# Trends in energy intensity in Australian industry

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# Foreword

Managing energy use will be one of the central issues that Australian industry faces in the future, as it responds to the twin challenges of a carbon pollution reduction scheme and volatile energy prices. Improvements in commercial and industrial energy use efficiency have the potential to slow the growth in demand for energy, reduce greenhouse emissions per unit of output and increase economic welfare.

In countries where an emissions trading scheme will cap overall emission levels, energy efficiency will play an important role in helping ease the economic adjustment path for consumers and industry. To assist companies, it will be particularly important to ensure there is adequate information for businesses regarding implementation of cost-effective energy efficiency improvements.

This publication analyses the changes in energy intensity of the Australian industrial and commercial sectors from 1989-90 to 2005-06 at the broad industry level. The methodology used decomposes the change in energy use into several contributing factors and removes the effect of structural change within the economy. However, at this level there can still be many factors affecting energy intensity that are not accounted for, as improvements in energy use efficiency can only be reliably measured at the level of individual production processes or plants. Energy intensity is therefore only an indicator of energy use efficiency.

Policies to encourage the uptake of cost-effective energy efficiency opportunities in the industrial and commercial sectors are an important part of the Australian Government's energy and climate change strategy. Publications such as Trends in Energy Intensity in Australian Industry will provide important information for making informed policy and investment decisions.

Phillip Glyde
Executive Director
December 2008

# Contents

# Summary

The Department of Resources, Energy and Tourism commissioned ABARE to undertake a study investigating energy intensity trends in Australian industry. The analysis was conducted at the national level for different energy consuming industrial and services sectors over the period 1989-90 to 2005-06. The analysis covers five major sectors of Australian industry including manufacturing, services, agriculture, mining and construction. For the manufacturing and services sectors, the analysis is also undertaken at the subsectoral level.

The objective of this study is to distinguish between different factors affecting the amount of energy consumed. This is done by using a 'factorisation' technique, a method that decomposes a change in energy use over time into an activity effect, a structural effect and a real intensity effect. These are defined as changes in:

- the level of economic activity — activity effect
- the sectoral composition of the economy — structural effect
- the energy intensities of sectors — real intensity effect.

A change in energy consumption can be expressed as the sum of the activity effect, the structural effect and the real intensity effect. The movements of these effects over time can be examined.

In this report the focus is on trends in real energy intensity. This measure provides a good indicator of the progress in reducing energy used to produce goods and services in the economy because it removes the influence of changes in the sectoral composition of the economy. However, improvements in energy intensity can only be reliably measured at the level of individual production processes or plants. In the absence of detailed data at that level, changes in the product-mix or production processes within each subsector are not captured in this report.

Energy consumption in the industries covered in this report accounted for 51 per cent of total final energy consumed in Australia in 2005-06, with the remainder consumed in the transport (37 per cent) and residential (12 per cent) sectors. Total energy consumption in Australian industry analysed in this report increased by 48 per cent from 1989-90 to 2005-06. The analysis demonstrates the dominance of economic growth (activity effect) as the major determinant of this increase in energy consumption. If this had been the only factor at work, energy consumption in Australian industry would have been 14 per cent higher than the realised

consumption. This is equivalent to a reduction in energy intensity (total energy consumed per unit of industrial output) of 0.9 per cent a year. These savings in energy consumption resulted mainly from shifts to less energy intensive sectors (structural effect). The change in real energy intensity had a relatively smaller effect on overall energy consumption. The trend in energy intensity in Australia is similar to those of other OECD economies, where the 1990s experienced weaker improvements in energy intensity, relative to the 1970s and 1980s (IEA 2007, Tedesco and Thorpe 2003).

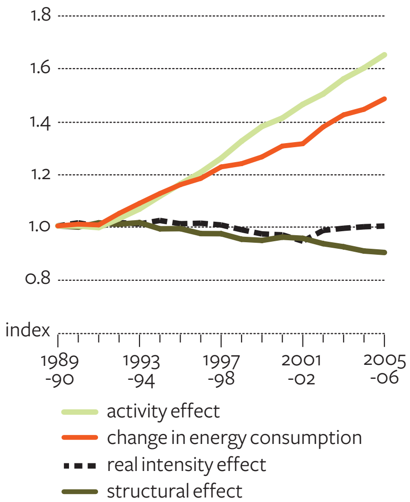
As part of the *APEC Leader's Declaration* in Sydney in September 2007, a target was set for a reduction in energy intensity in member economies of at least 25 per cent by 2030, compared with the 2005 base year. This is equivalent to an annual reduction in energy intensity of 1 per cent. The analysis in this report suggests that, if the trends in energy intensity observed over the past 16 years persist, energy intensity in Australian industry could be reduced by 20 per cent by 2030. However, the introduction of the Carbon Pollution Reduction Scheme can be expected to have significant implications for the pattern of energy consumption in Australia.

## Key findings

- Final energy consumption in Australian industry (including the manufacturing, services, agriculture, mining and construction sectors) grew from 1234 petajoules in 1989-90 to 1826 petajoules in 2005-06, at an average annual rate of 2.5 per cent.
- Over the same period, activity in these sectors increased by 62 per cent (3.2 per cent a year).
- In 2005-06, Australian industry, as covered in this report, used 48 per cent more energy than it did 16 years earlier. Without changes in energy intensity and sectoral structure the industry would have used 62 per cent more energy.
- Changes in activity remain the principal driver of changes in energy consumption. A change in the sectoral structure of Australian industry is estimated to have reduced energy consumption from the mid-1990s onward. Trends in real energy intensity had a negligible effect on energy consumption for most of the study period (figure a).
- Without changes to structure and real energy intensity, growth in activity alone would have resulted in energy consumption increasing by 759 petajoules (figure b).
- Structural shifts from relatively more energy intensive industrial activities to less energy intensive services activities are estimated to have reduced energy consumption by 170 petajoules in 2005-06 (figure b).

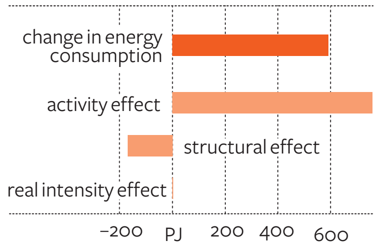
**a** Factored trends in energy consumption in Australian industry

1989-90 to 2005-06

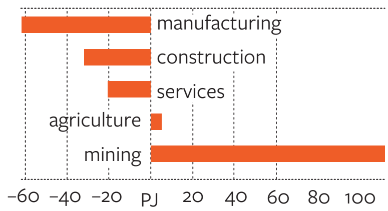


- Changes in real energy intensity created energy savings in all sectors except the agriculture (including forestry and fishing) and mining sectors (figure c). Overall, these savings were offset by higher energy intensity in agriculture and mining, resulting in an additional energy requirement of 3 petajoules.
- Manufacturing sector – Energy intensity declined at an average annual rate of 0.5 per cent over the past 16 years. This is estimated to have led to energy savings of 62 petajoules (figure c).
- Construction sector – Energy intensity declined at an average annual rate of 8.2 per cent over the study period. A reduction in real energy intensity is estimated to have delivered energy savings of approximately 32 petajoules (figure c).
- Services sector – Energy intensity declined at an average annual rate of 0.8 per cent over the study period. Such a reduction is estimated to have led to energy savings of 20 petajoules(figure c).
- Agriculture (including forestry and fishing) sector – Energy intensity increased at an average annual rate of 2.8 per cent. Such an increase in real energy intensity is estimated to have led to an additional energy requirement of approximately 5 petajoules over the period 1989-90 to 2005-06 (figure c). A reduction in output because of drought in 1994-95 and 2002-03, without changes in energy consumption, is assessed to have contributed to an increase in energy intensity in this sector.
- Mining sector – Energy intensity increased at an average rate of 3.7 per cent a year over the period 1989-90 to 2005-06. This is estimated to have led to an additional energy requirement of approximately 112 petajoules (figure c). Increases in the use of energy for exploration activity as the industry moved to deeper and lower grade ores, and increases in the energy intensive liquefaction of natural gas, have contributed to an increase in energy intensity in this sector.

**b** Decomposition of change in energy consumption in Australian industry
1989-90 to 2005-06




**c** Change in energy consumption in Australian industry because of the real energy intensity effect, by sector
1989-90 to 2005-06

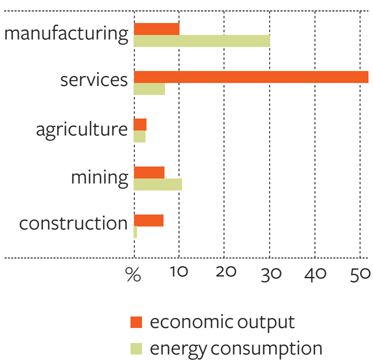


# 1 Introduction

The energy intensity of an activity is defined as the amount of energy consumed to produce one unit of output. Energy intensity is used to monitor changes in energy consumption over time and across activities. The objective in this study is to analyse trends in energy intensity in Australian industry over the period 1989-90 to 2005-06. Different factors affecting the amount of energy consumption are distinguished using a technique called 'factorisation'.

The analysis in this report covers five major sectors of Australian industry including the manufacturing, services, agriculture (including forestry and fishing), mining and construction sectors. For the manufacturing and services sectors, the analysis is also undertaken at the subsectoral level. These sectors together accounted for 51 per cent of total final energy consumption and 78 per cent of economic output in Australia in 2005-06. The shares of final energy consumption and economic output for sectors covered in this report are presented in figure d.

**d** Shares of energy consumption and economic output
2005-06




Over the past 15 years ABARE has produced a series of reports analysing trends in energy intensity in Australia (Wilson, Ho Trieu and Bowen 1993; Cox, Ho Trieu, Warr and Rolph 1997; Harris and Thorpe 2000 and Tedesco and Thorpe 2003). These ABARE studies were based on a decomposition method used by the IEA and others (see, for example, IEA 1997, Schipper et al 1990). In this report, ABARE introduces a new decomposition method — the log-mean divisia index I (LMDI I) — that brings the mechanics of the analysis in line with recent similar studies for other advanced economies.

The analysis undertaken is based on energy consumption data derived from ABARE's *Australian energy statistics* (AES), physical production data from ABARE's Australian commodities statistics (ACS) and gross value added data from the Australian Bureau of Statistics (ABS). The AES database provides comprehensive statistics on energy consumption by industry, fuel and state, much of which is unavailable elsewhere. The most recent version of the AES was released in July 2008, and is available at www.abare.gov.au.

# 2 Methodology

In this report, changes in energy use over the period 1989-90 to 2005-06 have been broken down into three components. A change in energy consumption is divided into the activity effect, the structural effect and the real intensity effect using a technique known as factorisation (also known as decomposition). This report uses an additive version of the log-mean divisia index I (LMDII) method to decompose changes in energy consumption into these three components (figure e). A mathematical framework of this method is provided in appendix A.

## e Decomposing changes in energy consumption

change in energy consumption = activity effect + structural effect + real intensity effect

The **activity effect** refers to the changes in energy consumption that arise solely due to the changes in the level of activity in the economy. The activity effect generally accounts for the majority of the observed changes in energy consumption in any particular sector. In this report, the level of activity is estimated using physical production for the iron and steel and basic non-ferrous metals subsectors, and using gross value added for other subsectors. The gross value added used in this report is based on chain volume terms, which removes the effect of price increases and therefore captures only the effect of changes in output.

The change in energy consumption associated with shifts in the economy's structure is referred to as the **structural effect**. The structural effect captures changes in energy consumption when sectors with different energy intensities grow or decline at different rates, after adjusting for growth in total output. The structural effect can be estimated only where subsectoral data are available.

Finally, the change in energy consumption associated with the changes in the amount of energy used to produce each unit of output is referred to as the **real intensity effect**. This measure provides a good indicator of the progress in reducing energy used to produce goods and services in the economy. This is because the real intensity effect removes the influence of changes in the sectoral composition of the economy, which is already captured through the structural effect.

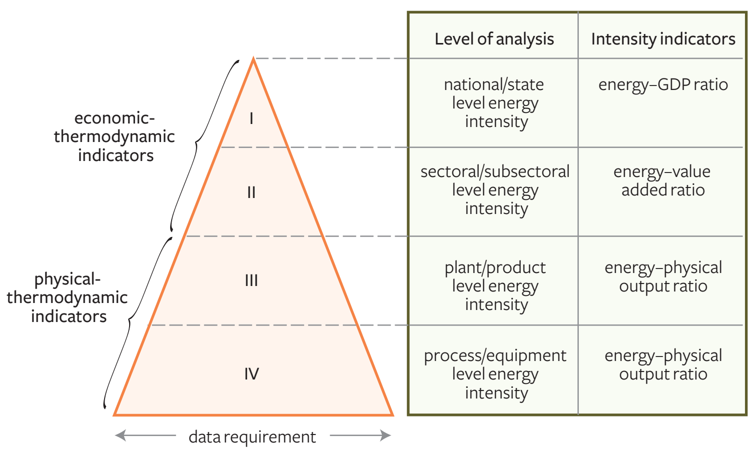
The real energy intensity effect can only be reliably measured at the level of individual production processes or plants where the structural effect can be fully captured. As shown in figure f, the energy intensity indicator can be constructed from the most aggregate level in the economy, in terms of the energy-to-GDP ratio (hierarchy level I), through to the most detailed level for a specific technology or production process (hierarchy level IV). As one moves down the level of hierarchy, the influence of the structural effect on the energy intensity indicator gradually reduces. However, moving down the hierarchy to accurately estimate the energy intensity indicator requires disaggregated data. In the absence of such disaggregated data, energy intensities in this report are estimated at the hierarchy level II. See appendix B for further discussion on the intensity (efficiency) indicators.

In this report the analysis is undertaken at the national level for a range of sectors, covering the period from 1989-90 to 2005-06. Changes in energy use associated with each effect are calculated from year to year and then re-based to 1989-90. This means that the activity, structural and real intensity effects can be presented as changes relative to 1989-90. Also, in this report, the amount by which actual energy use is lower than it would otherwise have been as a result of a reduction in real energy intensity is referred to as energy savings.

The sectors covered in this report are:

- manufacturing, comprising 10 manufacturing subsectors;
- services, comprising seven services subsectors;
- agriculture, including forestry and fishery;
- mining; and
- construction.

## f Hierarchy of energy intensity indicators




*Source*: adapted from IEA (1997) and Patterson (1996).

Activity and real energy intensity effects can be estimated for each subsector. However, structural effects can only be estimated at the sectoral level because they account for movements between subsectors. If there are no subsectors, then no shift from one subsector to another can be estimated, as is the case for the agriculture, mining and construction sectors. Further, structural shifts can only be estimated when the activity of every subsector (within a particular sector) is measured in identical units. Shifts can then be based on changes in each subsector's share of total activity from year to year.

# 3 The manufacturing sector

- Energy consumption in the manufacturing sector grew from 819 petajoules in 1989-90 to 1078 petajoules in 2005-06, at an average rate of 1.7 per cent a year.
- Activity in the manufacturing sector grew from $77 billion in 1989-90 (at 2005-06 prices) to $97 billion in 2005-06, at an average annual rate of 1.4 per cent.
- Without changes to structure and real intensity, the increase in activity alone would have resulted in energy consumption increasing by 218 petajoules over the period 1989-90 to 2005-06.
- Structural shifts within the manufacturing sector from less energy-intensive to more energy-intensive subsectors are estimated to have led to an increase in energy consumption of 103 petajoules.
- Changes in real energy intensity over the analysis period are estimated to have led to energy savings of 62 petajoules. This is equivalent to a reduction in real energy intensity of 0.5 per cent a year over the study period.

This chapter discusses trends in activity, structure and real energy intensity in the manufacturing sector for the period 1989-90 to 2005-06. The sector is split into 10 subsectors:

- food, beverages and tobacco
- textile, clothing, footwear and leather
- wood, paper and printing
- chemicals and associated products
- non-metallic mineral products
- iron and steel
- basic non-ferrous metals
- other metal products
- machinery and equipment
- other manufacturing

The definition of these subsectors by ANZSIC code is provided in appendix C. Data sources are presented in appendix D.

# Observed trends in energy consumption and activity

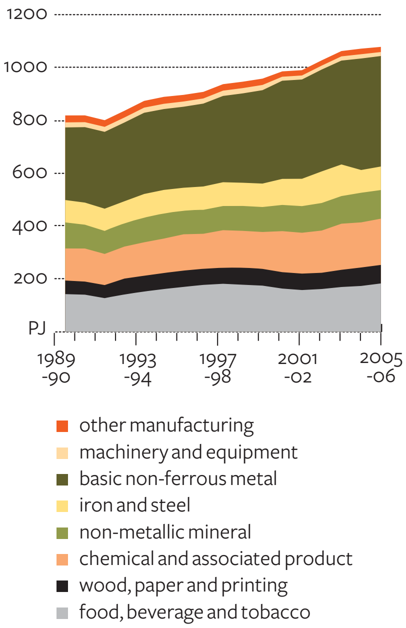
Energy consumption in the manufacturing sector grew from 819 petajoules in 1989-90 to 1078 petajoules in 2005-06 at an average annual rate of 1.7 per cent (figure g). In 2005-06, consumption in the manufacturing sector accounted for 59 per cent of the final energy consumed in Australian industries covered in this report. The basic non-ferrous metals subsector was the single largest energy user within the manufacturing sector, contributing 39 per cent of the sector's energy consumption in 2005-06. This subsector includes relatively energy-intensive aluminium production activities. Other major consumers of energy in 2005-06 were the food, beverages and tobacco subsector (17 per cent), chemicals and associated products subsector (16 per cent) and the non-metallic mineral products subsector (10 per cent). Iron and steel production accounted for 8 per cent of final energy consumption. The other five manufacturing subsectors together accounted for only 10 per cent of final energy consumption (table 1).

Growth in energy consumption varied considerably across the manufacturing subsectors. The other manufacturing subsector recorded the largest average annual growth rate from 1989-90 to 2005-06, at 8 per cent, but it contributed less than 1 per cent of energy consumed in the sector. The energy-intensive subsectors of basic non-ferrous metals and

## 1 Energy consumption and output in the manufacturing sector

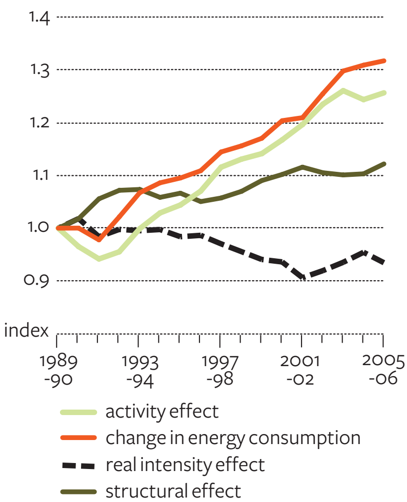
| | energy consumption | | | output | | |
|---|---|---|---|---|---|---|
| | 2005-06 | | average annual growth rate 1989-90 to 2005-06 | 2005-06 | | average annual growth rate 1989-90 to 2005-06 |
| | PJ | % | % | $b | % | % |
| Food, beverages and tobacco | 183 | 17.0 | 1.6 | 19 | 19.6 | 1.9 |
| Textile, clothing, footwear and leather | 11 | 1.1 | –1.9 | 3 | 3.1 | –5.3 |
| Wood, paper and printing | 70 | 6.5 | 2.0 | 17 | 17.3 | 1.1 |
| Chemicals and associated products | 175 | 16.2 | 2.3 | 11 | 10.9 | 1.9 |
| Non-metallic mineral products | 108 | 10.0 | 0.6 | 5 | 5.2 | 2.7 |
| Iron and steel | 89 | 8.3 | 0.3 | 4 | 4.3 | 1.0 |
| Basic non-ferrous metals | 418 | 38.8 | 2.7 | 7 | 6.7 | 3.0 |
| Other metal products | 7 | 0.6 | –2.6 | 8 | 8.5 | 1.7 |
| Machinery and equipment | 15 | 1.4 | –1.4 | 20 | 20.3 | 2.4 |
| Other manufacturing | 1 | 0.1 | 8.0 | 4 | 4.0 | 0.6 |
| Total manufacturing sector | 1 078 | 100.0 | 1.7 | 97 | 100.0 | 1.4 |

**g** Final energy consumption in the manufacturing sector




**h** Factored trends in energy consumption in the manufacturing sector

change relative to 1989-90




chemicals and associated products grew at an average annual rate of 2.7 and 2.3 per cent, respectively. Energy consumption in the textile, clothing, footwear and leather; other metal products and machinery and equipment subsectors actually fell over the analysis period (table 1). Note that the economic recession of the early 1990s, and the manufacturing moving offshore was felt strongly in almost all manufacturing subsectors (figure g). The two subsectors, textiles, clothing, footwear and leather, and other metal products are included in the other manufacturing subsector in figure g.

Activity in the manufacturing sector grew from $77 billion (not shown in table 1) in 1989-90 (at constant 2005-06 prices) to $97 billion in 2005-06 at an average annual rate of 1.4 per cent (table 1). Although the five largest energy consumers in 2005-06 (the basic non-ferrous metals; chemicals and associated products; food, beverages and tobacco; non-metallic mineral products and iron and steel subsectors) accounted for about 90 per cent of the sector's energy consumption, they produced only 47 per cent of the output. The largest subsectors in output value terms in 2005-06 were food, beverages and tobacco; wood, paper and printing and machinery and equipment.

Only the textile, clothing, footwear and leather and wood, paper and printing industries fell in terms of their share of output over the analysis period. The most significant increase in activity level was in the highly energy-intensive manufacturing subsector, the basic non-ferrous metals subsector, with an average rate of 3 per cent a year. This is followed by growth in the non-metallic mineral products subsector (2.7 per cent), the machinery and equipment subsector (2.4 per cent) and the food, beverages and tobacco, and chemicals and associated products subsectors (both 1.9 per cent).

## Factored trends in energy consumption

This section discusses factored trends in energy consumption for the manufacturing sector over the period 1989-90 to 2005-06. The change in final energy consumption over the analysis period is decomposed into the activity effect, structural effect and real intensity effect.

Trends in each factored component and in total energy consumption is shown in figure h. In general, the trend in the growth in the sector (activity effect) underpinned movements in energy consumption. It should be noted that the sector's output fell in the first two years of the analysis period, coinciding with the recession of the early 1990s. A shift toward the more energy-intensive subsectors of basic non-ferrous metals; non-metallic mineral products; chemicals and associated products; and food, beverages and tobacco from the less energy-intensive subsectors of textile, clothing, footwear and leather and wood, paper and printing is estimated to have led energy consumption to be higher than it would otherwise have been (structural effect). The growth in energy consumption was partially offset by decreases in real intensity, particularly from 1996-97 to 2001-02. However, in the last few years of the study period, increases in real energy intensity, especially in the basic non-ferrous metals subsector, eroded some of the energy savings. An increase in energy intensity in the basic non-ferrous metals subsector can be explained by a shift within the subsector toward the more energy-intensive production of non-ferrous metals, particularly aluminium production, and away from less energy-intensive production of finished products. This structural effect can be isolated from the real intensity trend only if a consistent data set below the subsector is available (see figure f).

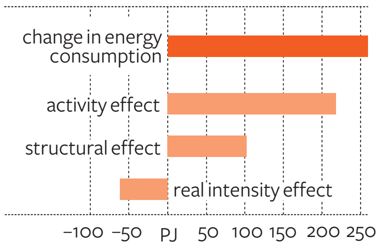
Over the period 1989-90 to 2005-06, consumption of final energy in the manufacturing sector increased by 259 petajoules (figure i). An increase in the sector's activity would have resulted in an increase in energy consumption of 218 petajoules if the sector's structure and real intensity had not changed. All manufacturing subsectors except textile, clothing, footwear and leather contributed to increases in energy consumption due to the activity effect. The subsectors that contributed to the largest increase in energy consumption because of the activity effect were basic non-ferrous metals; food, beverages and tobacco; chemicals and associated products; and non-metallic mineral products subsectors. Shifts within the sector from one subsector to another caused energy consumption to be 103 petajoules higher than it would otherwise have been. The share of the less energy-intensive textile, clothing, footwear and leather and wood, paper and printing subsectors fell and was replaced by the more energy-intensive basic non-ferrous metals; non-metallic mineral products; chemicals and associated products; and food, beverages and tobacco subsectors.

An overall reduction in the real energy intensity of the manufacturing sector created net energy savings of 62 petajoules. More than half of these savings (33 petajoules) were made in the non-metallic mineral products subsector. However, energy savings were not achieved across all subsectors (figure j).

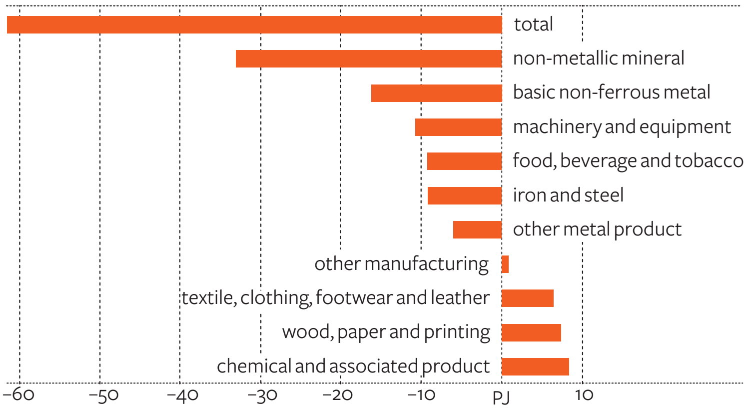
The six subsectors of non-metallic mineral products; basic non-ferrous metals; machinery and equipment; food, beverages and tobacco; iron and steel; and other metal products, together made savings of 84 petajoules. However, increases in energy intensity in the other four subsectors of chemicals and associated products; wood, paper and printing; textile, clothing, footwear and leather and other manufacturing, led to an additional energy requirement of 22 petajoules.

**i** Decomposition of change in energy consumption in the manufacturing sector

1989-90 to 2005-06



## j Change in energy consumption in the manufacturing sector because of the real energy intensity effect




This additional energy requirement is not necessarily a reflection of lower energy efficiency. It could instead be the result of changes in the product-mix within these subsectors toward the production of more energy-intensive products. For example, the output data from ABS (2007b) show that the basic chemical subsector (ANZSIC 253) within the chemicals and associated products subsector, which involves energy-intensive production of fertilisers and industrial gases, increased its share of the total output relative to other subsectors (ANZSIC 254-256). Despite a reduction in the energy intensity of the basic chemical subsector (table 2), increases in the relative value of that subsector resulted in an overall increase in energy intensity of the chemicals and associated products subsector. This example shows how structural shifts, or changes in the product-mix, within the subsector can influence real intensity change at a higher level of sectoral aggregation.

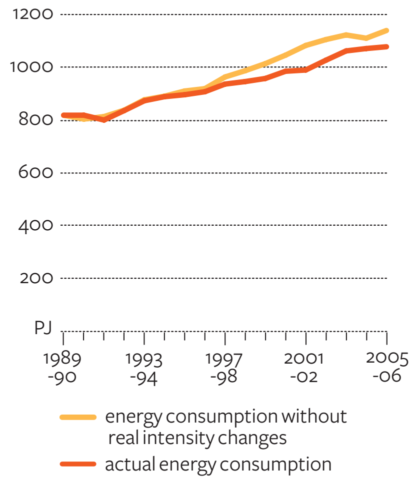
## 2 Energy intensities of the chemicals and associated products subsector

| | energy intensity (MJ per dollar value added a) 1989-90 | 2005-06 |
|---|---|---|
| Chemicals and associated products | 15.5 | 16.5 |
| Basic chemical (ANZSIC 253) | 69.2 | 52.5 |
| Other chemical, rubber and plastic (ANZSIC 254-256) | 1.5 | 3.8 |

a At constant 2005-06 prices.
*Sources*: ABARE (2007a) and ABS (2007b).

Figure k shows the evolution of actual energy consumption and what energy consumption would have been if energy intensity had remained at the 1989-90 level. It is clear that energy savings were made mostly in the second half of the analysis period. By 2005-06, the net effect of changes in energy intensity since 1989-90 was a reduction in energy consumption of 62 petajoules. This is equivalent to a reduction in real energy intensity of 0.5 per cent a year over the study period. Energy consumption would have been 1140 petajoules in 2005-06, instead of 1078 petajoules, if reductions associated with the real energy intensity effect had not been achieved. In this case, energy consumption would have increased at an average annual growth of 2.1 per cent.

**k** Manufacturing sector energy consumption with and without changes in real energy intensity



# 4 The services sector

- Energy consumption in the services sector grew from 159 petajoules in 1989-90 to 249 petajoules in 2005-06 at an average annual rate of 2.8 per cent.
- Activity in the services sector grew from $287 billion in 1989-90 (at 2005-06 prices) to $500 billion in 2005-06 at an average rate of 3.5 per cent.
- Without changes to structure and real intensity, the increase in activity alone is estimated to have resulted in energy consumption increasing by 118 petajoules over the analysis period.
- Structural shifts within the sector from more energy-intensive to less energy-intensive subsectors are estimated to have led to a reduction in energy consumption of 8 petajoules.
- A reduction in real energy intensity is estimated to have delivered energy savings of approximately 20 petajoules over the period 1989-90 to 2005-06. This is equivalent to a reduction in real energy intensity of 0.8 per cent a year.

This chapter discusses trends in activity, structure and real energy intensity in the services sector for the period 1989-90 to 2005-06. The sector is split into seven subsectors:

- water supply, sewerage and drainage
- wholesale and retail trade
- communication services
- finance, insurance, property and business
- government administration and defence
- education, health and community services
- accommodation, cultural and personal services

The definition of these subsectors by ANZSIC code is provided in appendix C. Data sources are presented in appendix D.

## Observed trends in energy consumption and activity

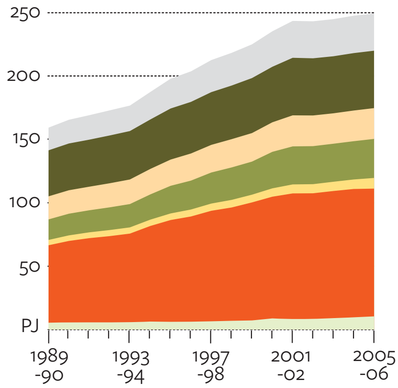
Energy consumption in the services sector increased from 159 petajoules in 1989-90 to 249 petajoules in 2005-06 at an average annual rate of

2.8 per cent (figure l). In 2005-06, energy consumption in this sector represented 14 per cent of final energy consumed in Australian industries covered in this report.

The wholesale and retail trade subsector accounted for the largest share of the sector's energy consumption in 2005-06, making up 40 per cent of final energy consumed in the services sector (table 3). Energy use in this subsector grew strongly over the analysis period, from 61 petajoules in 1989-90 to 101 petajoules in 2005-06. According to Pears (2007) this is a reflection of growth in energy-intensive food outlets, and increased use of lighting and airconditioning. Growth in energy consumption in the remaining subsectors was strong, although the government administration and defence and education, health and community services subsectors grew at an average annual rate of less than 2 per cent.

Activity in the services sector grew from $287 billion (not shown in table 3) in 1989-90 (at constant 2005-06 prices) to $500 billion in 2005-06 at an average annual rate of 3.5 per cent (table 3). The largest increase in the activity level was in the communication subsector (7 per cent), although it was from a low base of $7 billion in 1989-90 (at 2005-06 prices). This was followed by the growth in the finance, insurance, property and business subsector (4 per cent), the wholesale and retail trade subsector (3.4 per cent) and the education, health and community services and accommodation, cultural and personal services subsectors (both 3.2 per cent). The data also suggest energy consumption in the water supply, sewerage and drainage subsector grew at a significantly higher rate (4.2 per cent a year) than the growth in its activity (0.2 per cent a year).

l Final energy consumption in the sevices sector




accommodation, cultural and personal services
education, health and community services
government administration and defence
finance, insurance, property and business
communication services
wholesale and retail trade
water supply, sewerage and drainage

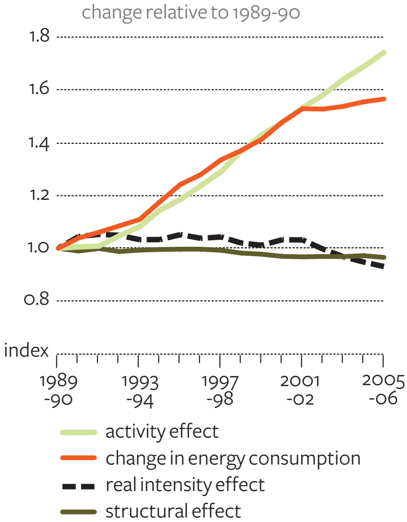
## 3 Services sector energy consumption and output

| | energy consumption | | | output | | |
|---|---|---|---|---|---|---|
| | 2005-06 | | average annual growth rate 1989-90 to 2005-06 | 2005-06 | | average annual growth rate 1989-90 to 2005-06 |
| | PJ | % | % | $b | % | % |
| Water supply, sewerage and drainage | 10 | 4.2 | 4.2 | 7 | 1.4 | 0.2 |
| Wholesale and retail trade | 101 | 40.4 | 3.2 | 100 | 20.0 | 3.4 |
| Communication services | 8 | 3.4 | 4.4 | 23 | 4.7 | 7.4 |
| Finance, insurance, property and business | 31 | 12.3 | 4.1 | 182 | 36.4 | 4.0 |
| Government administration and defence | 24 | 9.7 | 1.8 | 38 | 7.6 | 2.4 |
| Education, health and community services | 45 | 18.2 | 1.4 | 98 | 19.6 | 3.2 |
| Accommodation, cultural and personal services | 29 | 11.8 | 3.1 | 52 | 10.4 | 3.2 |
| Total services sector | 249 | 100.0 | 2.8 | 500 | 100.0 | 3.5 |

# Factored trends in energy consumption

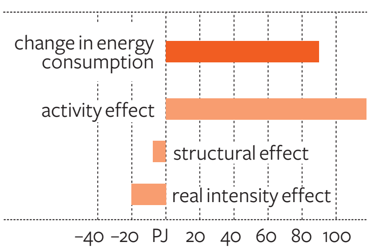
**m** Factored trends in energy consumption in the services sector

change relative to 1989-90




**n** Decomposition of change in energy consumption in the services sector

1989-90 to 2005-06




The change in final energy consumption over the analysis period is decomposed into the activity effect, structural effect and real intensity effect.

Trends in each of the factored components and in energy consumption for the period 1989-90 to 2005-06 are shown in figure m. It is clear that increases in the sector's activity level drove changes in energy consumption, particularly during the period prior to 2001-02. Shifts in the composition of the sector from the late 1990s onward, mostly toward the finance, insurance, property and business subsector, led to energy consumption being slightly lower than it would otherwise have been (structural effect). Note that for almost all of the analysis period increases in energy intensity in the services sector resulted in energy consumption being higher than it would otherwise have been. After 2001-02, consistent savings were made in energy consumption because of a sharp decline in the energy intensity trend. This coincides with the implementation of government policies designed to improve energy efficiency from the late 1990s. These include the minimum energy performance standards for appliances and equipment, energy efficiency standards for new and refurbished buildings, Australian government energy efficiency operations and other energy efficiency measures (DCC 2008).

Over the period 1989-90 to 2005-06, consumption of final energy in the services sector increased by 90 petajoules. Figure n shows how changes in activity, structure and real intensity affected the change in energy consumption. Based on activity alone, energy consumption would have increased by 118 petajoules, or 28 petajoules more than actual consumption. All subsectors grew in terms of their output and all contributed to the increase in energy consumption. Wholesale and retail trade contributed the greatest share of the increase in consumption because of the increases in activity. The effect of shifts toward less energy-intensive subsectors such as communication services and finance, property, insurance and business resulted in energy consumption being 8 petajoules less than it would otherwise have been.

An overall reduction in the energy intensity of the services sector generated net savings of 20 petajoules. More than half of these savings (11 petajoules) were made in the education, health and community services subsector (figure o). The wholesale and retail trade subsector also made significant savings. It should be noted that savings were made in all services subsectors except the water supply, sewerage and drainage subsector. In this subsector, an increase in energy intensity led to an additional energy requirement of 5 petajoules. The factors underpinning this result cannot be identified within the scope of this study and require further investigation.

**o** Change in energy consumption in the services sector because of the real energy intensity effect

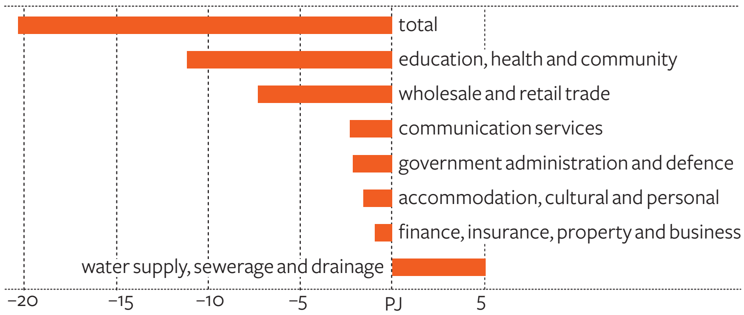
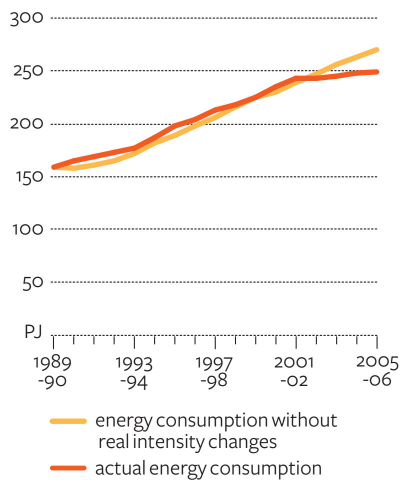



Figure p shows the evolution of actual energy consumption and what energy consumption would have been if energy intensity had remained at the 1989-90 level. In the case of the services sector, energy savings were made after 2001-02. The strong decrease in energy intensity after 2001-02 apparent in figure m was sufficient to overcome losses that had occurred throughout the 1990s. Without the decrease in energy intensity, energy consumption would have reached 277 petajoules (rather than 249 petajoules) in 2005-06. By 2005-06, the net effect of changes in energy intensity since 1989-90 was a reduction in energy consumption of 20 petajoules. This is equivalent to a reduction in real energy intensity of 0.8 per cent a year over the study period.

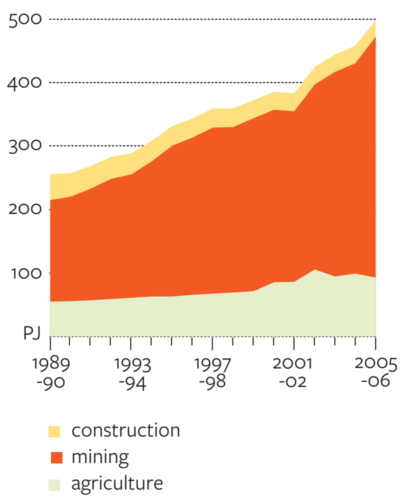
**p** Services sector energy consumption with and without changes in real energy intensity



# 5 Agriculture, mining and construction sectors

- Aggregate energy consumption in the agriculture (including forestry and fishing), mining and construction sectors grew from 256 petajoules in 1989-90 to 499 petajoules in 2005-06 at an average annual rate of 4.3 per cent. Activity in these sectors grew from $92 billion in 1989-90 (at 2005-06 prices) to $155 billion in 2005-06 at an average annual rate of 3.3 per cent.
- Energy consumption in the agriculture sector grew from 55 petajoules in 1989-90 to 93 petajoules in 2005-06 at an average annual rate of 3.3 per cent. Activity grew from $18 billion in 1989-90 (at 2005-06 prices) to $27 billion in 2005-06 at an average annual rate of 2.8 per cent.
- Energy intensity in the agriculture sector increased at an average annual rate of 2.8 per cent. Such an increase in real energy intensity is estimated to have led to an additional energy requirement of approximately 5 petajoules over the period 1989-90 to 2005-06.
- Energy consumption in the mining sector grew from 160 petajoules in 1989-90 to 380 petajoules in 2005-06 at an average annual rate of 5.6 per cent. Activity grew from $40 billion in 1989-90 (at 2005-06 prices) to $65 billion in 2005-06 at an average annual rate of 3 per cent.
- Energy intensity in the mining sector increased at an average annual rate of 3.7 per cent. This is estimated to have led to an additional energy requirement of approximately 112 petajoules over the period 1989-90 to 2005-06.
- Energy consumption in the construction sector fell from 41 petajoules in 1989-90 to 26 petajoules in 2005-06 at an average annual rate of 2.7 per cent. Activity grew from $34 billion in 1989-90 (at 2005-06 prices) to $62 billion in 2005-06 at an average annual rate of 3.8 per cent.
- Energy intensity in the construction sector declined at an average annual rate of 8.2 per cent. A reduction in real energy intensity is estimated to have delivered energy savings of approximately 32 petajoules over the period 1989-90 to 2005-06.

**q** Final energy consumption in the agriculture, mining and construction sectors




## Observed trends in energy consumption and activity

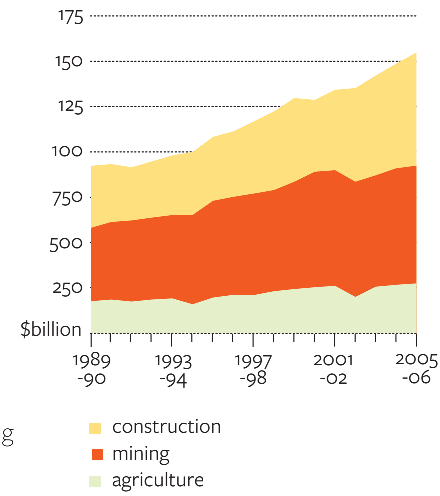
Aggregate energy consumption in the agriculture, mining and construction sectors grew from 256 petajoules in 1989-90 to 499 petajoules in 2005-06 at an average annual rate of 4.3 per cent (figure q). In 2005-06, consumption in these sectors accounted for 27 per cent of the final energy consumed by the Australian industries covered in this report. The data sources for these sectors are presented in appendix D.

The mining sector contributed about three-quarters of energy consumption (380 petajoules in 2005-06) in these sectors, which is equivalent to 21 per cent of energy consumed across industries covered in this report. The agriculture and construction sectors accounted for 5 per cent and 1 per cent of energy consumption, respectively.

Energy consumption in the mining sector grew the strongest, at an average annual rate of 5.6 per cent over the period 1989-90 to 2005-06. Growth in energy consumption in this sector has been particularly strong since 2001-02 (9.1 per cent a year). Energy consumption in the agriculture sector grew at an average rate of 3.3 per cent a year. Energy consumption in the construction sector fell over the study period, at an average rate of 2.7 per cent a year.

Activity in the combined agriculture, mining and construction sectors grew from $92 billion in 1989-90 (at 2005-06 prices) to $155 billion in 2005-06, at an average annual rate of 3.3 per cent (figure r). The largest increase in the activity level was in the construction sector, with an average rate of 3.8 per cent a year. This was followed by growth in the mining sector of 3 per cent which represents an increase in the volume of output rather than an increase in the value added that has increased dramatically in recent years (see box 1). Activity in the agriculture sector grew at an average annual rate of 2.8 per cent over the study period, with a marked decline in activity during the severe drought years of 1994-95 and 2002-03. However, the growth in activity level in the agriculture and mining sectors was slower than the growth in energy consumption.

**r** Output in the agriculture, mining and construction sectors 2005-06 dollars



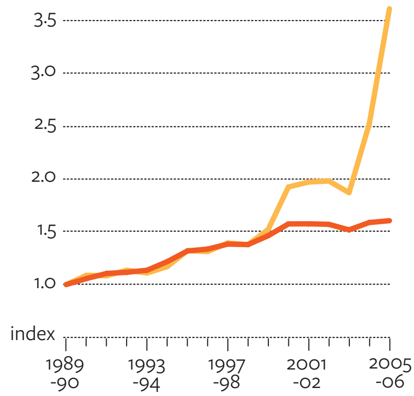

## Factored trends in energy consumption

There is no structural effect observed in any of the agriculture (including forestry and fishing), mining and construction sectors over the period 1989-90 to 2005-06 because there are no subsectoral energy and activity data underlying these individual sectors. Figure t presents change in energy consumption and decomposition results that have occurred during the analysis period for each of the sectors included in this chapter.

box 1 Growth in value added – mining sector

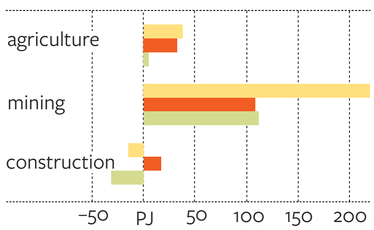
The global minerals boom, which has added significant value to the Australian mining sector, has been driven primarily by an increase in prices rather than an increase in output. The difference in the growth in prices (value terms) and output (volume terms) in the mining sector is shown in figure s (ABS 2007a). Overall, the mining sector's value added in value terms increased at an average annual rate of 9 per cent with most of that growth occurring in recent years. However, output measured by 'value added in volume terms' grew by only 3 per cent a year with most of that growth occurring prior to 2000-01.

s Growth in the mining sector
1989-90=100




## Agriculture (including forestry and fishing) sector

t Decomposition of change in energy consumption in the agriculture, mining and construction sectors




From 1989-90 to 2005-06, energy consumption in the agriculture sector increased by 38 petajoules. An increase in energy consumption in this sector is strongly influenced by changes in activity level, which would have resulted in energy consumption increasing by 33 petajoules. The remainder of the increase in energy consumption (5 petajoules) was because of an increase in real energy intensity. This is equal to an average annual increase in real energy intensity of 2.8 per cent. A significant increase in energy intensity occurred in 1994-95 and 2002-03 (figure u). A reduction in agriculture output because of the severe droughts in those two years, without corresponding changes in energy consumption, has contributed to an increase in energy intensity in this sector.

## Mining sector

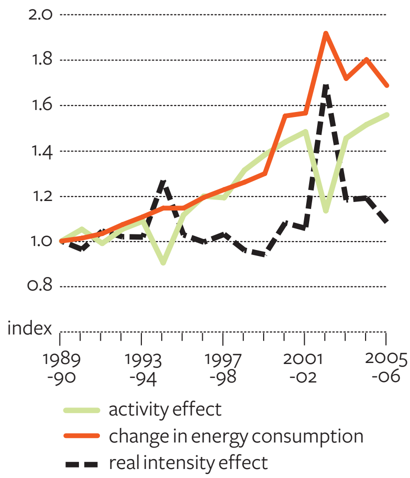
For the mining sector, energy consumption increased by 220 petajoules during the period 1989-90 to 2005-06 (figure t). Had energy intensity in this sector stayed at the 1989-90 level for the whole of the analysis period, activity growth would have resulted in energy consumption increasing by only 108 petajoules. The remainder of the increase in energy consumption (112 petajoules) was because of an increase in real energy intensity. Throughout the study period, energy consumption grew faster than the sector's output therefore leading to an increase in energy intensity (figure v). This is equal to an average annual increase in real energy intensity of 3.7 per cent. Various factors contributed to an increase in energy intensity in this sector. First, for the production of mineral commodities, high-grade minerals or those that can be accessed most cost effectively are generally extracted first. Over time, these deposits are used up leading to a shift to lower-grade minerals that require more energy intensive processes (Saddler, Diesendorf and Denniss 2004). Second, as mineral resources closer to the surface are depleted, increases in production require the extraction of resources located deeper underground needing more energy-intensive techniques. In the light of the recent minerals boom, mining companies in Australia have been increasing minerals exploration. The expenditure on minerals exploration activity in 2006-07 was $1 billion higher than in 2002-03 and the depth of metres drilled over the same period increased by 64 per cent (Geoscience Australia 2008). Another reason for the increase in energy intensity in the mining sector is the substantial increase in the relatively energy intensive production of liquefied natural gas (LNG). Over the period 1989-90 to 2005-06, the production of LNG increased at an average rate of 13 per cent a year (ABARE 2007b), compared with an average growth of 3 per cent a year in total mining output. Without additional subsectoral data within the mining sector, the influence of changes in the mining sector's structure cannot be removed from the energy intensity indicator (figure f).

## Construction sector

For the construction sector, energy consumption over the period 1989-90 to 2005-06 declined by 15 petajoules (figure t). Unlike the agriculture and mining sectors, energy consumption in the construction sector is strongly influenced by downward trends in energy intensity (figure w). While an increase in the sector's activity resulted in energy consumption increasing by 17 petajoules, energy intensity contributed to a reduction in energy consumption of 32 petajoules (figure t). This is equivalent to a reduction in real energy intensity of 8.2 per cent a year. Without the energy savings of 32 petajoules, energy consumption in this sector would have been 58 petajoules in 2005-06, rather than the observed 26 petajoules.

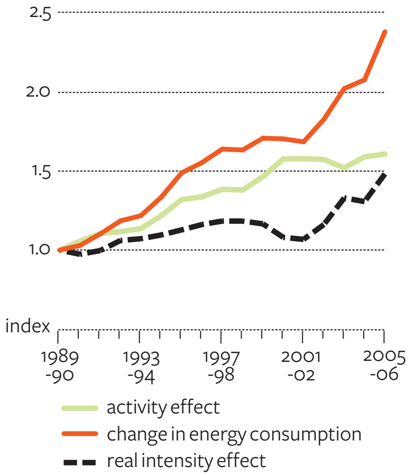
### u Factored trends in energy consumption in the agriculture (including forestry and fishing) sector

change relative to 1989-90



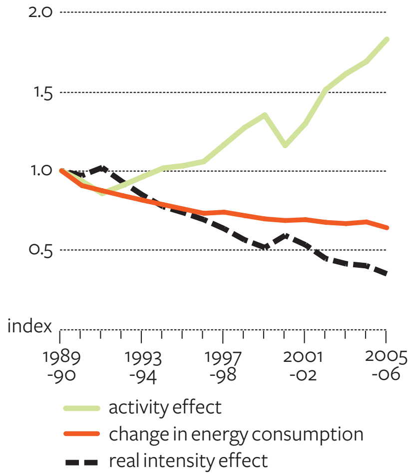
**V** Factored trends in energy consumption in the mining sector

change relative to 1989-90




**W** Factored trends in energy consumption in the construction sector

change relative to 1989-90



# 6 Conclusions

Between 1989-90 and 2005-06, final energy consumption in Australian industries analysed in this report increased by 48 per cent. This study decomposed the changes in energy use over time into an activity effect, a structural effect and a real intensity effect. Overall, sectoral activity was found to be the largest contributor to the growth in energy consumption. Without changes in real energy intensity and sectoral structure, final energy consumption would have increased by 62 per cent. A change in the sectoral structure, from relatively more energy intensive industrial activities to less intensive services activities, contributed to a 14 per cent reduction in energy used. However, real energy intensity has contributed to less than 1 per cent of the increase in final energy consumption.

The analysis highlights differences in trends in energy intensity across sectors. A reduction in real energy intensity in the manufacturing, services and construction sectors contributed to a 9 per cent reduction in energy used. However, this reduction in energy consumption was offset by higher energy intensity in the agriculture and mining sectors. A reduction in the output of the agriculture sector because of the severe droughts of 1994-95 and 2002-03, without apparent changes in energy consumption, was the main reason underlying an increase in real energy intensity in this sector. Similarly, declining ore grades, the need to access deeper deposits and significant increases in the liquefaction of natural gas have contributed to an increase in real energy intensity in the mining sector.

This report also highlights the lack of availability of more disaggregated data on energy used to produce goods and services in Australian industry. As identified, improvements in energy intensity can only be reliably measured at the level of individual production processes or plants. In the absence of detailed data at that level, changes in the product-mix or production processes within each subsector are not captured.

One of the advantages of the factorisation method adopted in this report is in providing a consistent trend to monitor the progress of energy intensity at the sectoral level, where data are available. These trends are comparable over time and provide valuable guidance to policy-makers. However, a lack of additional explanatory variables in this study, which have a major influence on the incentives to undertake energy intensity improvements means strong conclusions cannot be drawn about the factors underlying the intensity trends presented in this report. Future research should be focussed on providing a clearer understanding of the reasons behind some of the key changes in energy intensity trends identified.

# appendix A Mathematical framework

This report uses the log-mean divisia index I (LMDI I) method to decompose changes in energy consumption into three components — the activity effect, the structural effect and the real intensity effect. This method has a number of advantages over other decomposition methods, including that it does not leave an 'unexplained' or residual part.

In this appendix, the mathematical derivation of this method is presented. This framework is based on the additive form of the LMDI I decomposition method, proposed by Ang and Liu (2001).

Energy consumption *E* for a sector with *n* subsectors can be expressed algebraically as:

1. $$E=\sum_{i}^{n} A.\frac{A_i}{A}.\frac{E_i}{A_i}$$

Where $A_i$ is the activity of a sector's $i^{th}$ subsector, $A$ is the total activity for the sector, and $E_i$ is the energy consumption of the $i^{th}$ subsector. The second term on the right hand side gives the share of the subsector's activity of the total sectoral activity and the third term gives the energy intensity of the $i^{th}$ subsector. By defining $S_i=\frac{A_i}{A}$ and $I_i=\frac{E_i}{A_i}$, equation 1 can be written as:

2. $$E=A\sum_{i}^{n} S_i I_i$$

Equation 2 is the basis for various energy decomposition methods. See Ang, Liu and Chew (2003), Liu and Ang (2003) and Ang (2004) for comparisons of these methods. Ultimately, the interest is in how changes in energy consumption over time can be decomposed into the three factors on the right hand side. The additive type of the log-mean divisia index allows us to express a given change in energy consumption as the sum of a change in activity, a change because of shifts in structure and a change because of changes in real energy intensity:

3.

$$E_t-E_o=\sum_{i}^{n}\omega_i.(\ln A_T-\ln A_o)+\sum_{i}^{n}\omega_i.(\ln S_{i,T}-\ln S_{i,o})+\sum_{i}^{n}\omega_i.(\ln I_{i,T}-\ln I_{i,o})$$

where the subscripts 0 and $T$ refer to the value of the variables at the start and end of the interval of interest. The variable $\mathbf{w}_i$ is the logarithmic mean of energy consumption across the start and end periods and is defined as:

4. $$\mathbf{w}_i = \frac{E_{i,T} - E_{i,0}}{\ln\left[E_{i,T} / E_{i,0}\right]}$$

The first term on the right hand side of equation 3 is the activity effect, the second is the structural effect and the third is the real energy intensity effect.

For more details about the additive form of the LMDI I method see MKJA (2005) and Ang, Zhang and Choi (1998). For details of the multiplicative form see Ang and Liu (2001).

# appendix B Efficiency indicators

There is no unequivocal quantitative measure of energy efficiency. The measurement of progress in energy efficiency is generally based on a series of indicators that can be constructed using the available data. Patterson (1996) classified a number of indicators that can be used to measure changes in energy efficiency into four main approaches.

The first approach, the thermodynamic indicator, is an indicator based purely on an engineering perspective. The thermodynamic indicator relies exclusively on the measurement derived from the science of thermodynamics, that is, the science of energy and its processes. It can be measured in terms of the heat (energy) content of the outputs over energy inputs of the process. Because of its focus on the physical nature of energy involved in the process, the thermodynamic indicator is of limited use in assessing energy efficiency at the sectional level.

The second approach, an economic indicator, is based purely on an economic perspective. This indicator measures changes in energy efficiency purely in terms of market value. That is, energy consumed and output produced are measured in monetary terms. In economic jargon, energy efficiency measured from this approach is equivalent to energy productivity.

The other two approaches, which are more relevant to the energy intensity literature, are based on hybrids of the above indicators. These are the physical-thermodynamic and economic-thermodynamic indicators. The physical–thermodynamic indicator measures energy input in terms of thermodynamic units (that is, heat content of the input) and the output is measured in physical units such as tonnes or litres of product. The economic–thermodynamic indicator measures energy input in the same way as the physical-thermodynamic indicator, but the output is measured in terms of market prices. Both types of indicators can be estimated at various hierarchical levels within the economy (figure f).

All the efficiency indicators discussed above imply that the least use of energy to produce a given level of output would seem to be a worthwhile goal. However, this level of energy consumption may not be economically desirable from the viewpoint of an economic decision making unit, and considering the total cost of production. It therefore deserves some attention to also discuss the term efficiency from a broader economic perspective — economic efficiency. The preceding discussion of energy efficiency focuses only on efficiency of energy use and disregards the use of non-energy inputs. From a broader perspective, producers and consumers seek to economise on the use of all inputs, not just energy. That is, they tend to use a combination of inputs that is most cost effective for them.

Such a distinction in energy efficiency and economic efficiency can be illustrated in figure x. The curved line shows different combinations of energy and non-energy that can be used to produce a given level of output, *Q*. Any combinations that lie above this curve (point *A*) are considered to be technically inefficient as one input can be reduced without using more of the other input. From point *A*, a technical improvement to the production process can be made by reducing either energy input alone (point *B*) or non-energy input alone (point *C*) to achieve the same level of output. However, both types of choices still cannot lead to the most optimal combination of inputs. To achieve economic efficiency, the value of all inputs—the prices of energy and non-energy—also need to be taken into account, assuming that prices of all inputs reflect their marginal social cost. The line $X_oY_o$ shows the relationship between the values of both inputs in terms of willingness to substitute one input with the other. The economically efficient combination of energy and non-energy inputs is at point *O*, where the relative prices of energy and non-energy form a tangent to the technical efficiency curve. It is worth noting that increases in the energy price relative to the price of non-energy input will change the negatively sloped line from the original $X_oY_o$ to $X_bY_b$. Changes in the relative prices will make point *B* the economically optimal combination of inputs and thus reduce energy demand from $E_o$ to $E_b$.

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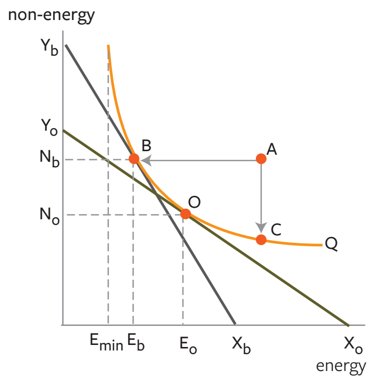
**X** Framework for optimal energy efficiency



# appendix C Industry coverage

In general, the industrial classification and sectoral definitions used in this study correspond to the 1993 Australian and New Zealand Standard Industrial Classification (ANZSIC). This classification has been slightly modified in order to represent the sectors that consume the final form of energy. That is, the sector that performs energy conversion activity is excluded in this report. Such a change gives the classification as shown in table 4. The changes are:

- the exclusion of electricity supply (ANZSIC 361) and gas supply (ANZSIC 362) sectors;
- the exclusion of petroleum refining (ANZSIC 251) and petroleum and coal product manufacturing (ANZSIC 252) subsectors from the manufacturing sector; and
- the exclusion of coke oven operations and blast furnace operations from the iron and steel manufacturing subsector (ANZSIC 271).

## 4 Industrial classifications used in the study

| sectors/sub-sectors | ANZSIC code |
|---|---|
| **Agriculture (including forestry and fishing)** | Division A |
| **Mining** | Division B |
| **Manufacturing** | |
| Food, beverages and tobacco | 21 |
| Textile, clothing, footwear and leather | 22 |
| Wood, paper and printing | 23-24 |
| Chemicals and associated products | 253-256 |
| Non-metallic mineral products | 26 |
| Iron and steel (excludes coke ovens and blast furnaces) | 2700-2713, 2716-2719 |
| Basic non-ferrous metals | 272-273 |
| Other metal products | 274-276 |
| Machinery and equipment | 28 |
| Other manufacturing | 29 |
| **Construction** | Division E |
| **Services** | |
| Water supply, sewerage and drainage | 37 |
| Wholesale and retail trade | Divisions F and G |
| Communication services | Division J |
| Finance, insurance, property and business | Divisions K and L |
| Government administration and defence | Division M |
| Education, health and community services | Divisions N and O |
| Accommodation, cultural and personal services | Divisions H, P and Q |

# appendix D Data sources and issues

This appendix discusses data sources as well as general issues about the appropriateness of various measures of activity and structure for the purpose of estimating intensity trends. Note that a trend analysis requires a reasonably long time series of consistent data for many sectors.

## Data sources used in the study

### *Measures of energy consumption*

The main source of energy consumption data used in this report is drawn from the *Australian energy statistics* (AES) published annually by ABARE (2007a). The AES database provides comprehensive statistics on energy consumption by industry, fuel and state, much of which is unavailable elsewhere. The most recent version of AES was released in July 2008, and is available at www.abare.gov.au.

Energy consumption data for the agriculture, mining, construction and services sectors covered in this report contain information at the division level of the ANZSIC code. For the manufacturing sector, it contains information at the 2-digit ANZSIC classification level. However, energy consumption data from the AES is available at a more disaggregated three digit ANZSIC level for the energy-intensive chemicals and associated products; non-metallic mineral products and metals subsectors. The list of sectors used in this report in accordance with the ANZSIC classification is provided in appendix C.

Some manufacturing subsectors undertake energy conversion activity. For example, the iron and steel industry converts large amounts of coal to coke for use in blast furnaces. Data in the AES is sufficiently detailed to allow these conversion activities to be isolated. Energy consumption in the manufacturing sector therefore includes consumption of final energy only. In the case of the iron and steel industry for example, final energy is assumed to include coke but not coal.

### *Measures of activity*

In this report, the level of activity is estimated using physical production for the iron and steel and basic non-ferrous metals subsectors, and using gross value added for other subsectors.

Measures of value added were drawn from the National Accounts (ABS 2007a). The value added series is based on chain volume measure in 2005-06 prices, which removes the effect of price increases. This makes the trends in value added a good proxy for changes in industrial production. For the iron and steel and basic non-ferrous metals subsectors, activity is based on ABARE's (2007b) estimates of physical production. Using the method proposed by MKJA (2005) a value added series and a physical production series can be aggregated. An aggregated series for different activity variables of the iron and steel and basic non-ferrous metals subsectors is constructed by multiplying an index series of physical production with the ABS's estimate of value added for 2005-06.

## Data issues

### *Data issues for the industrial sector*

In line with most international studies of energy intensity trends, this report uses value added to measure the activity of most industrial sectors (including agriculture, mining, manufacturing and construction). Broadly speaking, value added is the difference between an industry's revenue and its costs. Whether it is an appropriate activity variable depends on how intensity is defined. The trend internationally is to measure intensity using physical outputs where possible because these are seen as more closely approximating the service that energy provides. In other words, the focus is on physical-thermodynamic indicators rather than economic-thermodynamic indicators (appendix A). However, from an economic standpoint, intensity measures based on value added have the advantage of incorporating society's valuation of the goods and services being produced, at least to the extent that this is reflected in prices.

In most cases, the decision of whether to use value added or physical units is made by the availability of data. Physical production estimates are available from ABARE's Australian commodity statistics (2007b) for two manufacturing subsectors – iron and steel and basic non-ferrous metals. Although ABS publishes estimates of manufacturing production in physical units for 29 commodities, these do not align with ABARE's (2004). estimates of energy consumption In all cases, the diversity of processes and products in a complex industrial sector like Australia's makes it difficult to aggregate physical outputs consistently.

However, a recent report on energy efficiency trends in Canada (NRC 2006) gives an idea of what is possible. Of the 49 subsectors of manufacturing considered in the report, activity for 23 of them was measured using physical outputs such as tonnes of pulp and paper, litres of dairy products and cubic metres of concrete. The lack of such data, except for the iron and steel and basic non-ferrous metals subsectors, precluded a similar analysis in this report.

### *Data issues for the services sector*

Value added is not an ideal indicator for activity because the value of the services sector may not be directly related to the energy consumed. In major subsectors, energy is used mostly to provide heating, cooling, lighting and air handling, and to power office appliances and commercial refrigerators. In most cases, these services need to be provided whatever the level of activity. In other words, the link between value added and energy consumption in the services sector is perhaps not as strong as in the industrial sector where energy is often a significant input which increases as output increases. Instead, energy consumption in the services sector is more likely to be related to floor area, appliance diffusion and climate. More meaningful analysis of intensity trends for this sector would require estimates of energy end use for various subsectors, as well as activity variables for each.

There are a number of reports that analyse particular aspects of energy end use in the Australian services sector but their aim is generally not to provide a long time series. A key study is by George Wilkenfeld and Associates (2002) which estimates various energy end uses for the services sector as a whole for each Australian state for 1999. EMET Consultants and SOLARCH Group (1999) and EMET Consultants (2004) estimate various energy end uses in 1990 and 2000 for different services subsectors, including wholesale and retail trade; accommodation, cafes and restaurants; communication services; finance and insurance; government administration and community services and culture and recreation services. Estimates of energy end use by office appliance are provided in Sustainable Solutions (2003).

In relation to activity variables, NIEIR (1997) estimates floor area for various types of Australian buildings until 1996. Bader (2006) estimates floor space in 2002 and 2004 for various services sectors in Melbourne. However, a suitable time series of estimated appliance diffusion rates for the services sector is not available.

# Glossary and abbreviations

activity effect
The change in energy consumption that would result from a change in the overall level of production, other things being equal. It is one of the three factors used in this report to decompose changes in energy consumption (the others being the real intensity effect and the structural effect).

aggregate energy intensity
Energy consumed per unit of output, at any given level of industrial classification aggregation. At the economy wide level, this is equal to energy-to-GDP ratio. At the sectoral level, it is energy-to-output ratio. Also see real intensity effect.

derived energy
Forms of energy produced from primary energy or other derived energy through a conversion process (also known as secondary or tertiary energy). Derived energy includes petroleum products, electricity, town gas, coke oven gas, blast furnace gas and briquettes.

energy savings
The difference between actual energy consumption in 2005-06 and the estimated energy consumption that would have occurred in 2005-06 if real energy intensity had stayed at 1989-90 levels.

factorisation method
A method used to decompose trends in a series (such as energy consumption) over time into a range of effects. Each effect is isolated in the sense that changes in the series are calculated from that effect alone (all other effects are held constant).

final energy
Forms of energy that can be converted to useful energy (for powering a motor or cooking, for example) without further processing. It is also known as end use energy. Some primary energy are used directly as final energy (such as wood and coal) but most forms of final energy are derived fuels (such as petroleum products and electricity).

value added
Broadly, a sector's value added is a measure of its contribution to the total value of production of goods and services in Australia. It is roughly equivalent to a sector's receipts less its costs of production. Estimates of value added used in this report are provided by the Australian Bureau of Statistics.

log-mean divisia index
An energy decomposition (factorisation) method proposed by Ang and Liu using a logarithmic mean function to weight sector's share of energy consumption over the period (2001). This method provides a perfect decomposition and consistency in aggregation and therefore does not contain approximation error in the factorisation. See factorisation method.

primary energy
Forms of energy obtained directly from nature and not subject to further refining before being useful. These include coal, oil, natural gas, uranium and wood.

production effect
See activity effect

real intensity effect
One of the three factors used in this report to decompose changes in energy consumption (the others being the structural effect and the activity effect). The real intensity effect measures the change in energy consumption caused by changes in how much energy is used to produce each unit of output. At a given level of aggregation, it is the weighted sum of the energy-to-output ratios at lower levels of aggregation. This measure of energy intensity at a particular level differs from the aggregate energy intensity at that level by excluding the effect of changes in the structure of the economy (the structural effect).

secondary energy
See derived energy.

structural effect
The change in energy consumption resulting from changes in the mix of industrial output (for example, a contraction in energy intensive sectors relative to other sectors). For the energy consumption of a single sector, it is a shift in the shares within the subsectors, and so on. It is one of the three factors used in this report to decompose changes in energy consumption (the others being the real intensity effect and the activity effect).

total energy consumption
The total quantity of primary and derived energy consumed, less the quantity of derived energy produced in the energy conversion industries. Total energy consumption includes the consumption of petroleum in nonfuel uses.

# References

Australian Bureau of Agricultural and Resource Economics (ABARE) 2007a, *Australian energy consumption and production, 1973-74 to 2005-06*, Canberra (http://www.abareconomics.com/interactive/energyUPDATE08)

—— 2007b, *Australian Commodity Statistics 2007*, Canberra.

Australian Bureau of Statistics (ABS) 2004, *Manufacturing Production*, catalogue no. 8301.0, Canberra.

—— 2007a, *Australian National Accounts: National Income, Expenditure and Product*, catalogue no. 5206.0, Canberra.

—— 2007b, *Manufacturing Industry, Australia*, catalogue no. 8221.0, Canberra.

Ang, BW 2004, 'Decomposition analysis for policymaking in energy: which is the preferred method?', *Energy Policy,* vol. 32, pp. 1131–1139.

Ang, BW and Liu, FL 2001, 'A new energy decomposition method: perfect in decomposition and consistent in aggregation', *Energy,* vol. 26, pp. 537-48.

Ang, BW, Liu, FL and Chew, EP 2003, 'Perfect decomposition techniques in energy and environmental analysis', *Energy Policy*, vol. 31, pp. 1561–1566.

Ang, BW, Zhang, FQ and Choi, KH 1998, 'Factorizing changes in energy and environmental indicators through decomposition', *Energy Policy*, vol. 32, pp. 1131 1139.

Bader, K 2006, Municipal Strategic Statement: Performance Monitoring Report 2004, May.

Cox, A, Ho Trieu, L, Warr, S and Rolph, C 1997, *Trends in Australian Energy Intensity,* ABARE Research Report 97.5, Canberra.

Department of Climate Change (DCC) 2008, *Stationary Energy Sector Greenhouse Gas Emissions Projections 2007,* Commonwealth of Australia, Canberra, February.

EMET Consultants 2004, *Energy Efficiency Improvement in the Commercial Subsectors*, prepared for the Sustainable Energy Authority of Victoria, February.

EMET Consultants and SOLARCH Group 1999, *Baseline Study of Greenhouse Gas Emissions from the Commercial Buildings Sector with Projections to Year 2010*, May.

George Wilkenfeld and Associates 2002, *Energy End Use Analysis of Australia's Greenhouse Gas Emissions 1999*, Report to the Australian Greenhouse Office, September.

Geoscience Australia 2008, Sustaining the mineral resources industry – overcoming the tyranny of depth, in Australian Bureau of Statistics *Year Book Australia 2008*, catalogue no. 1301.0, Canberra, pp.551-552.

Harris, J and Thorpe, S 2000, *Trends in Australian Energy Intensity, 1973-74 to 1997 98*, ABARE Research Report 2000.13, Canberra.

International Energy Agency (IEA) 1997, *Indicators of energy use and efficiency – Understanding the link between energy and human activity*, Paris.

—— 2007, *Energy Use in the New Millennium – Trends in IEA Countries*, Paris.

Liu, FL and Ang, BW 2003, 'Eight methods for decomposing the aggregate energy-intensity of industry', *Applied Energy*, vol. 76, pp. 15-23.

MK Jaccard and Associates (MKJA) 2005, *Improvement of the OEE/DPAD Decomposition Methodology,* report prepared for Natural Resources Canada's Office of Energy Efficiency, March.

National Institute of Economic and Industry Research (NIEIR) 1997, *Estimates of Residential Household Numbers and Floor Area*, for Department of Primary Industries and Energy, Melbourne.

Patterson, MG 1996, 'What is energy efficiency? Concepts, indicators and methodological issues', *Energy Policy*, vol. 24, no. 5, pp. 377-90.

Pears, A K 2007, 'Imagining Australia's energy services future', *Futures,* vol. 39, pp. 253–71.

Saddler, H, Diesendorf, M and Denniss, R 2004, *A Clean Energy Future for Australi*a, A Study by Energy Strategies for the Clean Energy Future Group, March.

Schipper, L, Howarth, RB and Geller, H 1990, 'United States energy use from 1973 to 1987: the impact of improved efficiency', *Annual Review of Energy,* vol. 15, pp. 455–504.

Sustainable Solutions 2003, *A Study of Office Equipment Operational Energy Use Issues*, Final report prepared for the Australian Greenhouse Office, February.

Tedesco, L and Thorpe, S 2003, *Trends in Australian Energy Intensity, 1973-74 to 2000-01*, ABARE Report 03.9 for the Ministerial Council on Energy, Canberra, June.

Wilson, B, Ho Trieu, L and Bowen, B 1993, *Energy Efficiency Trends in Australia*, ABARE Research Report 93.11, Canberra.

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10.08

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Australian Government Department of Resources, Energy and Tourism

CRC Plant Biosecurity

CSIRO (Commonwealth Scientific and Industrial Research Organisation)

Dairy Australia

Department of Primary Industries, Victoria

Fisheries Research and Development Corporation

Fisheries Resources Research Fund

Forest and Wood Products Research and Development Corporation

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