy Agency (IAEA) have established an international scheme for uranium resources classification. Resource estimates are divided into categories which reflect different levels of confidence in the quantities reported. Within these main categories, resources are further subdivided on the basis of costs of production. Estimates are made of the quantities of uranium which could be recovered from minable ore and these estimates are reported as metric tonnes of recoverable uranium. The categories for identified resources are defined as (OECD/NEA & IAEA 1994):

- Reasonably Assured Resources (RAR) category represents the most reliable estimates of uranium resources and refers to uranium that occurs in known mineral deposits of delineated size, grade and configuration such that the quantities which could be recovered within the given production cost ranges with currently proven mining and processing technology, can be specified. Estimates of tonnage and grade are based on specific sample data and measurements of the deposits and on knowledge of deposit characteristics. Reasonably assured resources have a high assurance of existence.
- Estimated Additional Resources — Category I (EAR-I) refers to uranium in addition to RAR that is inferred to occur, mostly on the basis of direct geological evidence, in extensions of well-explored deposits, or in deposits in which geological continuity has been

established but where specific data, including measurements of the deposits, and knowledge of the deposits' characteristics are considered to be inadequate to classify the resources as RAR. Estimates of tonnage, grade and cost of further delineation and recovery are based on such sampling as is available and on knowledge of the deposits' characteristics as determined in the best-known parts of the deposit or in similar deposits. Less reliance can be placed on the estimates in this category than on those for RAR.

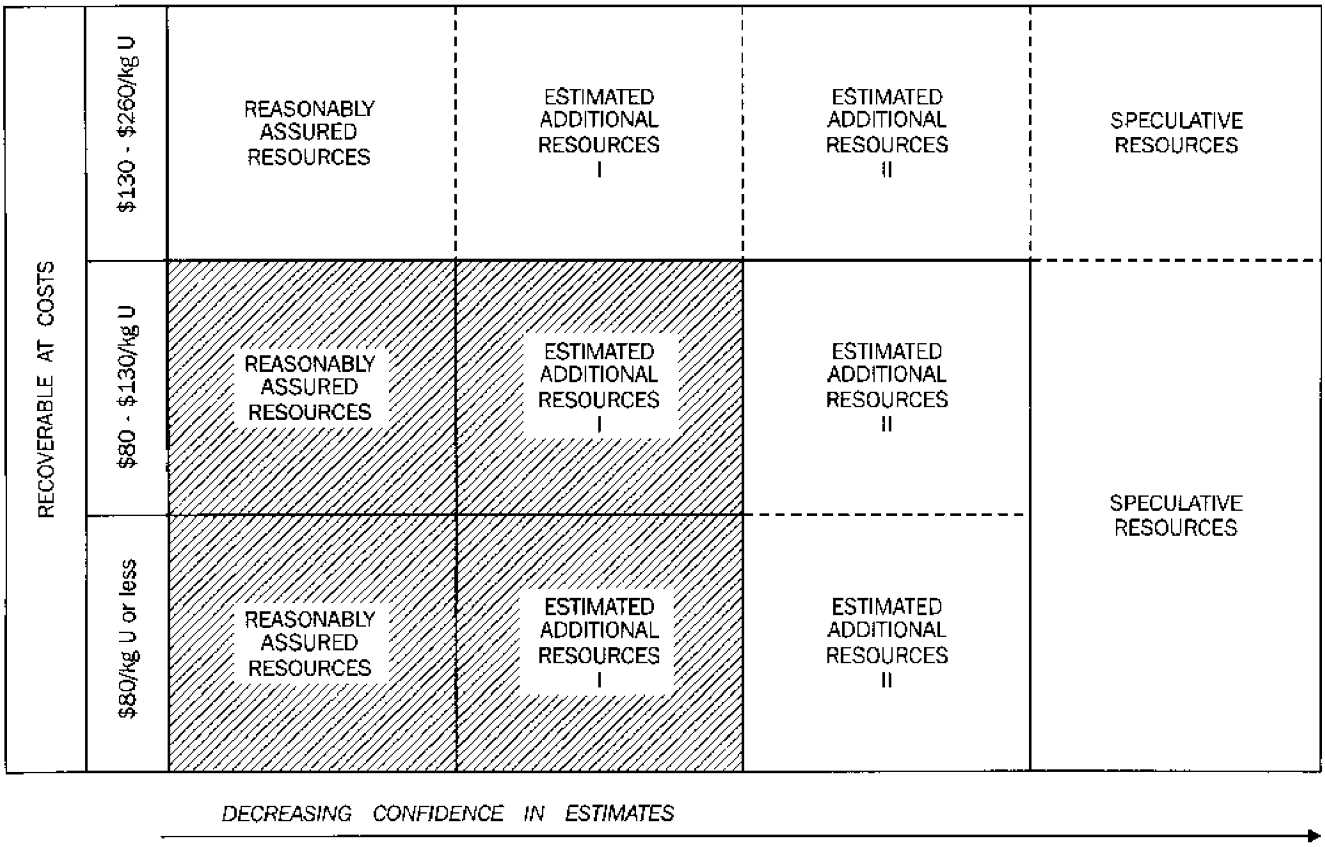
- Estimated Additional Resources — Category II (EAR-II) refers to uranium in addition to EAR-I that is expected to occur in deposits for which the evidence is mainly indirect and which are believed to exist in well-defined geological trends or areas of mineralisation with known deposits. Estimates of tonnage, grade and cost of discovery, delineation and recovery are based primarily on knowledge of deposits' characteristics in known deposits within the respective trends or areas and on such sampling, geological, geophysical or geochemical evidence as may be available. Less reliance can be placed on the estimates in this category than on those for EAR-I.
- Speculative Resources (SR) refers to uranium, in addition to EAR-II, that is thought to exist, mostly on the basis of indirect evidence and geological extrapolations, in deposits recoverable with existing exploration techniques. The location of deposits envisaged in this category could generally be specified only as being somewhere within a given region or geological trend. As the term implies, the existence and size of such resources are speculative.

The resource categories are subdivided according to cost of production into:

- less than US$80 per kilogram of uranium (less than US$30 per pound uranium oxide) (referred to as 'low-cost resources');
- US$80 to US$130 per kilogram of uranium (US$30 to US$50 per pound uranium oxide).

The costs considered are essentially forward costs and include operating costs and future capital expenditures. Past exploration costs and previous expenditures of a capital nature are not included, nor is any allowance made for operating profits in determining the total cost of production.

7.1 CLASSIFICATION SCHEME FOR URANIUM RESOURCES



Source: OECD/NEA & IAEA 1994.

Comparison OECD–NEA/IAEA Resource Classification for Uranium: McKelvey Resource Classification

The NEA/IAEA resource classification system for uranium and thorium, is a two-parameter classification involving the degree of assurance of occurrence, and the cost of production. This classification is based on recoverable resources (i.e. allowance is made for mining and milling losses) whereas the McKelvey Classification, unless specifically stated, is based on in situ resources.

Although the actual definitions differ, the NEA/IAEA categories for assurance of occurrence conform with those in the McKelvey system — i.e. RAR are equivalent to McKelvey's Demonstrated Resources (i.e. sum of Measured and Indicated Resources), and EAR-I are equivalent to Inferred Resources. EAR-II and SR, which are categories of Undiscovered Resources, are equivalent to McKelvey's Potential Resources.

National estimates of uranium resources are reported within the following cost categories:

- recoverable at costs of less than US$80 per kilogram of uranium; and
- recoverable at costs between US$80 to US$130 per kilogram of uranium.

In the McKelvey system, Australia's RAR and EAR-I are calculated within these cost categories.

The NEA/IAEA changed its cost categories on two occasions (1976 and 1977) to take account of changes in uranium prices. The NEA/IAEA cost categories do not conform with the economic boundaries of the McKelvey Classification. While in the past there have been periods when resources in the less than US$80 per kilogram of uranium cost category approximated 'economic resources', there has been no consistent relationship between cost categories and the economic boundaries of the McKelvey Classification because of changes in uranium prices. Resources in the less than US$80 per kilogram of uranium category now include 'economic' and 'uneconomic resources', while the US$80 per kilogram of uranium category now includes only 'uneconomic resources'. Because of the long-term decline in uranium market prices since the early 1980s, most uranium sales in recent years have been at prices well below US$80 per kilogram of uranium. Consequently, a significant amount of the resources in the less than US$80 per kilogram of uranium category are not economic under current market conditions. The OECD/NEA and IAEA recently introduced a cost category of less than US$40 per kilogram of uranium (less than US$15 per pound uranium oxide) in order to provide an estimate of known resources that may be recoverable at a cost level that is more relevant to current uranium market prices. The data on Australia's uranium resources in the less than US$40 per kilogram of uranium category are currently being compiled.

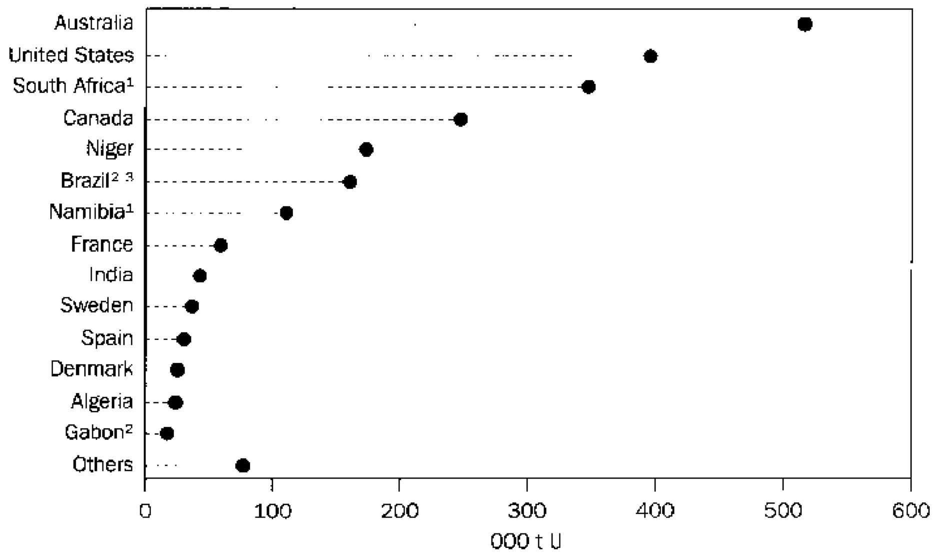
Australia's uranium resources

The estimates of Australia's uranium deposits within the RAR and EAR-I categories were prepared by using exploration and drilling data provided by the mining companies. (Note that the estimates of EAR-II and Speculative categories are not available for Australian uranium resources.) These estimates are aggregated to give Australia's total resources within the above categories, and expressed as tonnes uranium recoverable after due allowance for mining and milling losses. Australia's resources as at December 1994 were 633,000 tonnes uranium for RAR and 154,000 tonnes uranium for EAR-I, at cost range of less than US$80 per kilogram of uranium. At cost range of between US$80 to US$130 per kilogram of uranium, the RAR were 77,000 tonnes uranium and the EAR-I were 40,000 tonnes uranium (McKay, Miezitis & Lambert 1995).

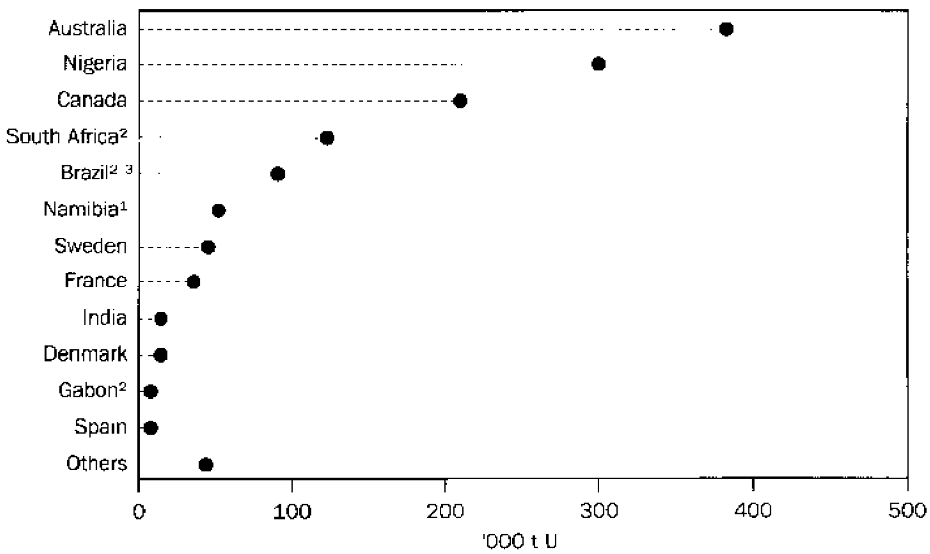
Australia's resources in the low cost RAR category are the largest of the former western world countries. Of the total low cost RAR in the former western world, about 98% are located in the following seven countries: Australia (40%), Brazil (10%), Canada (17%), Namibia (5%), Niger (10%), South Africa (9%) and the United States of America (7%). Graph 7.2 shows the distribution of RAR and EAR-I among western world countries.

7.2 DISTRIBUTION OF URANIUM RESOURCES IN SELECTED COUNTRIES, 1987

Reasonably Assured Resources



Estimated Additional Resources



[1] OECD (NEA)/IEA: Uranium Res ırces, Production and Demand, Paris, 1983, adjusted for production and estimated production.

[2] OECD (NEA)/IEA: Uranium Resources, Production and Demand, Paris, 1986, adjusted for production and estimated production.

Source: McKay, Miezitis & Lambert 1995.

Australian uranium mining

Map 7.3 shows Australia's uranium deposits and prospects. Uranium is currently mined at the Ranger mine (Northern Territory) and Olympic Dam mine (South Australia).

7.3 URANIUM DEPOSITS AND OCCURRENCES

Source: McKay, Miezitis & Lambert 1995.

Ranger consists of an open cut mining operation and a concentrating plant. The plant has a production capability of 3,000 tonnes uranium oxide per year. Since 1992, Ranger has operated on a cyclical basis of six months of mining operations followed by six months of milling operations. Production for the year ended 31 December 1994 was 1,462 tonnes uranium oxide.

Mining at Ranger No. 1 open cut was completed in December 1994. Surface stockpiles of ore, as at December 1994, contained an estimated 19,300 tonnes uranium oxide which is sufficient to maintain milling operations through to the end of 1999.

Energy Resources of Australia reported that it proposes to develop the Ranger No. 3 orebody, located 1.5 kilometres north of the No. 1 open cut, for future production. Development work for the open cut is planned to commence in 1997.

Olympic Dam consists of an underground mining operation and a metallurgical complex. The metallurgical complex includes a grinding/concentrating circuit, hydrometallurgical plant, copper smelter, copper refinery and a recovery circuit for precious metals. Production for the year ended 31 December 1994 was 64,071 tonnes of refined copper; 1,142 tonnes uranium oxide; 26,540 ounces of gold; and 347,617 ounces of silver. An optimisation program currently under way will increase annual production capacity at Olympic Dam to 84,000 tonnes of copper and 1,500 tonnes of uranium oxide.

STOCK ACCOUNTS FOR URANIUM

This section deals with uranium resources in Australia. 'Stock' here refers to the deposits of uranium remaining in the ground. Table 7.4 shows the Australian stock of uranium in the low-cost RAR category. Australia's low-cost RAR increased from approximately 8,000 tonnes of uranium metal in the late 1960s to 633,000 tonnes in 1994. Fluctuations in the level of these resources has been caused by a number of factors.

The initial growth in Australia's low-cost uranium resources was due to the discoveries of a number of large deposits between 1969 and 1975, including Ranger, Jabiluka, Nabarlek, Koongarra (Northern Territory), Beverley, Olympic Dam (South Australia), Yeelirrie and Lake Way (Western Australia). Continuing exploration and reassessment of resources at these discoveries, accompanied by transfer of resources from EAR-I to RAR continued to increase Australia's low-cost resources. Major increases to low-cost uranium resources in 1982 and 1992 were mainly from the ongoing exploration and assessment at the Olympic Dam copper-uranium-gold-silver deposit which is one of the world's largest uranium deposits. The discovery of the Kintyre deposit (Western Australia) in 1985 also contributed to increases in Australia's resources during the late 1980s.

Economic factors

Inflation during the 1980s, increasing mining costs, oversupply and falling uranium prices have resulted in resources in certain deposits being transferred from the low-cost resources category (less than US$80 per kilogram of uranium) to the higher cost categories.

Mine production

Production of uranium from the Mary Kathleen, Ranger and Nabarlek mines has reduced the resources in these deposits. Production from Olympic Dam commenced in 1988, however this has been offset by large increases in the resources of this deposit.

It should be noticed that the estimates of Australian uranium resources given here have been calculated within the resource categories of the OECD/NEA classification scheme. Data on resource estimates published by mining companies show that virtually all of the RAR recoverable at less than US$80 per kilogram uranium (OECD/NEA scheme) can be equated with Economic and Sub-economic Demonstrated Resources for the period covered in the following tables.

7.4 STOCK ACCOUNT FOR URANIUM, ECONOMIC DEMONSTRATED RESOURCES (RECOVERABLE)

	Opening stock	Adjustment	Production	Closing stock	Net change
Year	'000 t U	'000 t U	'000 t U	'000 t U	'000 t U
1982–83	314.0	162.9	–4.5	474.0	160.0
1983–84	474.0	–7.8	–3.2	463.0	–11.0
1984–85	463.0	6.4	–4.4	465.0	2.0
1985–86	465.0	0.3	–3.3	462.0	–3.0
1986–87	462.0	12.2	–4.2	470.0	8.0
1987–88	470.0	13.8	–3.8	480.0	10.0
1988–89	480.0	–2.5	–3.5	474.0	–6.0
1989–90	474.0	–1.3	–3.7	469.0	–5.0
1990–91	469.0	8.5	–3.5	474.0	–5.0
1991–92	474.0	–8.2	–3.8	462.0	–12.0
1992–93	462.0	173.0	–2.3	631.0	169.0
1993–94	631.0	4.3	–2.3	633.0	2.0
1994–95	633.0	n.a.	–2.2	n.a.	n.a.

Source: BRS 1996.

Based on the production rates in 1994, the remaining uranium resources in the low-cost RAR category could support uranium production for a further 287 years if there were no other constraints such as land use.

Table 7.5 shows RAR Recoverable at US$80 to US$130 per kilogram of uranium. During the period from 1982 to 1994, the stock increased from zero to 77,000 tonnes.

7.5 STOCK ACCOUNT FOR URANIUM, SUB-ECONOMIC DEMONSTRATED RESOURCES (RECOVERABLE)

Year	Opening stock '000 t U	Adjustment '000 t U	Closing stock '000 t U
1982–83	22.0	42.0	64.0
1983–84	64.0	–1.0	63.0
1984–85	63.0	–7.0	56.0
1985–86	56.0	0.0	56.0
1986–87	56.0	0.0	56.0
1987–88	56.0	2.0	58.0
1988–89	58.0	0.0	58.0
1989–90	58.0	2.0	60.0
1990–91	60.0	–5.0	55.0
1991–92	55.0	0.0	55.0
1992–93	55.0	21.0	76.0
1993–94	76.0	1.0	77.0
1994–95	77.0	n.a.	n.a.

Source: BRS 1996.

Tables 7.6 and 7.7 provide the stocks for the EAR-I category in the less US$80 and the US$80 to US$130 per kilogram of uranium, respectively.

7.6 STOCK ACCOUNT FOR URANIUM, ECONOMIC INFERRED RESOURCES (RECOVERABLE)

Year	Opening stock '000 t U	Adjustment '000 t U	Closing stock '000 t U
1982–83	369	–134	235
1983–84	235	–16	251
1984–85	251	5	256
1985–86	256	1	257
1986–87	257	10	267
1987–88	267	–5	262
1988–89	262	2	264
1989–90	264	0	264
1990–91	264	5	269
1991–92	269	3	272
1992–93	272	123	149
1993–94	149	5	154
1994–95	154	n.a.	n.a.

Source: BRS 1996.

7.7 STOCK ACCOUNT FOR URANIUM, SUB-ECONOMIC INFERRED RESOURCES (RECOVERABLE)

Year	Opening stock '000 t U	Adjustment '000 t U	Closing stock '000 t U
1982–83	25	103	128
1983–84	128	–2	126
1984–85	126	1	127
1985–86	127	0	127
1986–87	127	0	127
1987–88	127	4	131
1988–89	131	–5	126
1989–90	126	0	126
1990–91	126	–4	122
1991–92	122	0	122
1992–93	122	–82	40
1993–94	40	0	40
1994–95	40	n.a.	n.a.

Source: BRS 1996.

FLOW ACCOUNTS FOR URANIUM

Table 7.8 shows the production and export of uranium during the period 1982 to 1995. The difference between production and exports contributes to stockpiles. The highest exporting year was 1990–91 with over 5,000 tonnes of uranium exported. Table 7.9 lists the flow account in energy units.

7.8 FLOW ACCOUNT FOR URANIUM

Year	Production t	Exports t	Other[1] t
1982–83	3 888	–3 783	105
1983–84	3 717	–2 904	813
1984–85	3 669	–2 919	750
1985–86	3 774	–2 734	1 040
1986–87	3 820	–3 700	120
1987–88	3 556	–3 860	–304
1988–89	3 821	–4 291	–470
1989–90	3 467	–3 157	310
1990–91	3 722	–5 197	–1 475
1991–92	3 688	–4 010	–322
1992–93	2 293	–1 941	352
1993–94	2 333	–3 385	–1 052
1994–95	2 459	–3 392	–933

[1] Stock changes and discrepancies.

Source: ABARE 1995.

7.9 FLOW ACCOUNT FOR URANIUM

Year	Production PJ	Exports PJ	Other[1] PJ
1982–83	2 177.3	–2 118.5	58.8
1983–84	2 081.5	–1 556.8	524.7
1984–85	2 054.6	–1 621.2	433.4
1985–86	2 091.5	–1 515.3	576.2
1986–87	2 117.4	–2 050.6	66.8
1987–88	1 970.7	–2 139.4	–168.7
1988–89	2 140.3	–2 378.3	–238.0
1989–90	1 921.8	–1 749.8	172.0
1990–91	2 062.8	–2 879.7	–816.9
1991–92	2 044.0	–2 222.6	–178.6
1992–93	1 270.9	–1 075.8	195.1
1993–94	1 293.0	–1 876.2	–583.2
1994–95	1 363.0	–1 880.0	–517.0

[1] Stock changes and discrepancies.

Source: ABARE 1995.

RESIDUAL ACCOUNTS FOR URANIUM

Wastes from mining and milling

There are two main types of waste from the mining and milling of uranium ores:

- waste rock and overburden; and
- tailings from processing the ore.

Waste rock/overburden

Large amounts of waste rock are mined by both open cut and underground methods. Waste rock and overburden are stored in waste rock dumps. For the Ranger open cut, the overall ore:waste ratio was approximately 1:3.8, which means that, on average, for each tonne of ore mined, approximately 3.8 tonnes of waste rock were mined. For underground mines, such as Olympic Dam, most of the waste rock comes from tunnels and shafts excavated to gain access to the orebody.

Tailings

Uranium ore is processed in a mill/metallurgical plant to produce uranium oxide concentrate. The ore is crushed and then ground to a slurry of fine ore particles suspended in water. Uranium is recovered from this slurry by an acid leach process. The waste products after extraction of uranium from the ore are called tailings. These consist of finely crushed rock material and are disposed of in specially constructed dams.

Uranium mining operations in Australia are controlled by Commonwealth and State regulations governing environment protection. These regulations require that there is no release of any mining or milling waste nor any adverse environmental impacts outside the mine sites. For Ranger operations, the Office of the Supervising Scientist supervises the implementation of regulations governing environmental protection relevant to mining and milling wastes (*Environment Protection (Alligator Rivers Region) Act (1978), Environmental Protection Nuclear Codes Act (1978)*). The Olympic Dam operation is regulated under South Australian Government legislation.

Background information on radioactive wastes not related to mining or energy

All of Australia's mine production is exported. There are no commercial nuclear power stations in Australia. A small research reactor, HIFAR, operated by the Australian Nuclear Science and Technology Organisation at Lucas Heights is Australia's only nuclear reactor. Spent fuel generated by the reactor is stored at Lucas Heights in monitored retrievable facilities in accordance with international standards and guidelines. In April 1996, a quantity of spent fuel was shipped to the United Kingdom for reprocessing. The spent fuel elements stored at Lucas Heights contain a total of 0.23 tonnes of uranium and other heavy metals.

Non-uraniferous radioactive wastes are generated in the production and use around Australia of radiopharmaceuticals, isotopes and radiochemicals for medical, industrial and research purposes. These low-level radioactive wastes include: components from the HIFAR reactor, paper, plastic, glassware, protective clothing, radiation sources, and lightly contaminated soil. Other low-level radioactive wastes include electron tubes, radium painted watches, compasses, industrial gauges, exit signs and smoke detectors.

At present, low-level radioactive wastes are held at some 50 interim storage sites throughout Australia. It is the responsibility of the Commonwealth Government, and State and Territory Governments to manage these radioactive sites. A quantity of low-level radioactive waste has been temporarily relocated from Sydney to the Woomera rocket range in South Australia pending selection of the site for a long-term repository.

CHAPTER 8 WOOD FUEL AND BAGASSE

BACKGROUND

Wood is a traditional fuel used since the discovery of fire by human beings. It is solid, highly combustible and also renewable, and is regarded as the most economical fuel in many countries. In Australia wood is still used for industrial boilers and dryers, cooking and metallurgical processes. Wood is also used for home heating in open and slow combustion stoves. In Tasmania, wood fuel is important because of extensive forest reserves and limited coal production, as well as limited availability of oil and natural gas.

Bagasse is the fibrous residue from the production of sugar, and is used as fuel to provide process energy in sugar mills in New South Wales and Queensland. It is burnt and the heat is converted into electricity. In terms of energy units, bagasse is the second largest renewable energy source used in Australia, contributing more than hydro, wind and solar-renewable resources. Bagasse has also been recognised as an important feedstock for fuel ethanol production. It is expected that use of bagasse will be extended in the future.

Production of alcohol fuels can also use other biomass feedstocks such as cereal grains and straw, cassava, fodder beet and sweet sorghum. For diesel engines, vegetable oils such as sunflower, rapeseed and peanut oil have also been considered as biomass feedstocks. However, based on current economic conditions, research shows that using these biomass feedstocks to make fuels in Australia would cost considerably more than the equivalent petroleum-based fuels.

The production of synthetic gas from biomass has been practised since World War II. The energy from cellulosic waste such as crop and timber residuals, was thermochemically converted to produce gas, which was used for charcoal-fired vehicles at that time. This technology has been proven for small-scale electricity generation for local or remote areas. Australia has also developed technology to use landfill gas for electricity generation. Landfill gas is produced by anaerobic decomposition of organic matter in rubbish tips, to form combustible methane gas. Methane gas is collected, filtered and then used in a gas turbine to generate electricity.

This chapter presents physical accounts for wood and bagasse resources in Australia. For forest reserves, there are many valuable uses other than as a fuel (wood used in construction, timber products, pulp and paper making as well as recreation activity). The sections of the chapter, in turn, provide background information on wood fuels, estimates of Australian forest resources in terms of normal rates of extraction for fuel purposes, the production and consumption of wood and bagasse and the emissions from these sources.

In the energy cycle, plants such as trees, convert solar energy into chemical energy which is stored as carbohydrate. Apart from having a substantial content of carbon, wood is also rich in the elements of oxygen and hydrogen. Scientific experiment shows that for typical air-dried wood, carbon, oxygen and hydrogen are about 85% of the total composition, and in wood pellets are about 88%. All wood fuels are free from sulphur elements.

Table 8.1 provides an estimate of the available energy in wood. Comparing green wood, air-dried wood and wood pellets of the same weight, the available energy is about double if the wood is dried. The highest energy is provided by wood pellets.

8.1 AVAILABLE ENERGY IN WOOD

	Green wood	*Air-dried wood*	*Wood pellet*
Item	*MJ/kg*	*MJ/kg*	*MJ/kg*
Gross specific energy	10.00	16.35	16.92
Less latent heat at 2.44 MJ/kg in water vapour from			
Moisture in wood	–1.17	–0.37	–0.29
Combustion moisture	–0.66	–1.07	–1.12
Net specific energy	8.17	14.91	15.51
Less sensible heat (27°C to 250°C) in			
Water vapour (0.427 MJ/kg)	–0.32	–0.29	–0.28
Oxygen (0.212 MJ/kg)	–0.06	–0.10	–0.10
Nitrogen (0.234 MJ/kg)	–0.76	–1.25	1.28
Carbon dioxide (0.209 MJ/kg)	–0.20	–0.32	–0.34
Available energy	6.83	12.95	13.51

Source: HEC 1986.

Wood fuel cons ts of a range of energy products. They can be in solid, liquid and gase is form. However, solid wood fuels, dominate the general market id usage (firewood, woodchips, fuel pellets, charcoal and wood wast).

At considerable ost, wood can be processed to yield ethanol and methanol as liq d fuels. Under a high temperature (approximately 900 degrees Ce ius in the presence of oxygen), wood may be gasified to produce high, edium and low specific energy combustible gases, such as carbon mon ide, hydrogen and methane.

STOCK ACCOUNTS FOR WOOD FUELS

Wood fuels are orest products so availability depends on the stock of forest. In curre economic conditions, forest logging only occasionally takes place for wood fuel production. In most cases, wood fuels are extracted from forestry residues, using remaining sawlogs and pulplogs which are poor in quality.

There is still insufficient information to determine the extent to which wood fuel might economically be extracted from forestry residues. In the absence of other information, a broad estimation method used as a convenient rule of thumb, recommended by the Forestry Commission of Tasmania, is that the bole of sawlogs and pulplogs are normally considered to be 60% of the logging volume, while smallwood and other wood fibre of the tree are about 40% of the total. Allowing for material lost during felling and skidding plus material too small to handle economically, a recovery factor for smallwood and other wood fibre which might be used as wood fuel would possibly be about 25%.

Therefore, during a combined extraction operation of pulpwood, sawlog and fuel wood, the proportion of 25% of the total volume might be regarded as a basis for estimating levels of possible wood fuels extracted. This proportion is used here for estimating the theoretical potential stock of wood fuels from existing forests. The unit used for assessing existing forest is 'merchantable wood volume'. 'Merchantable' means that the volume of the tree bole meets current commercial product specifications for diameter, length and form. Once merchantable wood volume of existing forests is known, the hypothetical wood fuel resource may be derived.

Complete forest stock accounts are beyond the scope of this publication and table 8.2 is included simply to provide an estimate of potential stocks of wood fuels. It should be noted that such estimates are only for indicative purposes and do not take into account other environmental and social issues. In fact, a large proportion of merchantable wood resources are protected by national parks and other forest conservation programs.

Table 8.2 lists the stock account for New South Wales, Queensland, Western Australia, Tasmania and the Australian Capital Territory. There are no data currently available in Victoria, South Australia and the Northern Territory regarding wood fuels. It appears that an increase in potential wood fuel stock can be observed in New South Wales, Queensland and the Australian Capital Territory, due to rapid growth of softwood volume. In Western Australia and Tasmania, wood stocks have declined as well as wood fuel production.

8.2 THEORETICAL WOOD FUEL STOCK ACCOUNTS OF STATE FORESTS

	1987	*1988*	*1989*	*1990*
	'000 m³	'000 m³	'000 m³	'000 m³
NEW SOUTH WALES WOOD FUEL (HARDWOOD AND SOFTWOOD)				
Opening stock	13 142	13 344	13 538	13 705
Adjustment	904	904	904	904
Production	–702	–709	–737	n.a.
Closing stock	13 344	13 538	13 705	n.a.
Net change	202	194	167	n.a.
QUEENSLAND WOOD FUEL (SOFTWOOD)				
Opening stock	n.a.	25 218	26 973	28 691
Adjustment	1 879	1 879	1 879	1 879
Production	n.a.	–124	–161	–173
Closing stock	25 218	26 973	28 691	30 398
Net change	n.a.	1 718	1 706	1 706
WESTERN AUSTRALIA WOOD FUEL (HARDWOOD AND SOFTWOOD)				
Opening stock	n.a.	2 641	2 466	2 291
Adjustment	334	334	334	334
Production	n.a.	–515	–509	–468
Closing stock	2 641	2 466	2 291	2 156
Net change	n.a	–175	–175	–135
TASMANIA WOOD FUEL (HARDWOOD AND SOFTWOOD)				
Opening stock	n.a.	2 869	2 495	2 181
Adjustment	350	350	350	350
Production	n.a.	–724	–664	–619
Closing stock	2 869	2 495	2 181	1 912
Net change	n.a.	–374	–314	–269
AUSTRALIAN CAPITAL TERRITORY WOOD FUEL (SOFTWOOD)				
Opening stock	n.a.	795	811	823
Adjustment	54	54	54	54
Production	n.a.	–38	–41	39
Closing stock	795	811	823	838
Net change	n.a.	16	12	15
TOTAL FUEL (HARDWOOD AND SOFTWOOD)				
Opening stock	n.a.	44 867	46 283	47 691
Adjustment	3 521	3 521	3 521	3 521
Production	n.a.	2 110	2 112	n.a.
Closing stock	44 867	46 283	47 691	n.a.
Net change	n.a.	1 379	2 374	n.a.

Source: Derived from data published by RAC 1991.

FLOW ACCOUNTS FOR WOOD FUELS AND BAGASSE

The flow account for wood fuels and bagasse (production and consumption) are given in tables 8.3 to 8.5. Table 8.3 shows that there is steady growth of wood fuel production during the period of 1982–94, (about 26%). As expected, the residential sector was the major consumer of wood fuels, (more than 75% of the total), and the use of wood fuels in this sector increased by about 18% during the same period. The manufacturing sector was also a major user of wood fuels and its demand increased by about 66% in the period.

8.3 FLOW ACCOUNT FOR WOOD FUELS

	Supply						*End use*
	Production	*Total supply*	*Iron and steel*	*Other industry*	*Commercial*	*Residential*	*Consumption*
Year	PJ	PJ	PJ	PJ	PJ	PJ	PJ
1982–83	85.1	85.1	0.2	14.8	1.0	69.1	85.1
1983–84	85.4	85.4	0.2	15.0	0.8	69.3	85.4
1984–85	86.1	86.1	0.2	15.4	0.7	69.7	86.1
1985–86	87.6	87.6	0.2	16.7	0.8	69.9	87.6
1986–87	88.7	88.7	0.2	17.2	0.7	70.6	88.7
1987–88	90.6	90.6	0.2	18.9	0.7	70.7	90.6
1988–89	93.9	93.9	0.2	21.0	0.7	72.0	93.9
1989–90	97.8	97.8	0.1	22.9	0.7	74.1	97.8
1990–91	100.1	100.1	0.2	23.0	0.7	76.2	100.1
1991–92	101.6	101.6	0.2	22.3	0.7	78.4	101.6
1992–93	104.7	104.7	0.1	23.3	0.7	80.7	104.7
1993–94	107.1	107.1	—	24.9	0.6	81.6	107.1

Source: ABARE 1995.

Table 8.4 lists more detailed information on consumption of wood fuels by type of equipment. Home heating in open and slow combustion stoves (domestic appliances) was the major consumer of wood fuels. Industrial boilers used for local electricity generation also consumed significant quantities of wood fuels. Commercial appliances had relatively limited but steady consumption of wood fuels over most of the period.

8.4 WOOD FUEL USE, BY EQUIPMENT TYPE

Year	*Boilers*	*Industrial dryers*	*Kilns*	*Metallurgical process equipment*	*Commercial appliances*	*Domestic appliances*	*Others*	*Total*
	PJ	PJ	PJ	PJ	PJ	PJ	PJ	PJ
1982–83	14.4	0.3	0.6	0.2	0.6	69.1	—	85.2
1983–84	14.3	0.2	0.7	0.3	0.6	69.3	—	85.4
1984–85	14.3	0.3	0.9	0.2	0.6	69.7	—	86.0
1985–86	15.6	0.5	0.7	0.2	0.6	69.9	—	87.5
1986–87	16.1	0.4	0.8	0.2	0.6	70.6	—	88.7
1987–88	16.6	0.5	0.7	0.5	0.6	70.8	1.1	90.8
1988–89	17.5	0.5	0.6	0.6	0.6	72.0	2.1	93.9
1989–90	18.2	0.9	1.1	0.9	0.6	74.1	2.2	98.0
1990–91	18.2	0.7	1.0	1.0	0.6	76.2	2.3	100.0
1991–92	19.1	0.7	0.8	0.2	0.6	78.4	1.9	101.7
1992–93	20.1	0.7	0.7	0.1	0.6	80.7	2.0	104.9
1993–94	21.8	0.7	0.8	0.0	0.4	81.6	1.9	107.2

Note: Totals in this table do not necessarily equal Consumption in table 8.3 due to some conversion activities within those sectors.

Source: ABARE 1995.

Bagasse is only produced in sugar manufacturing, and used directly as an energy source to produce electricity in sugar mills. The supply of bagasse depends upon farm production levels, usage beyond the farm and processing facility or storage capacity. Table 8.5 shows that during the years, 1982–94, the production and use of bagasse fluctuated between 64 and 85 petajoules per year.

8.5 FLOW ACCOUNT FOR BAGASSE

	Supply	*End use*
	Production	*Food industry*
Year	PJ	PJ
1982–83	71.9	71.9
1983–84	69.0	69.0
1984–85	72.9	72.9
1985–86	71.4	71.4
1986–87	73.4	73.4
1987–88	73.9	73.9
1988–89	80.7	80.7
1989–90	81.5	81.5
1990–91	78.2	78.2
1991–92	63.5	63.5
1992–93	78.0	78.0
1993–94	84.5	84.5

Source: ABARE 1995.

RESIDUAL ACCOUNTS FOR WOOD FUELS AND BAGASSE

As with fossil fuels, air pollution is a major concern for wood fuels and bagasse, because they release a range of pollutants into the atmosphere during combustion. Wood fuel combustion normally produces higher levels of carbon dioxide emissions than black coal but slightly less than brown coal, while bagasse is the highest emitter of carbon dioxide amongst all common fuels. In general, wood fuels and bagasse also generate higher emissions of carbon monoxide and methane than coal. Table 8.6 lists the emission factors of some air pollutants and greenhouse gases from wood fuels and bagasse combustion.

In table 8.6, it can be seen that industrial combustion of wood fuels has much lower emission factors for carbon monoxide and methane than for domestic use. Residential wood burning causes much higher air pollution. For example, using residential wood-fireplaces produces 11 times more carbon monoxide (7,800 tonnes per petajoule) than industrial wood-fired boilers (680 tonnes per petajoule). Commercial boilers have about half the carbon monoxide emissions of industrial boilers and are also lower in methane and oxides of nitrogen emissions. The use of bagasse causes higher emissions of carbon monoxide (1,625 tonnes per petajoule) than wood-fired boilers.

8.6 EMISSION FACTORS FOR WOOD FUEL AND BAGASSE COMBUSTION

	Pollutants			
	CO	*CH_4*	*NOx*	*N_2O*
	Mg/PJ	Mg/PJ	Mg/PJ	Mg/PJ
Other energy transformation and industrial				
Wood-fired boilers	680.0	4.2	75.0	4.1
Bagasse-fired boiler	1 625.0	10.0	84.0	4.1
Commercial				
Wood boilers	330.0	3.4	19.0	4.1
Residential				
Wood-fireplaces	7 796.0	2 686.0	80.0	4.1
Wood-stoves	7 123.0	148.0	86.0	4.1

Source: NGGIC 1996.

Table 8.7 provides estimates of air pollutants and greenhouse-gas emissions from wood-fuel combustion in 1993–94. As expected, wood fireplaces and wood-stoves in the residential sector contributed most of the emissions: in 1993–94 about 76% of the total carbon dioxide emissions, 97.3% of carbon monoxide, 99.8% of methane and 79% of oxides of nitrogen.

Following the increase of wood fuel use from 97.6 petajoules in 1989–90 to 106.8 petajoules in 1993–94 (9.4%) as shown in table 8.7, the carbon dioxide emissions increased by 9% in total while carbon monoxide, methane and oxides of nitrogen emissions increased by 10%.

8.7 AIR POLLUTANTS AND GREENHOUSE-GAS EMISSIONS FROM WOOD-FUEL COMBUSTION

	Energy use	*CO_2*	*CO*	*CH_4*	*NOx*	*N_2O*
	PJ	'000 t	'000 t	t	t	t
		1989–90				
Food, beverages and tobacco	2.7	251.0	1.9	10.0	200.0	10.0
Paper, pulp and print production	8.2	758.0	5.6	30.0	600.0	30.0
Wood and wood products	7.9	728.0	5.4	30.0	600.0	30.0
Other manufacturing	3.9	360.0	2.7	20.0	300.0	20.0
Commercial and services	0.7	68.0	0.2	0.0	0.0	0.0
Residential	74.1	6 614.0	544.5	74 880.0	6 200.0	300.0
Total	**97.6**	**8 780.0**	**560.3**	**74 980.0**	**7 900.0**	**400.0**
		1993–94				
Food, beverages and tobacco	3.4	310.0	2.3	10.0	300.0	10.0
Paper, pulp and print production	10.4	961.0	7.1	40.0	800.0	40.0
Wood and wood products	8.5	781.0	5.8	40.0	600.0	30.0
Other manufacturing	2.3	215.0	1.6	10.0	200.0	10.0
Commercial and services	0.6	53.0	0.2	0.0	0.0	0.0
Residential	81.6	7 284.0	599.7	82 460.0	6 900.0	330.0
Total	**106.8**	**9 605.0**	**616.6**	**82 560.0**	**8 700.0**	**440.0**

Source: NGGIC 1996.

Air pollutants and greenhouse-gas emissions from bagasse combustion are given in table 8.8. During the period shown, the use of bagasse increased by 4% and consequently the estimates of emissions for all gases increased by about the same amount.

8.8 AIR POLLUTANTS AND GREENHOUSE GAS EMISSIONS FROM BAGASSE COMBUSTION

	Energy use	*CO_2*	*CO*	*NOx*
	PJ	'000 t	'000 t	'000 t
1989–90	81.5	7 735.0	132.5	6.8
1993–94	84.5	8 014.0	137.3	7.1

Source: NGGIC 1996.

CHAPTER 9 OTHER RENEWABLE ENERGY SOURCES: SOLAR AND WIND

The extensive use of fossil fuels has introduced a number of environmental problems, such as air pollution and the 'Enhanced Greenhouse Effect'. Although natural gas might significantly reduce the pollution level, long-term resource availability is questionable. With current technology, nuclear power has barriers associated with operational safety and nuclear waste disposal, so that it has not been adopted by Australia.

Renewable sources of energy have a relatively low impact on the environment when compared with the non-renewable sources. Apart from hydro, wood and bagasse, vast potential sources of energy exist with wind, solar, other biomass, geothermal, tidal, wave and ocean thermal energy. In Australia, wind and solar energy have been used in small-scale applications, and geothermal and other biomass energy are still at the research stage.

This chapter discusses renewable sources of energy in Australia with the emphasis being placed on currently-used energy forms such as wind and solar.

SOLAR ENERGY

Background

Solar energy is essential to support the life cycle of the earth. Many physical, chemical and biological phenomena depend upon solar energy, for example, atmospheric circulation, ozone layer formation and plant growth. The sun's energy has been used in warming and drying for a variety of industrial and domestic purposes. With the development of technology, solar energy can be used in many areas, such as heating and cooling, and electricity generation.

Current solar energy systems are of two major types: solar thermal and solar photovoltaic systems. Both of them are widely used in solar energy systems.

Solar thermal systems concentrate sunlight to produce hot liquids, solids and gases. In a power station, the collected heat is transferred to turbine-generator systems which produce electricity. For domestic water heating, water is heated directly and is ready for use.

Common photovoltaic systems use photovoltaic modules rather than solar collectors. Photovoltaic modules consist of a number of solar cells to convert sunlight directly into electricity. To produce a large amount of power, many photovoltaic modules are mounted together to form a photovoltaic array.

For large-scale power generation with a high proportion of the overall load (over 30%), both systems may comprise electrical storage and electronic control equipment. They could also be attached to a generator which may use diesel, petrol or gas as fuel in order to supplement the electricity supply in case of bad weather or at night.

Currently no large-scale solar power plants are located in Australia. There are some 300,000 installations of solar thermal systems and over 10,000 solar photovoltaic installations, which meet less than 0.1% of Australia's total energy requirements.

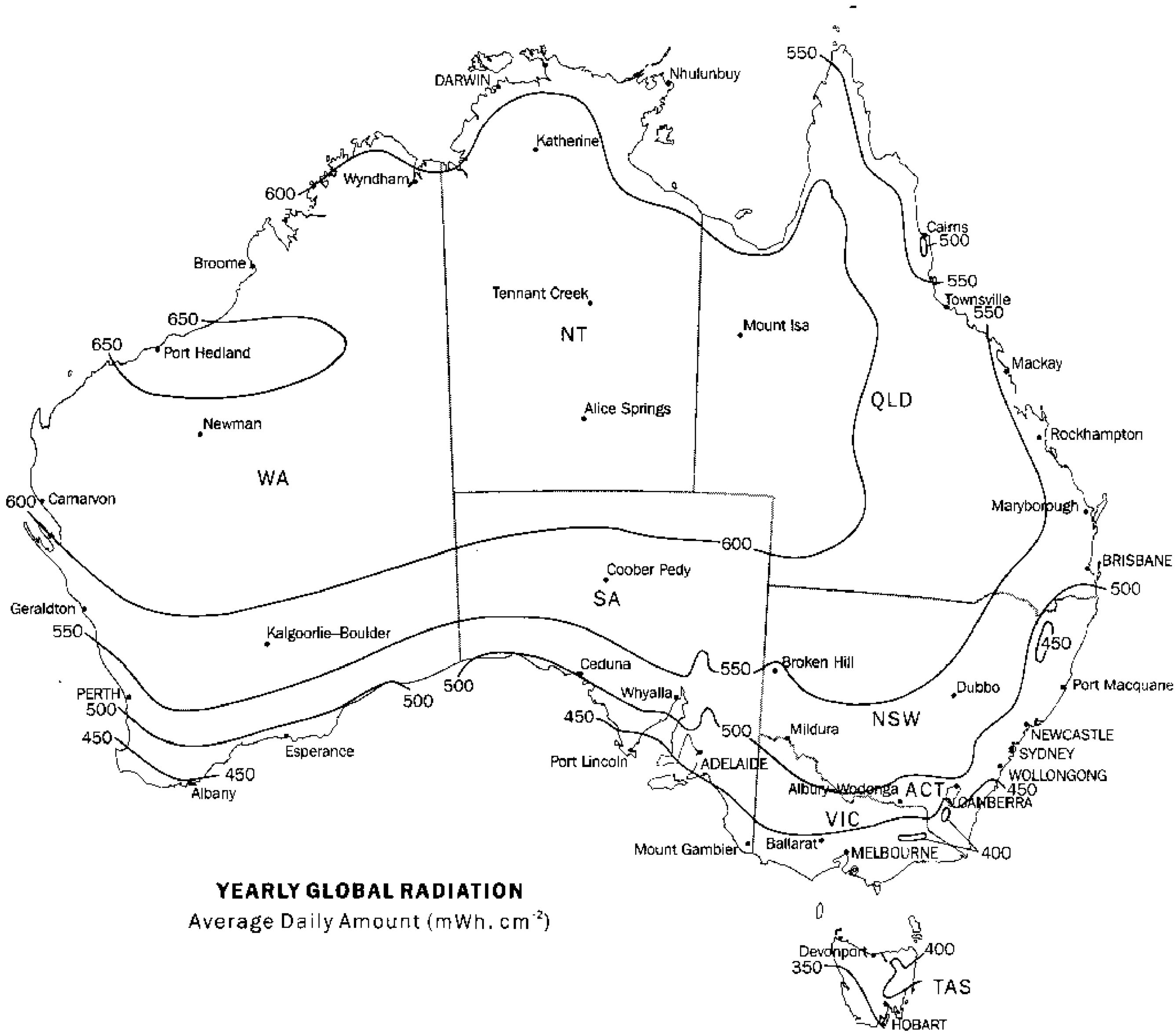
Stock (potential) accounts for solar energy

Australia has vast solar energy potential because of its land area and position in the southern high pressure belt region, thereby receiving a large amount of sunshine compared with many other countries. It has been estimated that the average solar energy received by Australia is approximately 60 million petajoules per year. This amount is more than 20,000 times the current energy use and about 39,000 times current electricity consumption. Therefore, solar energy has the theoretical potential to meet Australia's electricity requirements.

Solar energy can be measured by radiation level and bright sunshine level during the day. These are monitored in meteorological stations. Radiation from the sun can be a direct beam or indirect diffuse in nature; the sum is called global radiation. A quantitative measure is the amount of radiation received per unit area in a given time (the irradiation levels, for example, watts per square metre per day). Map 9.1 presents the average daily amount of global radiation on a horizontal surface in Australia.

Map 9.1 shows that there is a significant variation in the irradiation level on a horizontal surface in Australia. In the densely populated areas such as the south-east of Australia, the average daily irradiation level received is relatively low, between 400 and 500 milliwatt hours per square centimetre. Areas inland from the Great Dividing Range, show a significant increase in the irradiation level, while the highest irradiation occurs in the north-west of Australia, topping 650 milliwatt hours per square centimetre.

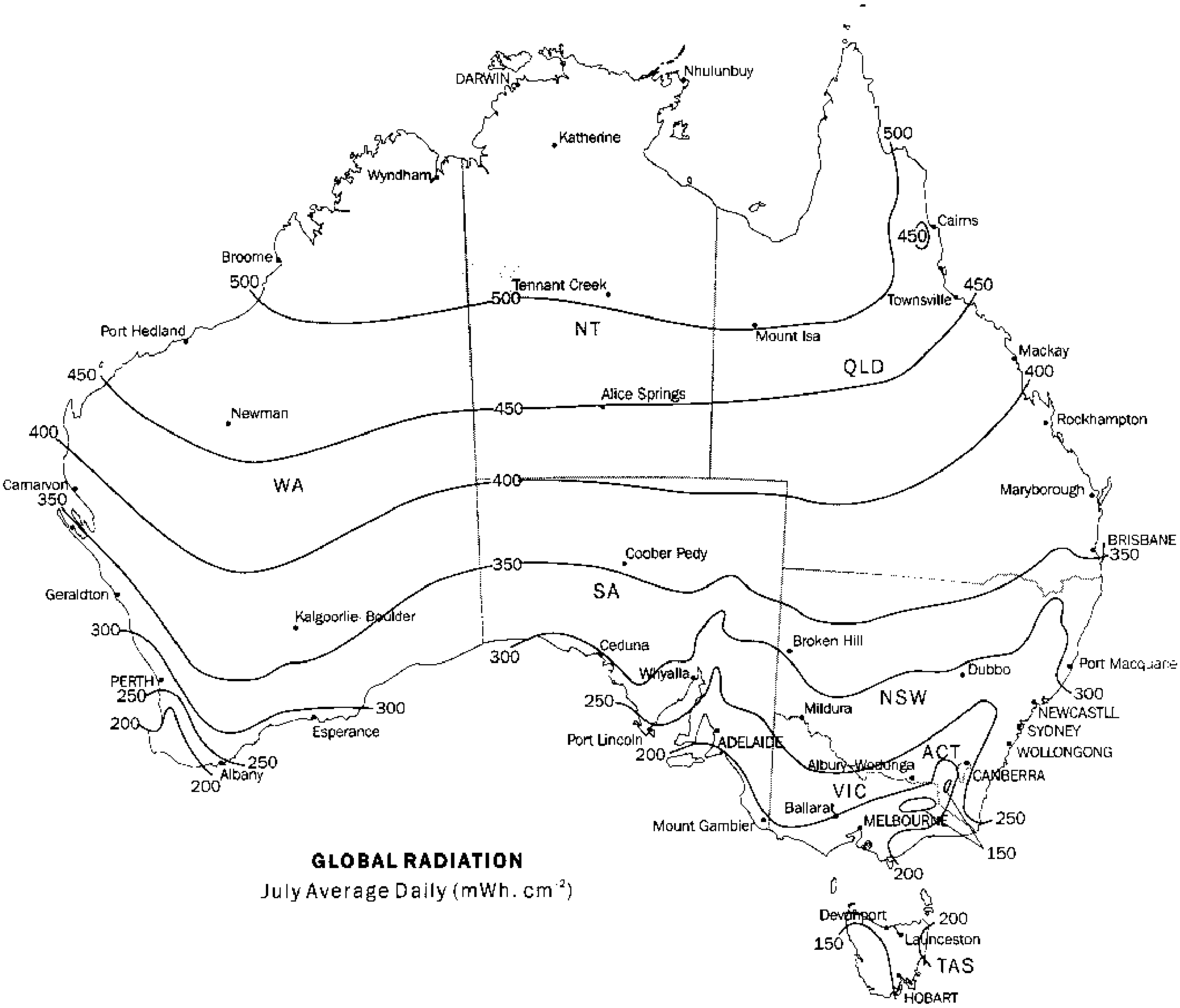
9.1 AVERAGE DAILY GLOBAL RADIATION ON A HORIZONTAL SURFACE



Source: DASETT 1991a.

Map 9.2 illustrates the change in the irradiation level with the seasons. In January, some areas in Western Australia can reach about 900 milliwatt hours per square centimetre on average, the highest irradiation level of the year. July is the lowest month, with the irradiation level averaging about 50 milliwatt hours per square centimetre in some areas of New South Wales and Tasmania. Average daily global irradiation levels for 22 selected locations around Australia are tabulated in table 9.3. The average daily global irradiation in Australia is 21 megajoules per square metre or 583 milliwatt hours per square centimetre.

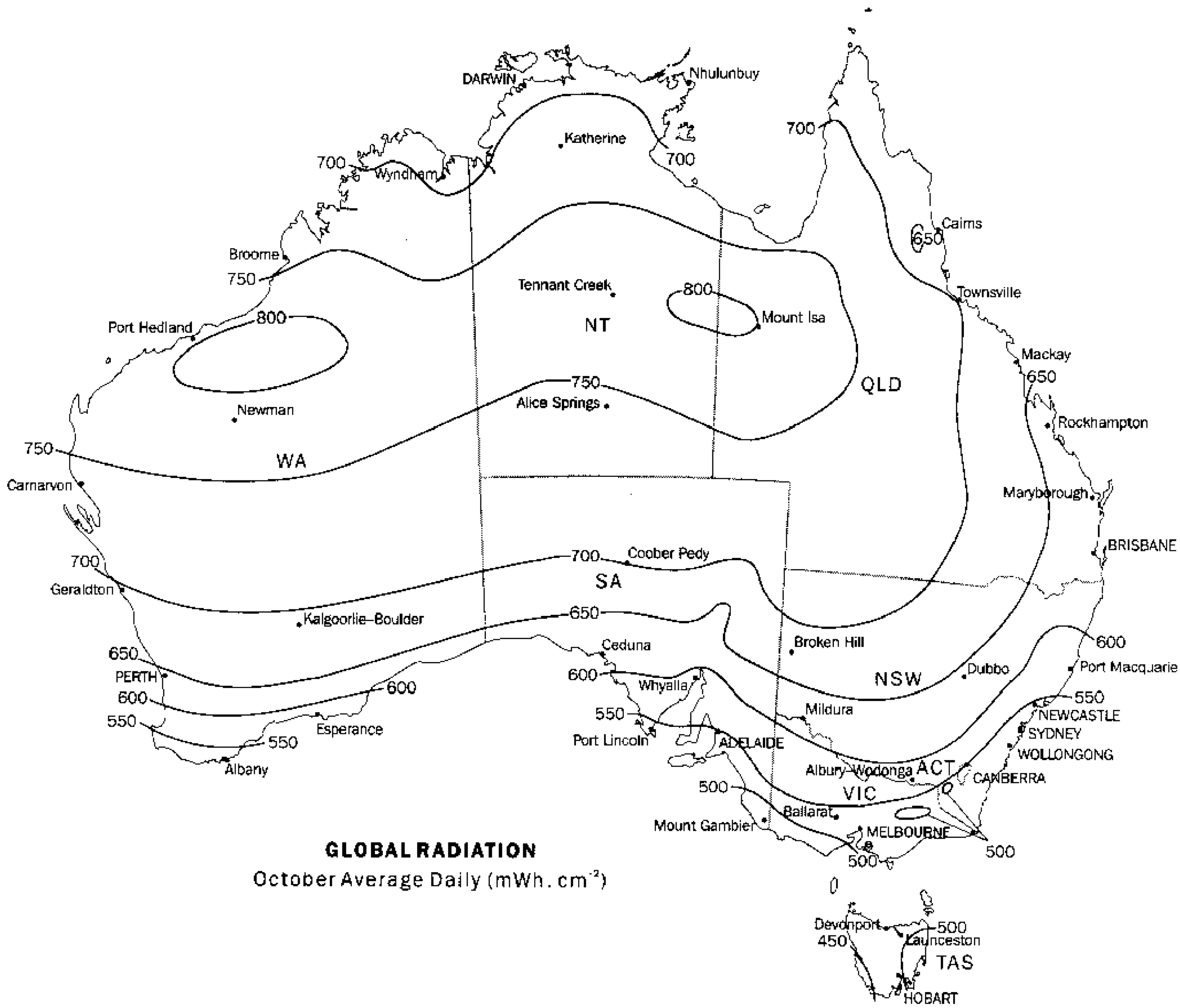
9.2 AVERAGE DAILY GLOBAL RADIATION ON A HORIZONTAL SURFACE BY SEASON



GLOBAL RADIATION
July Average Daily (mWh. cm^{-2})

Source: DASETT 1991a.

9.2 AVERAGE DAILY GLOBAL RADIATION ON A HORIZONTAL SURFACE BY SEASON — *continued*



GLOBAL RADIATION
October Average Daily ($mWh.cm^{-2}$)

Source: DASETT 1991a.

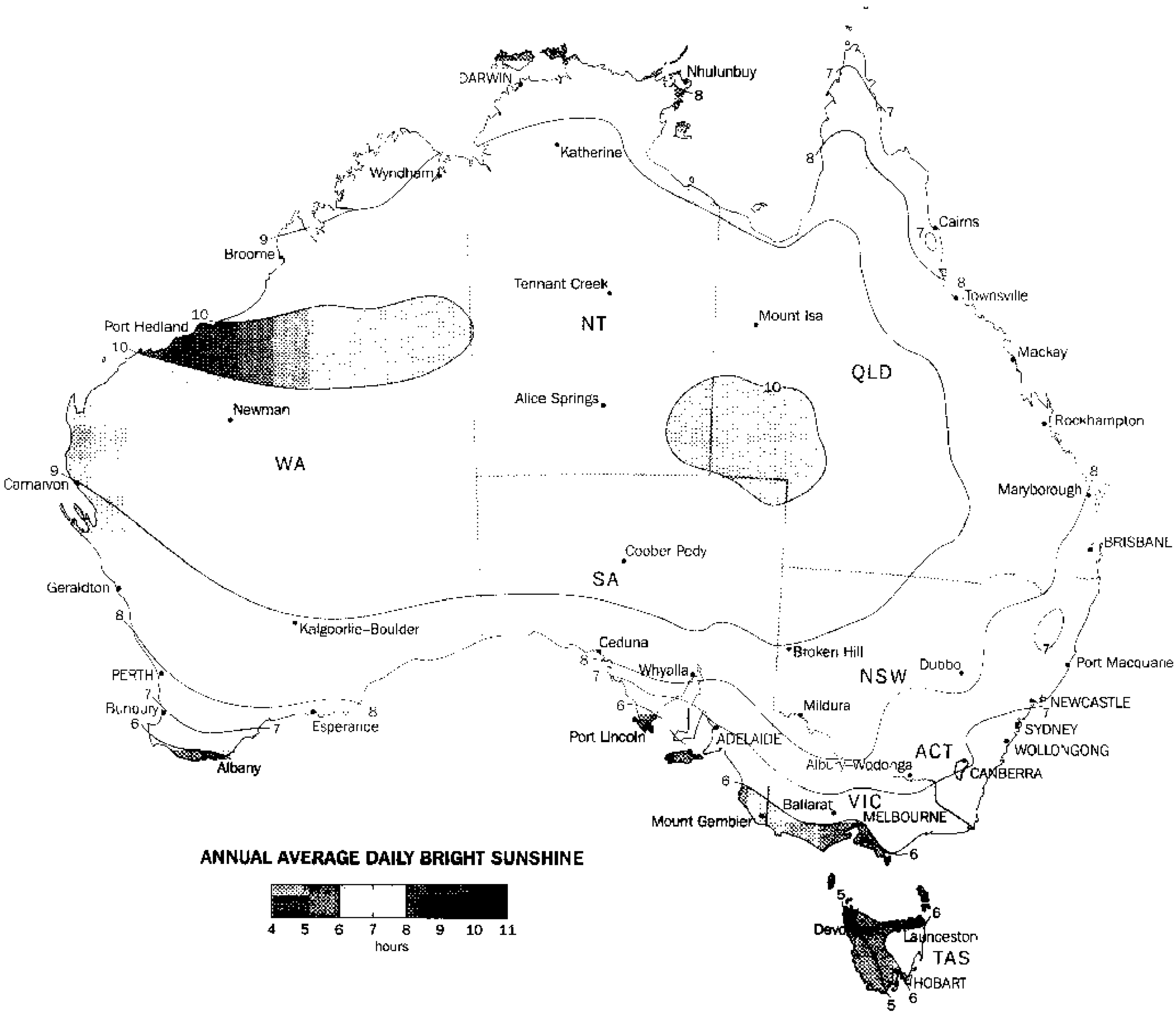
9.3 AVERAGE DAILY GLOBAL IRRADIATION LEVELS FOR 22 LOCATIONS (HORIZONTAL COLLECTING SURFACE)

Town	*Irradiation* MJ/m^2
Adelaide	17.9
Albany	15.5
Alice Springs, NT	22.2
Brisbane, Qld	17.8
Canberra, ACT	17.4
Darwin, NT	21.7
Forrest, WA	20.0
Geraldton, WA	20.9
Halls Creek, NT	22.3
Hobart, Tas.	13.7
Laverton, Vic.	15.3
Longreach, Qld	22.0
Melbourne, Vic.	14.6
Mildura, Vic.	18.6
Mt Gambier, SA	14.9
Oodnadatta, SA	21.3
Perth, WA	18.3
Port Hedland, WA	23.1
Rockhampton, Qld	19.0
Sydney, NSW	16.9
Wagga, NSW	17.9
Williamtown, NSW	17.4
Australia	**21.0**

Source: DASETT 1991a.

The data on bright sunshine are normally not as accurate as radiation data. However, they are useful as indicators to determine those locations which have long periods of cloud-free sky and are suitable for installing solar-concentrating systems. Bright sunshine is recorded by Campbell-Stokes recorders. The hours of sunshine during a day depends upon the period between sunrise and sunset, and the occurrence of cloud. Map 9.4 shows the annual average daily bright sunshine in Australia.

9.4 ANNUAL AVERAGE DAILY BRIGHT SUNSHINE



Source: AUSLIG 1986.

More than three-quarters of Australia averages at least eight hours of bright sunshine a day or about 3,000 hours a year. Maximum sunshine hours are around the channel country of south-west Queensland and in a narrow belt running east from Port Hedland to the Northern Territory border, being over 10 hours a day or 4,400 hours a year. Lowest average sunshine hours are recorded on the west coast and adjacent highlands of Tasmania, accounting for less than five hours a day. Table 9.5 lists the monthly and annual average daily hours of bright sunshine for 11 selected locations.

9.5 ANNUAL AVERAGE DAILY HOURS OF BRIGHT SUNSHINE

Station	*Years of record*	*Sunshine hours*
Adelaide, SA	95.0	6.9
Alice Springs, NT	31.0	9.5
Brisbane, Qld	40.0	7.6
Canberra, ACT	7.0	7.7
Darwin, NT	33.0	8.4
Hobart, Tas.	54.0	5.9
Melbourne, Vic.	85.0	5.6
Mount Isa, Qld	9.0	9.4
Perth, WA	54.0	8.0
Sydney, NSW	54.0	6.7
Townsville, Qld	27.0	8.3

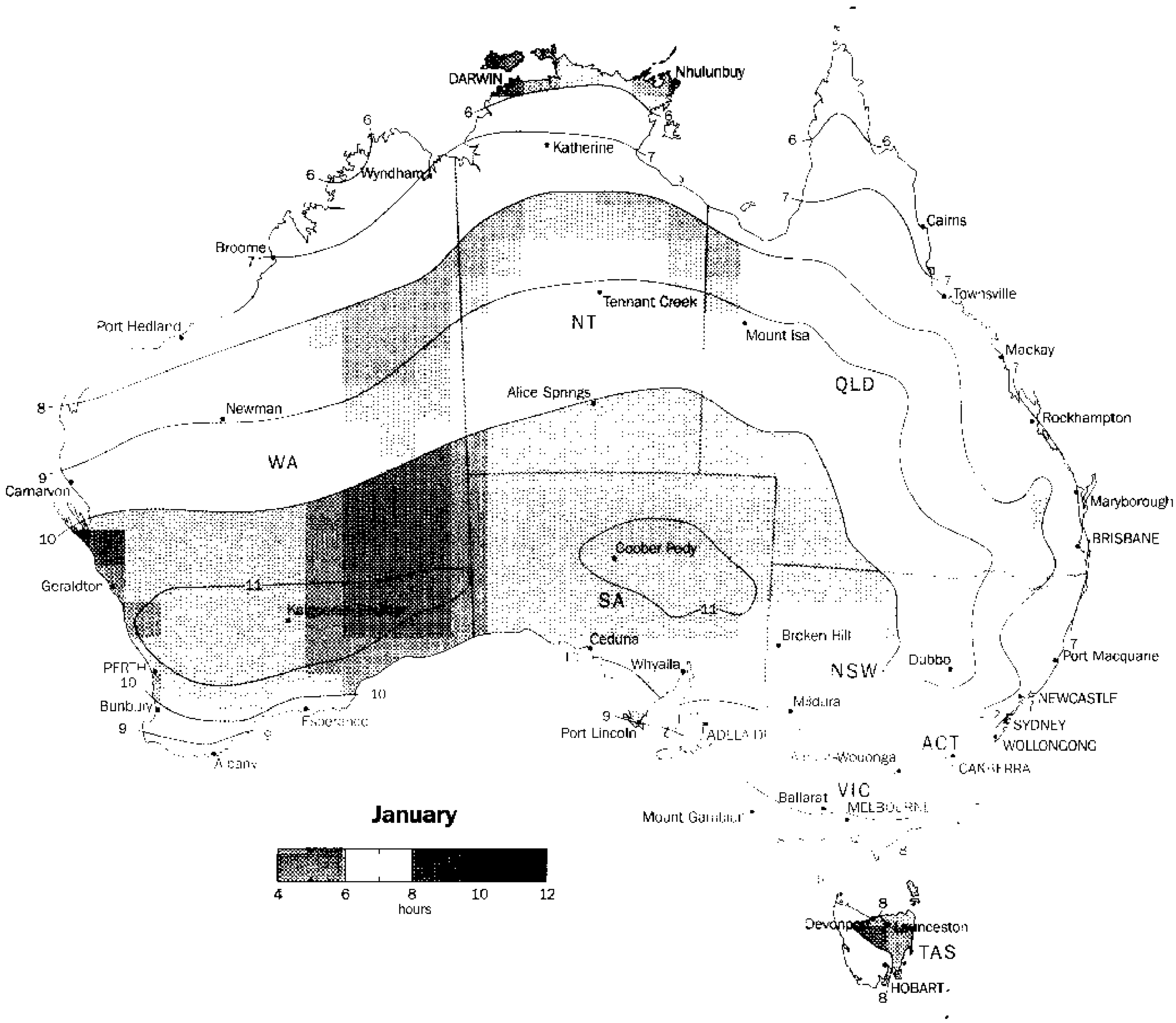
Source: AUSLIG 1986.

The sunshine hours vary a great deal with the seasons. Map 9.6 shows that October has the highest average sunshine hours. The duration of sunshine is reduced in January despite the maximum possible of up to nearly 15 hours. By April, sunshine hours are substantially reduced due to cloud associated with the increasing frequency of mid-latitude depressions. In July, greatest cloudiness in the south of the mainland and Tasmania reduce the sunshine further to record the lowest sunshine period during a year.

Using the irradiation level of inland Australia and the current output from the photovoltaics array in the United States of America with a capacity factor of 25%, a theoretical calculation shows that an area of approximately 2,500 square kilometres would be required to meet Australia's annual electricity consumption of about 570 petajoules. By installing solar thermal systems, the theoretical calculation shows that the current demand for electricity would be generated from solar energy with land coverage of approximately 1,550 square kilometres (Department of the Arts, Sport, the Environment, Tourism and Territories (DASETT) 1991a). It should be noted that there are still a number of technical and economical problems associated with large-scale use of solar energy in Australia, such as transmission loss and cost of installation and maintenance.

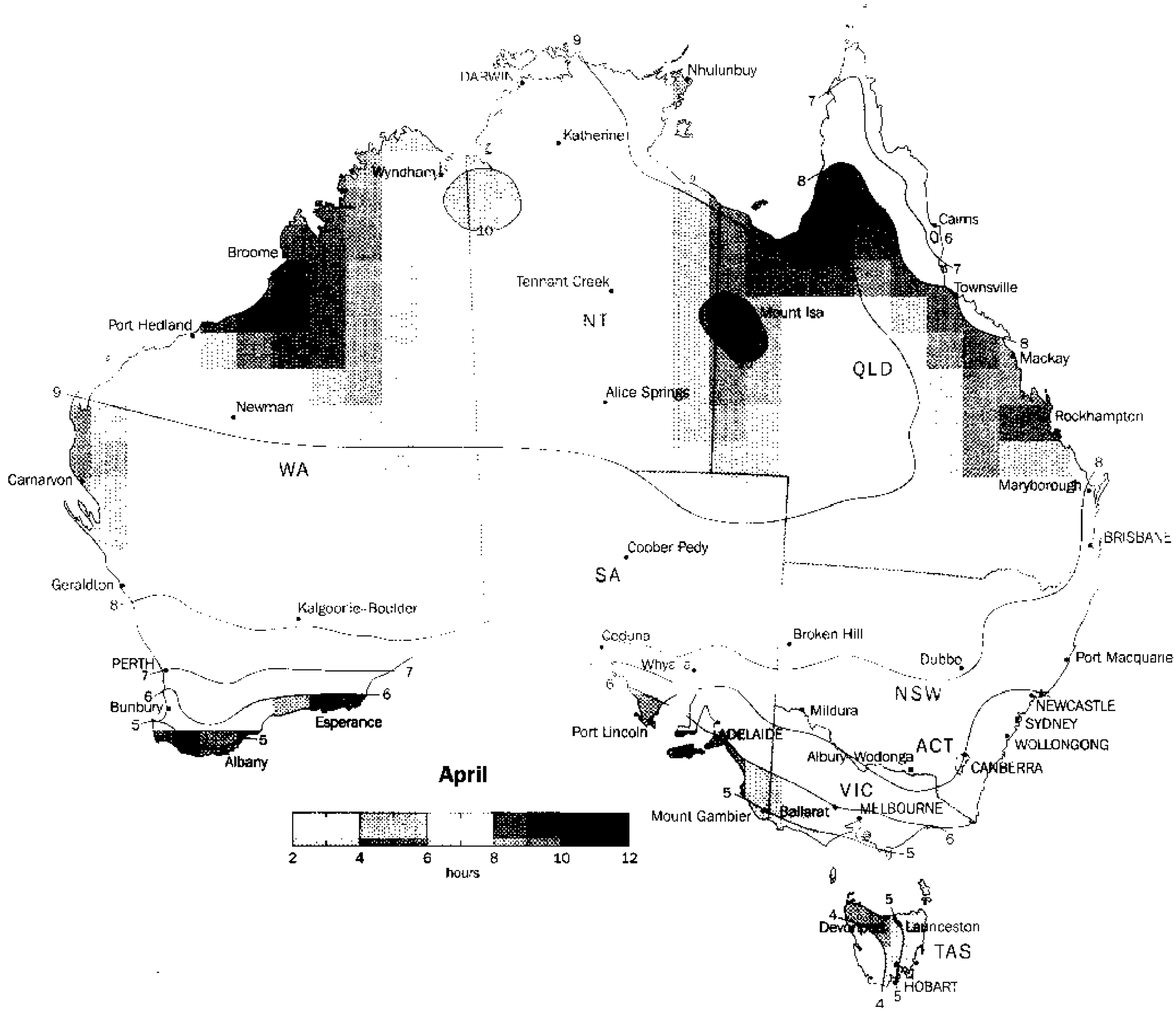
Australia was one of the first countries in the world to apply solar energy technology in telecommunication systems and other applications in remote areas and in regions where it is not possible to be connected to the main electricity supply grid. It is estimated that about 5–7 megawatts of photovoltaic solar power units have been installed across Australia with average production capacity of 36 megajoules (10 gigawatt hour) a year. In the past there were several attempts in Australia to install solar electricity power plants, such as the Meekatharra project (56 kilowatts), North of Perth solar power plant (35 kilowatts), and White Cliffs solar power plant (25 kilowatts). A new solar power system has been installed in Kalbarri of Western Australia with capacity of about 22 kilowatts.

9.6 AVERAGE DAILY BRIGHT SUNSHINE BY SEASON

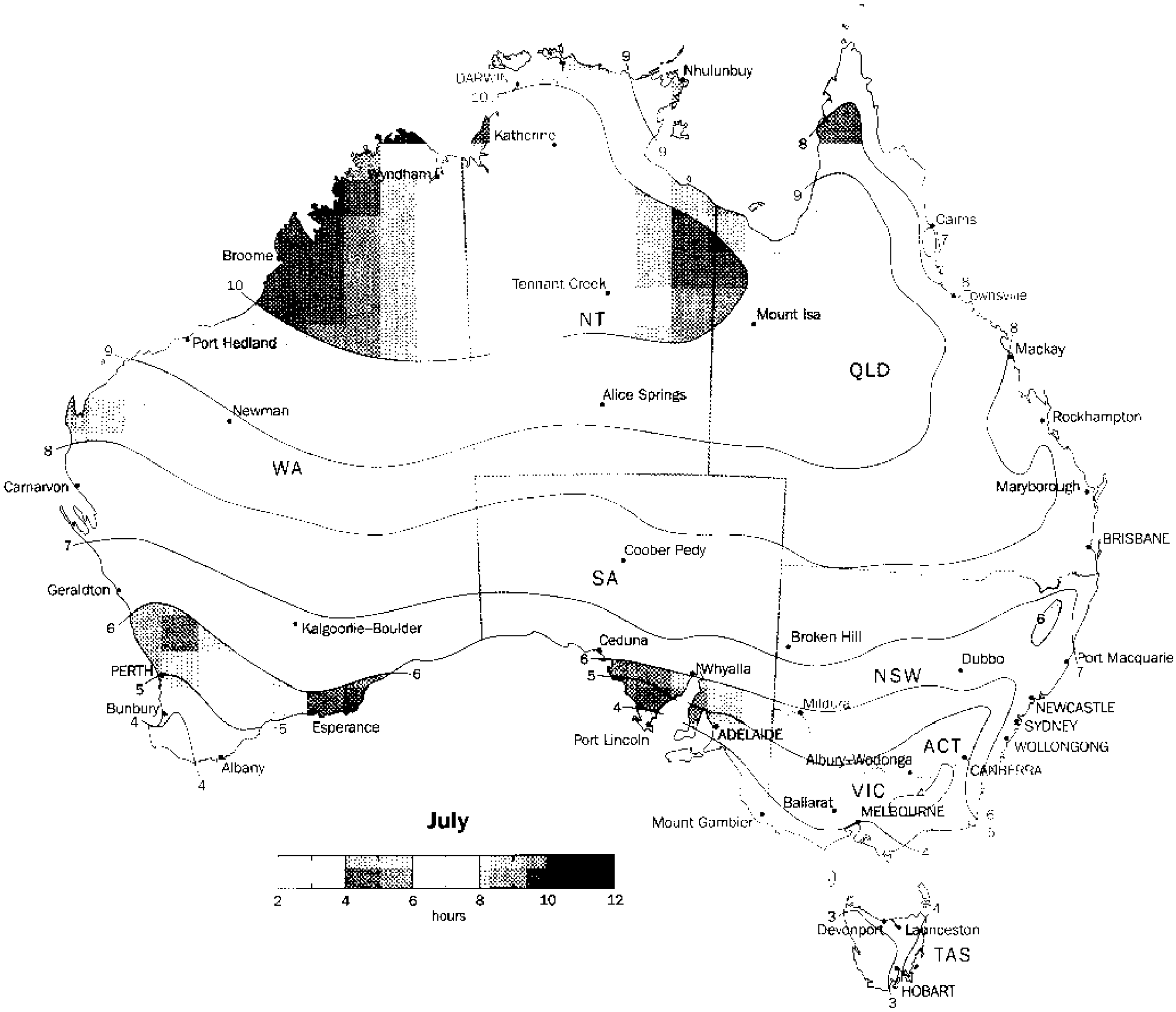


Source: AUSLIG 1986.

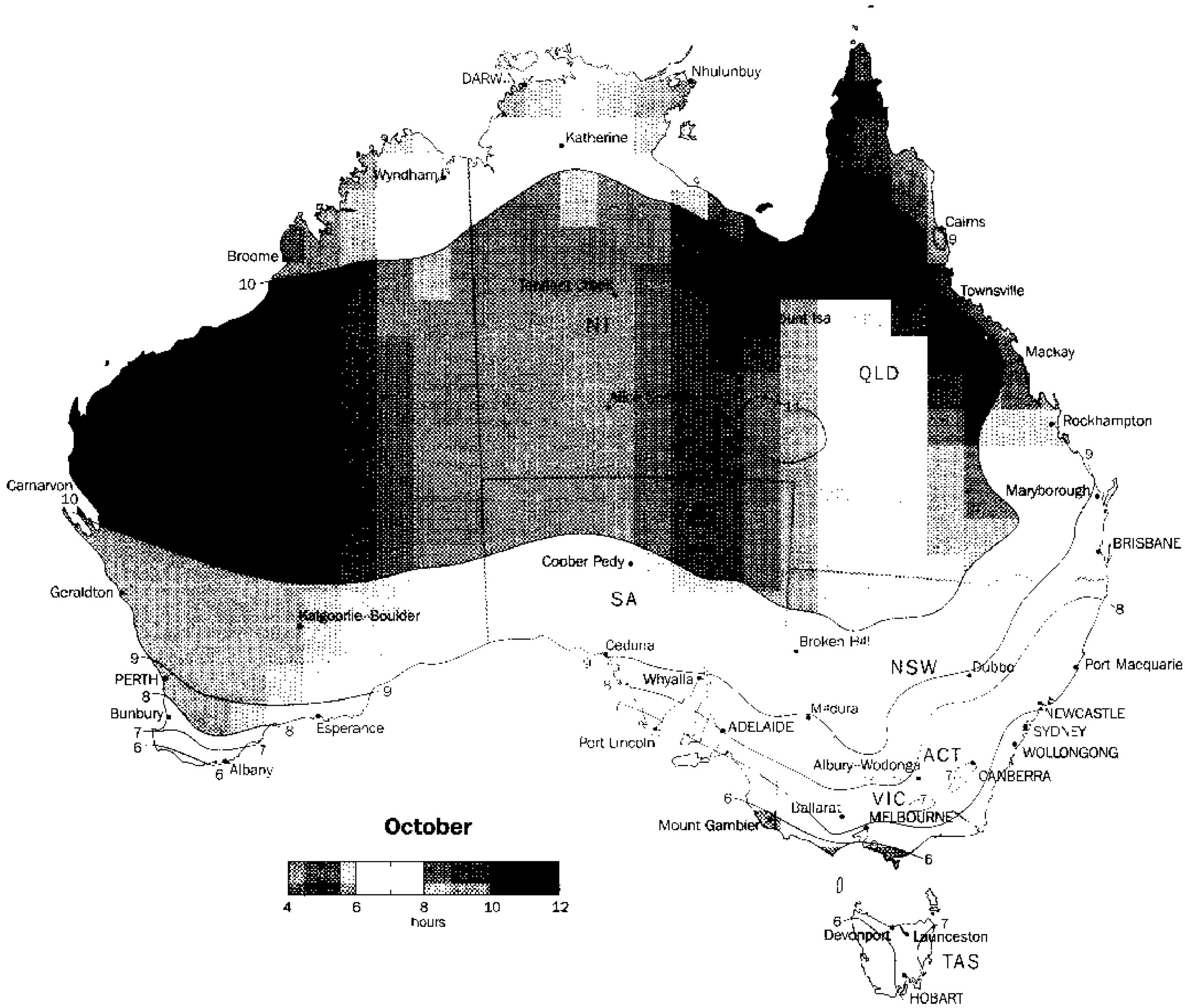
9.6 AVERAGE DAILY BRIGHT SUNSHINE BY SEASON — *continued*



Source: AUSLIG 1986.



Source: AUSLIG 1986.



Source: AUSLIG 1986.

FLOW ACCOUNT FOR SOLAR ENERGY USAGE

Most conventional solar energy uses, such as agricultural crop growth, laundry drying and passive building heating, are difficult to quantify and aggregate although they would usually consume large amounts of solar energy. Current attention mainly focuses on the substitution possibilities for primary fuels and electricity generation by using solar energy. These include applications such as hot water heating systems, air-conditioning systems, solar pool heaters, water pumps, solar-powered vehicles or other machines, solar-powered communications systems, and grid or non-grid solar power stations. However, quantitative data on the use of solar technology for this range of applications is very limited.

Information is only available for domestic hot water heating systems. About 5% of Australian residences have domestic solar hot water units (based on June 1994 Australian Bureau of Statistics (ABS) household survey). Table 9.7 provides estimates of the consumption of solar energy used for hot water heating. This estimate was based on the installation of solar hot water systems and has taken into account the amount of energy consumed in a typical household hot water system, including heat losses, and the proportion replaced by solar collector (Australian Bureau of Agricultural and Resource Economics (ABARE 1995). During the period 1982 to 1994, the solar energy used for domestic hot water systems has increased about 50%. However, compared with the total of public electricity supply, solar energy used was still a minor quantity being less than 1% of the electricity supply.

9.7 SOLAR ENERGY USED FOR DOMESTIC HOT WATER SYSTEMS

Year	*Solar energy* PJ	*Electricity supply* PJ	*Total* PJ	*Proportion solar* %
1982–83	1.6	383.8	385.4	0.4
1983–84	1.8	405.9	407.7	0.4
1984–85	2.1	435.5	437.6	0.5
1985–86	2.5	457.0	459.5	0.5
1986–87	2.6	477.7	480.3	0.5
1987–88	2.4	500.7	503.4	0.5
1988–89	2.8	532.1	534.9	0.5
1989–90	2.4	557.6	561.3	0.5
1990–91	2.4	563.6	568.0	0.6
1991–92	2.4	573.8	576.3	0.6
1992–93	2.4	578.5	580.9	0.4
1993–94	2.4	602.0	604.4	0.4

Source: ABARE 1995.

The conventional solar energy uses, such as passive solar heating, laundry drying and crop growing are extensive. For illustrative purposes, the consumption of solar energy used for evaporation in salt production is shown below. The Australian salt industry operates over 28,000 hectares of evaporative ponds to produce 8.4 million tonnes of salt per year. Table 9.8 lists some of the evaporative solar salt ponds and estimates of solar energy used. The estimate shows that salt production in Australia uses about 177 megajoules of solar energy per day, with annual power equivalent of more than 121 gigawatts a year. During the eight operating months in a year, the total solar energy consumed in salt production is about 973 petajoules.

9.8 EVAPORATIVE SOLAR SALT PONDS, 1991

Location	*Production* mill. t/year	*Area* ha	*Estimate* MJ/day	*Average* GW
Lake Macleod	1.6	1 970	24	5.5
Karratha	2.6	9 850	23	38.0
Useless Inlet	0.7	3 950	24	21.0
Hedland	2.3	7 780	23	25.0
South Australia	1.0	4 000	20	9.0
Victoria	0.2	600	18	1.3
Queensland	0.2	700	22	1.8
Total	**8.4**	**28 850**	**23**	120.6

Source: DASETT 1991c.

Residual accounts for solar energy usage

The utilisation of solar energy is one alternate energy resource to reduce environmental pollution, including greenhouse gas emissions. As indicated in previous chapters, use of fossil fuels is a major factor in the impact on environmental media. During combustion, fossil fuels provide a supply of energy for human consumption but at the same time release residuals causing environmental damage.

Solar energy is in itself residue-free. There are a wide range of applications where solar energy can replace fossil fuels, such as process heat and electricity generation. Table 9.9 provides an account of potentials for using solar thermal energy to displace carbon dioxide. Note that the result is hypothetical and only illustrates the possible positive impact of using solar energy. The term 'Solar fraction' refers to the percentage of solar energy which could be used to displace other energy forms.

9.9 POTENTIALS FOR SOLAR THERMAL ENERGY TO DISPLACE CO_2

Area	Solar fraction %	CO_2 saving/year[1] %
Domestic hot water	70.0	2.4
Space heat and cooking	70.0	4.4
Process heat general	50.0	2.9
Petroleum refineries[2] and basic chemical process heat	25.0	1.6
Recycling CO_2 and natural gas	33.0	3.0
Processing bauxite to alumina	50.0	1.3
Drying brown coal	90.0	0.7
Electricity generation solar[3]	26.0	15.8
Bagasse/biomass backup[4]	25.0	3.0
Natural gas backup[4]	25.0	4.0
Total	—	**38.8**

[1] CO_2 saving/year is based on ABARE Business As Usual 2004/05 projection of 379 million tonnes CO_2.
[2] Displacing natural gas to generate electricity — with no storage.
[3] Alternatively 51% solar fraction (load factor) and 25% penetration by using thermal storage.
[4] Displacing average black and brown coal.

Source: DASETT 1991a.

An environmental impact of using solar energy is land use. The energy collected from the sun is proportional to the area coverage of irradiation. As mentioned previously, in order to supply the current level of electricity consumption, if adopting photovoltaic arrays located in inland Australia, an area of approximately 2,500 square kilometres would be required. When employing solar thermal systems, solar collectors would cover 1,550 square kilometres of land (DASETT 1991a). However, this is less than 0.1% of Australia's land area.

Other indirect impacts on the environment occur during the manufacture of materials and equipment for solar energy systems. For example, production of the silicon solar cell of a photovoltaic array involves use of toxic chemicals. Preparation of other basic materials, such as steel and concrete causes pollution. The energy invested in the manufacture of solar energy equipment should be a small fraction of the energy produced by the solar energy system over its lifetime. The energy payback period for photovoltaic cells comprised of silicon wafers is presently in the region of five years, while under current development, new thin film photovoltaic cells would have energy payback periods of less than one year. Their life is expected to be over 20 years.

WIND ENERGY

Background

Wind energy has long been used in transportation and agricultural production such as pumping water and grinding grain. There are two basic types of wind generators: vertical axis and horizontal axis. In modern windfarms, the horizontal axis wind generator is most commonly used. Wind generators are generally installed with single or multiple blades, sweeping an area with a diameter of 20–50 metres, and the capacity of each machine in the range 15–650 kilowatts.

Wind energy resources depend upon climate and topography in the region. The best sites for the large-scale use of wind power station tend to lie in the latitude range 30–70 degrees, often near mountain and coastal areas. However, inland areas also have large wind resource potential. The measurement used for determining wind resources is local wind speed. Theoretical analysis indicates that the energy carried by the wind is proportional to the cube of wind speed. For example, if the wind speed doubles then the wind energy will increase eight times. Average wind speed is used as an indicator for assessment of wind energy in an area of interest, and the lower limit of annual average wind speed for an economically viable site is commonly considered to be not below 5 metres per second (18 kilometres per hour), ideally reaching 6–7 metres per second (22–25 kilometres per hour) (DASETT 1991b).

Stock (potential) accounts for wind energy

Australia abounds with wind energy potential, and large quality wind sites are identified in coastal regions of Tasmania, South Australia, Victoria and the southern part of Western Australia. In Queensland and New South Wales, several locations are also considered as economically viable sites for developing grid or off-grid wind generation of electricity.

Nationwide wind speed data are collected at Bureau of Meteorology stations. These are useful as a rough guide to the general distribution of wind energy in Australia. Map 9.11 shows local surface winds, indicating the most windy areas along the coast. Wind speed is classified as light winds (0–10 kilometres per hour), moderate (10–30 kilometres per hour) and strong (over 30 kilometres per hour). Local winds in coastal areas are strongly affected by sea breezes and land breezes.

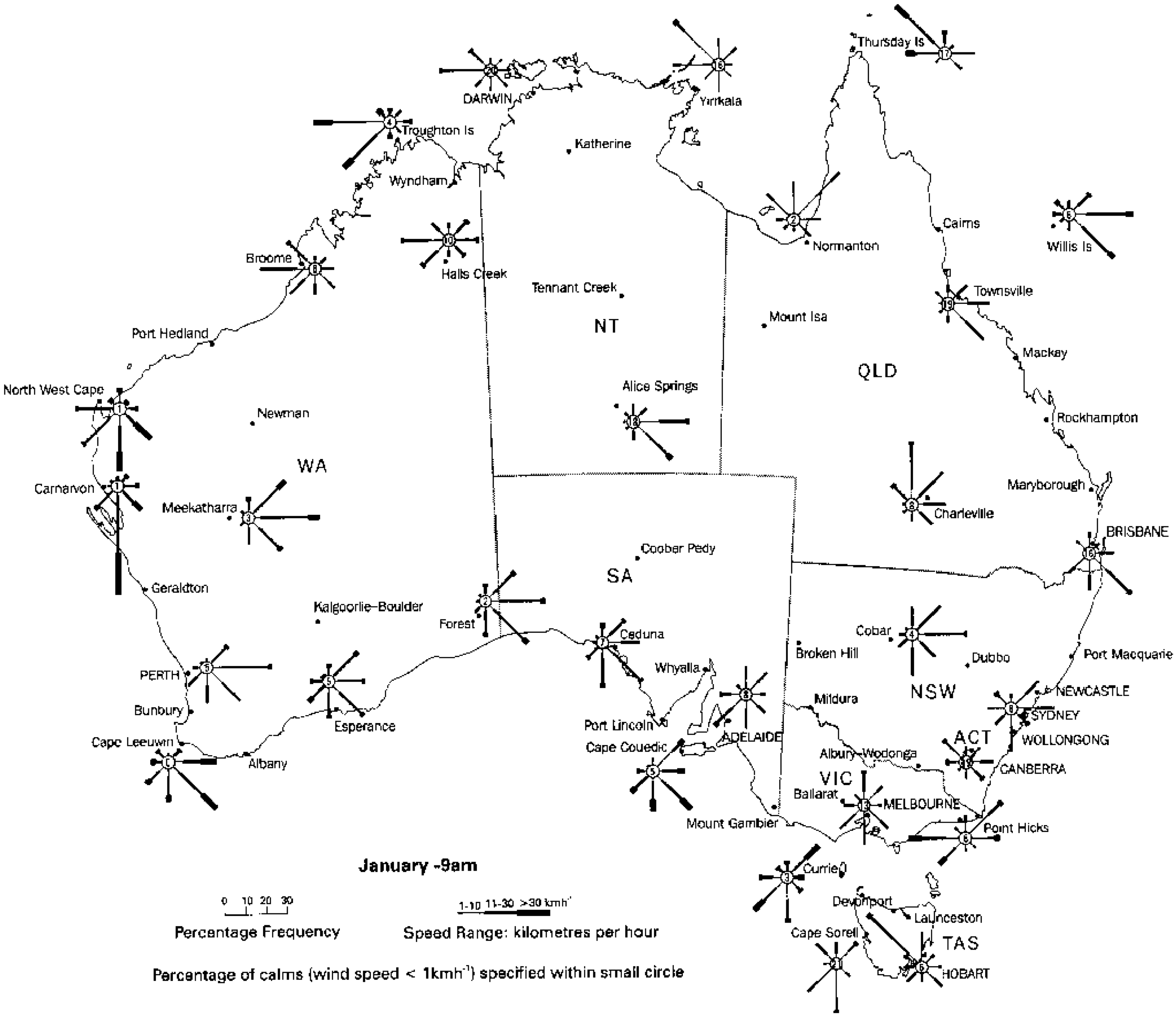
In general, the windiest areas occur along the west and south-west coast of Australia and in Bass Strait. Inland areas have mainly lighter surface winds but some inland areas at certain times of the year experience quite windy conditions. Table 9.10 lists the median wind speeds for some selected areas.

9.10 MEDIAN WIND SPEED

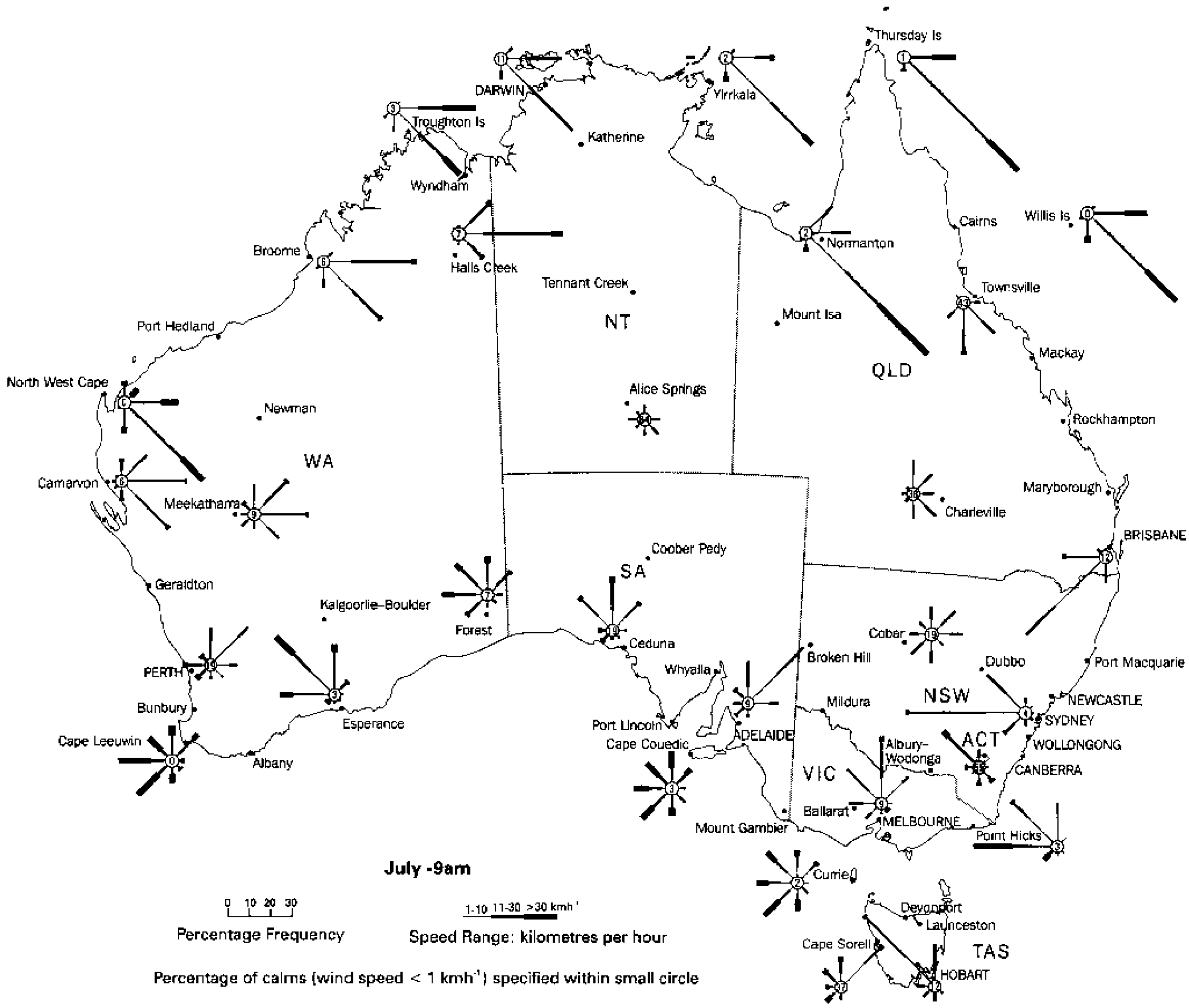
		January		April		July		October	
		9 a.m.	3 p.m.	9 a.m.	3 p.m.	9 a.m.	3 p.m.	9 a.m.	3 p.m.
Station	Years record	km/h	km/h	km/h	km/h	km/h	km/h	km/h	km/h
Darwin	24.0	9.4	17.5	9.1	16.0	11.9	16.2	7.9	18.9
Troughton Island	17.0	15.5	21.2	9.5	10.2	18.1	17.4	8.9	15.8
Cairns	43.0	7.4	14.8	14.5	17.3	15.5	17.3	9.9	17.4
Tennant Creek	15.0	14.5	12.9	22.8	15.9	21.0	14.8	24.4	12.6
Port Hedland	42.0	12.8	24.0	15.0	18.4	19.8	17.4	16.4	23.9
Alice Springs	44.0	11.4	14.9	0.0	13.4	0.0	12.3	15.1	15.0
Lady Elliott Island	26.0	22.0	22.4	25.5	24.2	26.2	21.2	19.0	17.6
Charleville	42.0	14.5	14.0	10.0	11.4	5.0	11.4	15.2	13.5
Meekatharra	34.0	21.0	13.9	18.3	13.3	14.9	13.5	19.9	16.2
Brisbane	33.0	7.1	14.6	6.9	11.0	9.4	9.9	6.1	14.9
Forrest	44.0	19.2	19.3	17.3	15.2	16.4	18.2	20.5	19.5
Perth	42.0	14.0	21.2	9.6	14.7	9.1	14.3	12.6	19.4
Broken Hill	10.0	15.2	12.6	9.0	10.2	7.8	12.8	17.5	17.5
Cape Naturaliste	27.0	27.4	34.0	24.8	24.9	32.4	32.3	25.5	29.1
Sydney	45.0	13.1	22.9	10.4	17.4	11.3	16.5	14.6	22.8
Adelaide	29.0	12.3	21.9	11.5	16.5	12.3	17.1	17.6	20.8
Canberra	45.0	4.6	15.5	0.0	13.3	0.0	16.4	7.6	20.5
Spencers Creek	6.0	16.5	16.8	13.6	13.6	22.1	20.0	18.1	17.4
Melbourne	29.0	9.5	16.4	8.2	14.3	10.8	16.0	13.1	16.9
Wilsons Promontory	27.0	27.2	27.5	24.7	24.2	28.1	25.5	26.5	26.8
Hobart	40.0	12.8	17.7	12.6	13.5	12.0	12.3	14.8	16.6

Source: Bureau of Meteorology.

9.11 SURFACE WIND



Source: ABS 1992.



Source: ABS 1992.

Surveys of wind speeds in specific areas of interest are necessary in order to assess wind potential more accurately. Surveys of wind energy potential have been conducted in limited sites in most States, particularly in Victoria, South Australia, Western Australia and Tasmania. Some results for Victoria follow.

Wind energy potential for Victoria

To investigate the prospects for large-scale electricity generation in Victoria using wind energy, 10 sites along the Victorian coastline were selected, from Swan Reach near Lakes Entrance in the east to Bridgewater near Portland in the west.

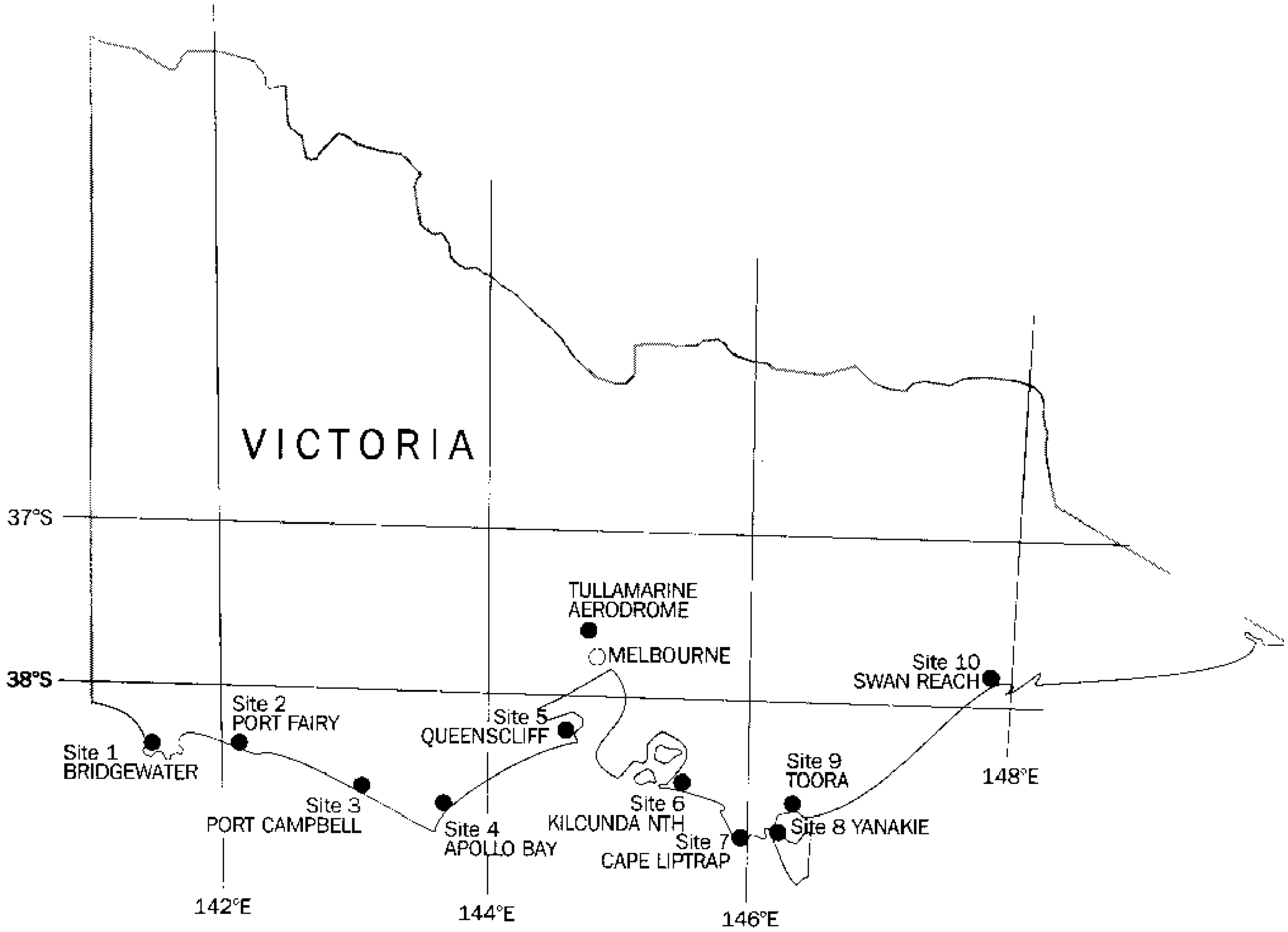
Observed wind speed and direction data were used together with topographic and surface information for a 400 square kilometre area surrounding the stations. Four sites near each station were selected as candidate wind farm locations. They are located on favourable terrain features, such as hills or ridges with good exposure to prevailing winds. Table 9.12 summarises annual mean wind speed at 30 metres height for all the stations and the candidate wind farm locations. Map 9.13 illustrates the location of wind monitoring sites.

9.12 ANNUAL AVERAGE WIND SPEEDS AT 30 METRES HEIGHT

	Station	*Site 1*	*Site 2*	*Site 3*	*Site 4*
Location	m/s	m/s	m/s	m/s	m/s
Bridgewater	8.7	7.9	8.6	7.5	8.2
Port Fairy	8.3	8.1	7.2	6.7	6.6
Port Campbell	7.7	7.8	8.7	8.0	7.7
Apollo Bay	8.5	6.6	5.7	5.6	7.3
Queenscliff	6.8	6.8	6.6	6.5	6.6
Kilcundan	8.8	7.9	8.8	8.3	7.9
Cape Liptrap	8.4	8.5	7.5	7.5	7.5
Yanakie	8.2	7.2	7.6	7.7	n.a.
Toora	8.9	8.3	7.7	8.7	7.6
Swan Reach	5.2	5.8	5.4	5.1	5.6

Source: Dear 1991.

9.13 STATE ELECTRICITY COMMISSION OF VICTORIA/VICTORIAN SOLAR ENERGY COUNCIL WIND MONOTORING SITES, 1985–87



Source: DASETT 1991b.

The candidate sites for megawatt scale wind farms were selected based on wind speed of approximately eight metres per second or greater and the areas being sufficient to hold several machines are shown in table 9.14.

9.14 POSSIBLE CANDIDATE SITES FOR MEGAWATT SCALE WIND FARMS

Location	*Site*
Bridgewater	Station, sites 1, 2, 4
Port Fairy	Site 2
Port Campbell	Station, sites 1–4
Apollo Bay	Station
Kilcundan	Sites 1–4
Cape Liptrap	Station, site 1
Yanakie	Station
Toora	Station, site 1, site 3

Source: Dear 1991.

Flow accounts for wind energy usage

There are no data available on conventional wind energy use, such as water pumping, grinding and sailing. As with solar energy, the major current interest is in using wind energy for electricity generation in order to reduce environmental pollution from fossil fuel combustion. In fact, prior to World War II, small wind generating systems were widespread in rural Australia, with a typical rating of 1–2 kilowatts and providing direct current power at 12, 24 and 32 volts. The number of these small wind generators remaining in Australia is not documented.

The first wind farm in Australia was established in 1987 at Esperance in Western Australia. Six 60-kilowatt wind turbines operate in parallel to feed power into the town's electricity grid. They are located about five kilometres from the townsite and diesel power station. Each incorporates a two-speed 80 kilovolt-Ampere, 3-phase, 50 hertz, 415 volt induction generator. Three fixed-pitch composite fibreglass blades drive the generator. They sweep a diameter of 16 metres and operate at wind speeds of 1.4 to 14 metres per second.

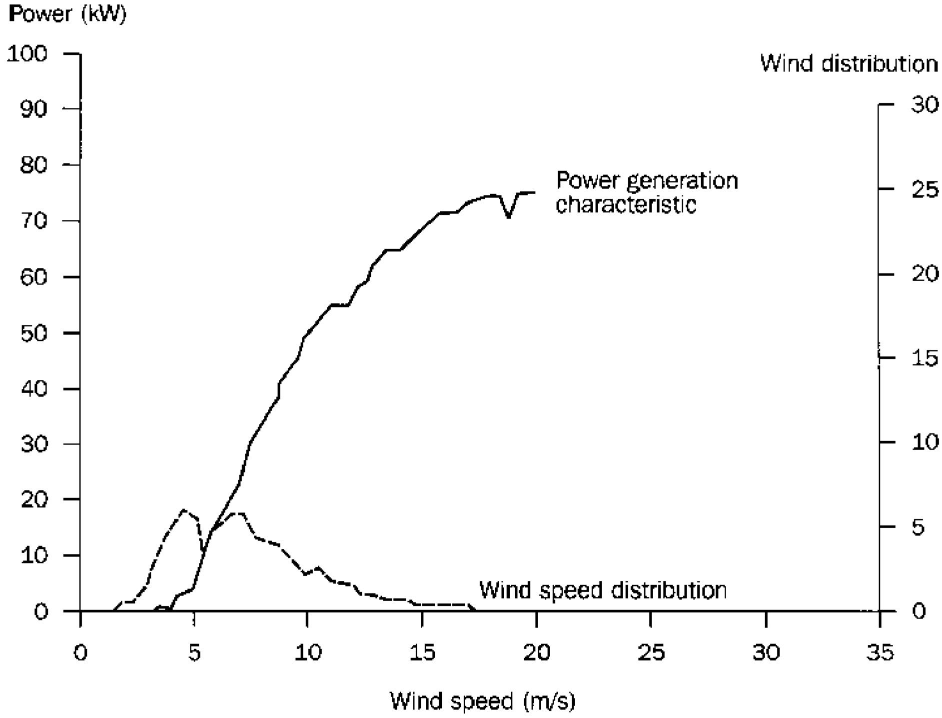
The average wind speed in 1987–88 was 6.2 metres per second, being well below the 7.5 metres per second average recorded over the preceding four years. In the first year, the gross turbine output (after compensating for outages) was 834,966 kilowatt hours which was 9% below the expected 960,000 kilowatt hours as shown in table 9.15. During the second 12 months, the gross output from the turbines increased to 977,859 kilowatt hours. Graph 9.16 illustrates a typical average power output against wind speed and wind distribution for the wind turbine generator.

9.15 INDIVIDUAL PERFORMANCE OF EACH WIND TURBINE FOR THE FIRST (1987–88) AND SECOND (1988–89) YEARS OF OPERATION

	No. 1	*No. 2*	*No. 3*	*No. 4*	*No. 5*	*No. 6*	*Total*
Generation (kW)							
1987–88	146 203.0	146 810.0	130 509.0	131 075.0	136 388.0	143 981.0	834 966.0
1988–89	162 639.0	159 658.0	168 673.0	154 268.0	149 689.0	182 932.0	977 859.0
Capacity factor							
1987–88	71.0	72.1	75.9	70.8	66.8	75.1	71.9
1988–89	30.9	30.4	32.1	29.4	28.5	34.8	31.0
% Time on high							
1987–88	59.2	68.8	56.8	59.5	52.9	60.1	59.5
1988–89	10.2	11.4	12.9	13.9	14.6	10.8	12.3
% Time on low							
1987–88	15.1	15.6	16.4	18.0	24.2	14.2	17.2
1988–89	10.2	11.4	12.9	13.9	14.6	10.8	12.3
% Time on line							
1987–88	74.4	84.5	73.3	77.5	77.1	74.3	76.8
1988–89	81.2	83.4	88.8	84.7	81.4	85.9	84.2
Average generation while on line (kW)							
1987–88	22.4	19.8	20.3	19.3	20.2	22.1	20.6
1988–89	22.9	21.8	21.7	20.8	21.0	24.3	22.1

Source: DASETT 1991b.

9.16 AVERAGE POWER OUTPUT RELATED TO WIND SPEED AND DISTRIBUTION



Source: DASETT 1991b.

Other wind generators in Australia

The initial capacity of the Esperance wind farm is 360 kilowatts. To enhance the capacity of electricity generation in this area, Ten Mile Lagoon wind farm was installed some 14 kilometres west of Esperance in 1993. It comprises nine 225 kilowatt variable pitch wind generators with total capacity of 2,025 kilowatts. Hence the total wind generator capacity in this region increased to 2.4 megawatts, produced 4,670 megawatt hours of electricity in the period from October 1993 (installation) to end of September 1994. This was about 14% of the total electricity requirement in the region.

Apart from Western Australia, there are small-scale wind generators in other States. South Australia installed a 150 kilowatt unit at Cooper Pedy, commissioned in 1992. In the first year the wind power unit generated 360 megawatt hours, but in 1992–93 the output fell to 284 megawatt hours. Tasmania's wind farm has a capacity of 55 kilowatts. During three consecutive years from 1990–91, the output of electricity was 86, 111 and 145 megawatt hours, respectively.

Residual accounts for wind energy usage

With the public's interest in the enhanced greenhouse effect and environmental pollution, wind energy has increasingly attracted attention as a replacement for fossil fuels in order to reduce the current emission levels. A comparison shows that the utilisation of wind energy is ranked as having the lowest carbon dioxide coefficient among available energy resources (DASETT, 1991b).

As with solar energy, wind energy is also residual-free in operation. The power carried by the wind pushes the blades of the wind generator converting kinetic energy into electricity. An account of environmental benefits at the Esperance wind farm in Western Australia is a good example, see table 9.18.

9.17 REDUCTION OF POLLUTANT EMISSIONS BY ESPERANCE WIND FARM WITH 14 MONTHS OPERATION, 1987–88

	Unit	*Reduction quantity*
Diesel fuel	L	250 000
COemission	t	700
CO_2 emission	t	2
N_2O emission	t	6
SO_2 emission	t	7

Source: DASETT 1991b.

A major environmental impact of using wind energy is the visual effect since the wind generators are erected about 20–30 metres above ground.

Land use is also one of the environmental concerns for wind farms. The land area required for a 1,000 megawatts wind farm is about 200–400 square kilometres (DASETT 1991b). Compared with land use of solar energy, wind farms need much larger areas to reach the same capacity of electricity generation. However, in many cases on agricultural land, a wind farm only occupies a small fraction of the land while pasture and cropping can still continue at ground level.

Noise is also an issue for wind farms. Noise may come from the rotating blades, whirring of gears and the hum of the generator. It has been found from the wind farm at Esperance that noise is undetectable above the background level at the nearest residence, some 500 metres distant. Measurements taken at 10 metres from towers in wind speeds of 6–7 metres per second, with the units operating in low speed, produced a noise level of 50–56 decibels. As wind speed increases, the background noise will increase, at the rate about two decibels for every metre per second. However, there is little increase in the mechanical noise from the turbines (DASETT 1991b).

Because wind generators are normally erected about 20–30 metres above the ground, there are no dangers to the animals passing through the ground. However there is some concern about preventing bird kills. So far bird death is not regarded as a problem at Esperance.

Finally, wind farms have an indirect impact on the environment during manufacture of materials and equipment for wind farms. A study shows that the energy required to construct each one kilowatt capacity of a wind generator was approximately 3,000 kilowatts hour. The energy payback time at 35% capacity factor is about 12–18 months while the life of a wind farm is about 25 years.

GLOSSARY

Bagasse Residue of the sugar cane milling process.

Biomass Total quantity or weight of biological organisms in a given area.

Bole Stem or trunk of tree.

Calorific value Amount of heat given by specified quantity of fuel.

Condensate A liquid mixture of pentanes and heavier hydrocarbons that are contained in the vapour phase in natural gas in the reservoir and become liquid at standard field separation conditions.

Crude oil A mixture of hydrocarbons, existing in the liquid state both in natural underground reservoirs and at atmospheric pressure after passing through surface separating facilities.

Global irradiation Light directly from the sun and indirectly from the sky and clouds.

Irradiation The energy from the sun which can be measured in units of million joules per square metre per day.

Isotope One or more forms of an element differing from each other in atomic weight and in nuclear but not chemical properties

Liquefied natural gas (LNG) Natural gas which has been processed and then natural gas refrigerated to the very low temperatures needed (LNG) to reach the liquid state.

Liquefied petroleum gas (LPG) Consists of propane, butane and isobutane and petroleum is derived by processing, through a low pressure gas (LPG) separation plant, the natural gas produced from either gas or oil reservoirs.

McKelvey Classification (MC) For classifying resources into categories that classification are based on the certainty that the resources exist and the best estimate of the economic feasibility of producing them.

Nuclear fission Splitting of heavy atomic nucleus spontaneously or on impact of another particle, with release of energy.

Petroleum Naturally occurring hydrocarbon or mixture of hydrocarbons as oil or gas, or in solution found in sedimentary rocks.

Photovoltaic (PV) Using means of the PV effect directly converting sunlight to electricity.

Primary oils Crude oil and condensate which are the normal feedstocks, but refinery inputs can be other feedstocks.

Radioactivity Property of spontaneous disintegration of atomic nuclei, usually with emission of penetrating radiation or particles.

Refined products Includes fuel products and non-fuel products. Fuel products include automotive gasoline and diesel, aviation gasoline and turbine, kerosine and heating oil, industrial diesel and fuel oil, and others such as naphtha and petroleum coke used as fuel. Non-fuel products include solvents, lubricants, bitumen, waxes and others such as sulphur and petroleum coke.

Sales gas Derived by processing the natural gas produced from either gas or oil reservoirs. It contains mainly methane, ethane, minor amounts of other hydrocarbon gases and some carbon dioxide.

Solar energy The energy from the sun.

Topography Detailed representation of natural and artificial features of a region.

Uranium Radioactive grey heavy metallic element, that is used as a source of nuclear energy.

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