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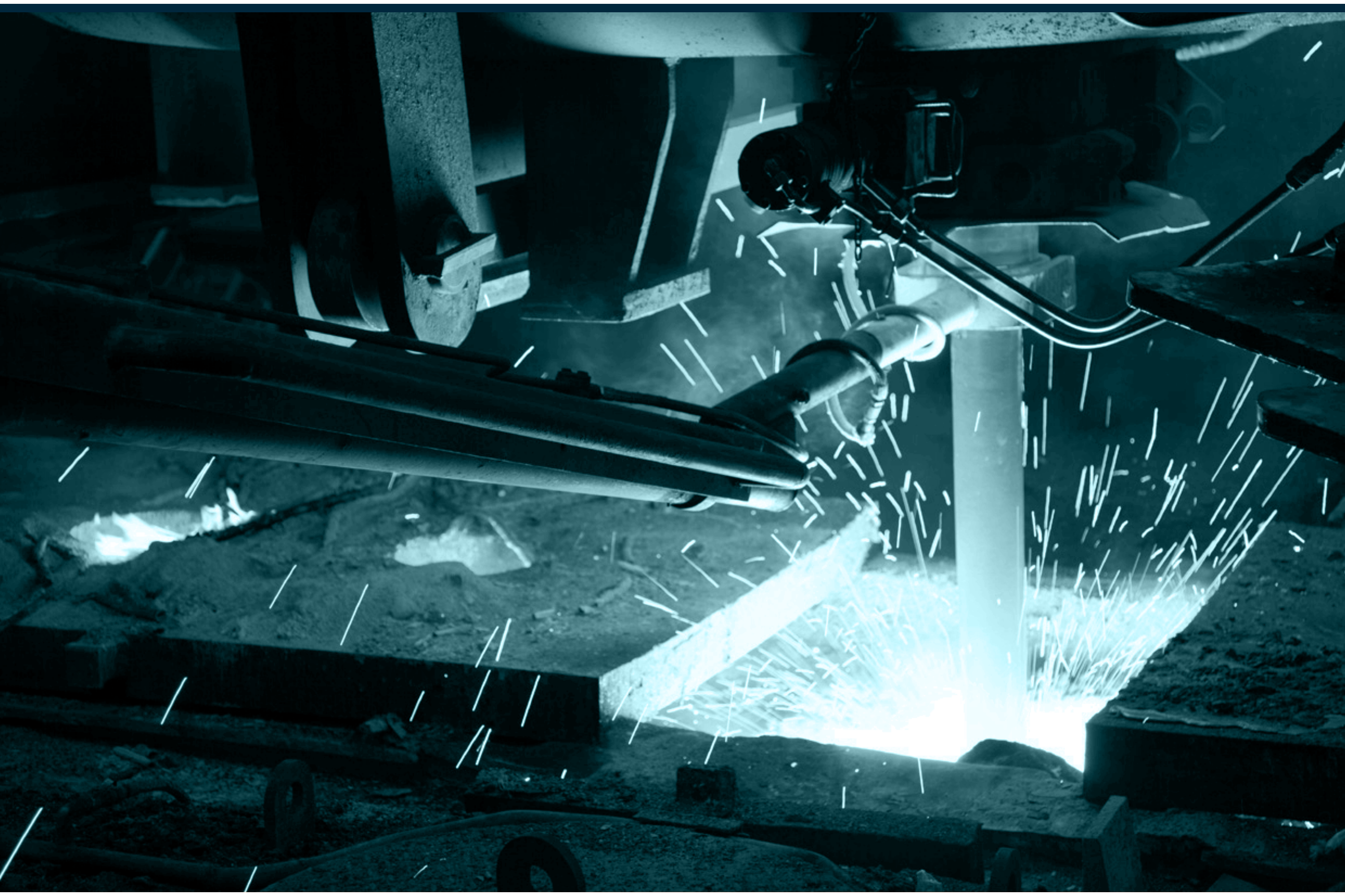

END-USE ENERGY INTENSITY IN AUSTRALIA

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End-use energy intensity in Australia

George Stanwix, Pam Pham and Allison Ball

June 2015

Office of the Chief Economist

For further information on this report please contact:

Office of the Chief Economist

Department of Industry and Science

GPO Box 9839

Canberra ACT 2601

Email: chiefeconomist@industry.gov.au

Web: www.industry.gov.au/oce

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Foreword

One of the main themes of the recently released Australian Government Energy White Paper is to improve our energy productivity, to lower costs to households and businesses and stimulate economic growth.

Australia's energy productivity has been improving over the past three decades, although results have varied between different sectors of the economy. This has been partly through improvements in energy efficiency, including improved technologies and standards, as well as changes in behaviour by businesses and households in response to higher energy prices. It has also been underpinned by a shift in Australia's economic structure towards less energy-intensive sectors such as services.

A common indicator of energy productivity is the ratio of economic activity to energy use, or its inverse, energy intensity. While this is relatively simple to measure and track changes in over time, it does not consider to what extent the changes have been driven by real energy productivity improvements, or are instead due to changes in the structure of the economy.

This report provides insights into this question. It decomposes the change in Australia's historical energy consumption to quantify the respective contributions of structural effects and energy efficiency effects. The results are presented at both the national and sectoral level.

It is hoped that the report will assist in improving our understanding of the changes occurring in Australia's energy use and productivity, and inform the development of strategies under the National Energy Productivity Plan.

Mark Cully
Chief Economist
Department of Industry and Science
June 2015

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Abbreviations and acronyms

ABS	Australian Bureau of Statistics
AES	Australian Energy Statistics
ANZSIC	Australian and New Zealand Standard Industrial Classification
BITRE	Bureau of Infrastructure, Transport and Regional Economics
BREE	Bureau of Resources and Energy Economics (former)
GVA	Industry gross value added
LMDI-I	Log-Mean Divisia Index Method-I
NABERS	National Australian Built Environment Rating System
PJ	Petajoules
FCE	Final consumption expenditure
TPES	Total primary energy supply
TFEC	Total final energy consumption

Glossary

Activity effect: A measure of the contribution of the scale of economic activity to changes in energy consumption. It is one of the three explanatory factors used in this report to decompose and explain changes in energy consumption.

Annual growth: Compound annual average growth rate.

Composite indicator of energy intensity: Measures energy intensity in the economy and individual sectors by taking into account changing patterns of energy use as well as structural change in the economy. The indicator has been calculated from an index decomposition analysis method (Log-mean divisia index method-I) using a bottom up approach.

End-use sectors: Economic sectors that consume final energy. Excludes energy conversion sectors.

Energy efficiency: Measured as the ratio of activity or output to energy inputs.

Energy intensity: The ratio of energy used per unit of output. Energy intensity is often used as an indicator to measure changes in energy productivity and energy efficiency over time.

Energy productivity: The ratio of economic output to energy consumption.

Energy/output ratio: A measure of energy intensity calculated from the ratio of energy consumption to output. The measure illustrates a simple relationship between energy consumption and economic activity at the aggregate level.

Industry gross value added (GVA): The value of output at basic prices minus the value of intermediate consumption at purchasers' prices. The term is used to describe gross product by industry and by sector.

Intensity effect: A measure of how the relative share of and patterns of energy use contribute to changes in energy consumption. It is one of the three explanatory factors used in this report to decompose and explain changes in energy consumption.

Log-Mean Divisia Index Method-I (LMDI-I): An index decomposition analysis (factorisation) method that attempts to breakdown changes in energy intensities over time into various driving forces for change, most importantly the differences between true energy efficiency increases and changes in the structure of an economy. Using the method, changes in energy use are split into three components, including changes due to intensity, output mix, and aggregate production.

Structural effect: A measure of how the relative shares of and the composition of economic activity contribute to changes in energy consumption. It is one of the three explanatory factors used in this report to decompose and explain changes in energy consumption.

Total final energy consumption (TFEC): The total energy consumed in the final or end-use sectors. It is equal to total primary energy supply (TPES) less energy consumed or lost in conversion, transmission and distribution.

Total primary energy supply (TPES): A measure of the total energy supplied within the economy. It is equal to indigenous production plus imports minus exports, minus stock changes and statistical discrepancies. TPES includes both primary and secondary or final fuels.

1. Executive summary

Changes in energy consumption in end-use sectors in Australia over the past three decades can be explained by:

- the contribution of the expansion of economic activity to increasing energy use;
- compositional changes in the economy towards less energy-intensive sectors that has partly offset the magnitude of increasing energy consumption;
- declining energy intensity, which has dampened growth in energy use; energy intensity has declined by 1.0 per cent a year from 1980–81 to 2012–13; and
- improvements in energy productivity, which are mainly attributed to energy efficiency activity in the transport and manufacturing sectors.

Energy is important to the Australian economy. Using energy resources more efficiently supports economic productivity and growth as well as improvements in social well-being. An improvement in energy efficiency means less energy is required to produce goods and services. Energy intensity, the ratio of energy use to a level of activity, is widely used as a proxy for estimating energy efficiency. A decline in energy intensity can also be considered an improvement in energy productivity.

Australia's energy use has been consistently growing more slowly than economic output since the mid-1980s. This can be interpreted as an improvement in Australia's energy productivity and a decline in the energy intensity of the economy. The change in Australia's energy use is partly attributable to improvements in energy efficiency, such as through technological change, and a response to higher energy prices. It is also partly due to a shift in the structure of the economy, from more energy-intensive manufacturing, to less energy-intensive services.

The objective of this study is to distinguish between different factors contributing to changes in Australia's final energy consumption since 1980–81. A factorisation technique is used to examine how aggregate activity, the activity mix, and energy intensity explain changes in energy consumption in end-use sectors of the economy. This allows the contribution of real energy efficiency improvements and structural changes in the economy to be quantified, and helps to better understand why Australia's energy use is changing.

The report presents analysis of energy intensity in Australia in two parts:

- **Part I:** A long-run analysis, over the period 1980–81 to 2012–13, of changes in aggregate energy consumption and intensity in key end-use sectors: the transport, manufacturing and construction, mining, residential, and services sectors.

- **Part II:** A sectoral analysis of changes in energy consumption and intensity for the period 2002–03 to 2012–13 for the five end-use sectors listed above.

1.1 Methodology

Index decomposition analysis is used to explain changes in final energy consumption over time with respect to three effects:

- changes in the scale of economic activity (the **activity effect**);
- changes in the activity mix in economic sectors of the economy (the **structural effect**); and
- changes in the productivity of energy use (the **intensity effect**).

The study focuses on key end-use sectors of the economy that consume final forms of energy, including the transport, mining, manufacturing, construction, residential, and services sectors. Sectors that perform energy conversion activities (transforming one form of energy to another) are excluded in this study, including the electricity and gas supply sectors (Division 26 and 27); and petroleum refining and petroleum and coal product manufacturing subsectors (Subdivision 17 of Division C) from the manufacturing sector. These conversion sectors have been excluded to make consistent the comparison of energy consumption in final or end-use sectors.

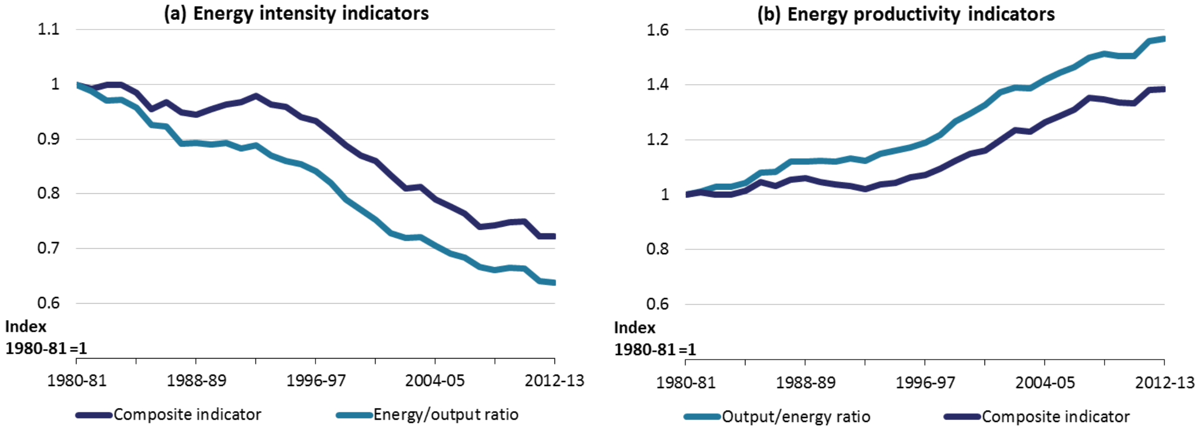
1.2 Measures of energy intensity

Common measures of energy intensity include the energy/output ratio, and the composite indicator that measures the relative contributions of factors leading to changes in the energy intensity of the economy. The key differences between these measures of energy intensity are the degree of information portrayed and how the measures are calculated. A composite indicator of energy intensity is calculated using decomposition analysis and a bottom up approach, taking into account structural shifts and changing patterns of energy use within the economy and its economic sectors.

Energy intensity in Australia, calculated using the energy/output ratio, declined at an average annual rate of 1.4 per cent over the period 1980–81 to 2012–13 (Figure 1.1a). When calculated using the composite indicator, energy intensity declined by 1.0 per cent a year over the same period. The difference between these two indicators is largely a result of the structural shift in the Australian economy from energy-intensive manufacturing to services, as well as changes in the shares of energy use within sectors.

Energy productivity can be depicted as the inverse of energy intensity. The composite indicator can be used to show the role that real improvements in energy efficiency have played in the improvement in Australia's energy productivity over time (Figure 1.1b).

Figure 1.1: Indicators for energy intensity and energy productivity in end-use sectors of the Australian economy



Note: Includes final energy consumption in transport, manufacturing, construction, mining, residential and services sectors.

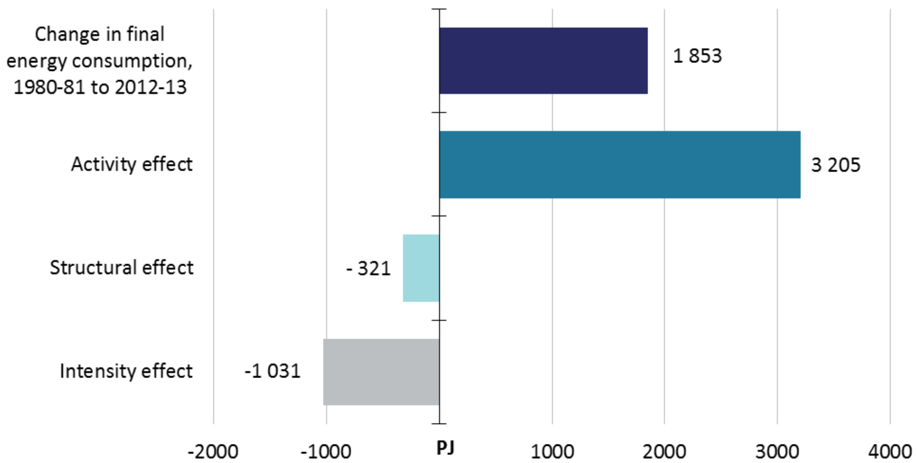
Source: Department of Industry and Science 2015; BREE 2014; ABS 2015b.

1.3 Changes in energy consumption, 1980–81 to 2012–13

Growth in economic activity has been the major determinant of the increase in final energy consumption in Australia from 1980–81 to 2012–13. Apart from the two economic recessions of the early 1980s and 1990s, the Australian economy has experienced largely uninterrupted growth since 1980–81, with the size of the economy almost tripling from 1980–81 to 2012–13 (equal to growth of 3.2 per cent a year). In comparison, final energy consumption in the end use sectors nearly doubled over the same period, increasing by 1 853 petajoules (equal to growth of 2.0 per cent a year).

The results of the decomposition analysis are shown in Figure 1.2.

Figure 1.2: Change in final energy consumption in end-use sectors in Australia, 1980–81 to 2012–13



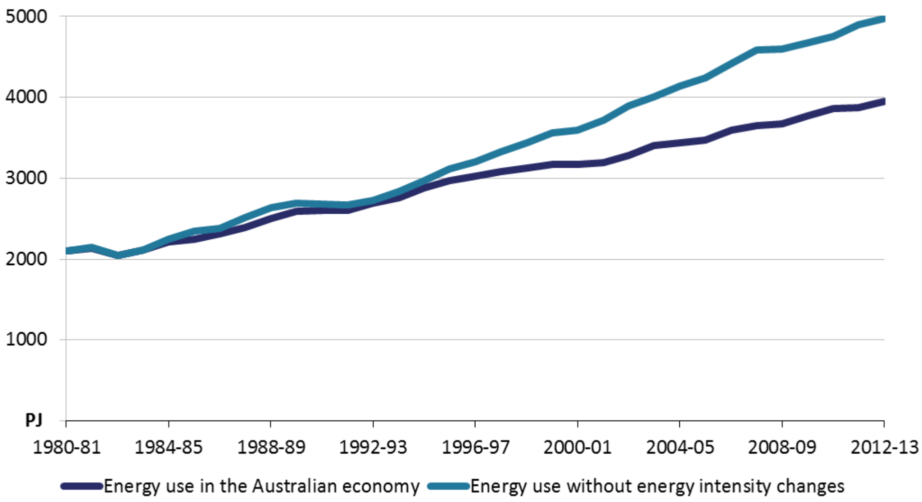
Source: Department of Industry and Science 2015

While the majority of changes in energy consumption may be attributed to economic activity, the analysis suggests improvements in energy efficiency and structural change made a large contribution to dampening the growth in energy use. In particular, if the activity effect had been the only factor at work, energy consumption in 2012–13 would have been 153 per cent higher relative to 1980–81, compared with the actual increase of 88 per cent. Final energy consumption would have been 5 301 petajoules in 2012–13, instead of actual consumption of 3 979 petajoules, if reductions in energy use explained by the intensity effect and structural effect had not been achieved.

The structural effect contributed to reducing energy consumption by 321 petajoules over the period 1980–81 to 2012–13. Structural change in the Australian economy reflects both a shift away from relatively more energy-intensive manufacturing to services, as well as changes in activity within sectors.

Overall, the Australian economy has become less energy-intensive, with the intensity effect accounting for 1 031 petajoules of energy savings over the past three decades (Figure 1.3).

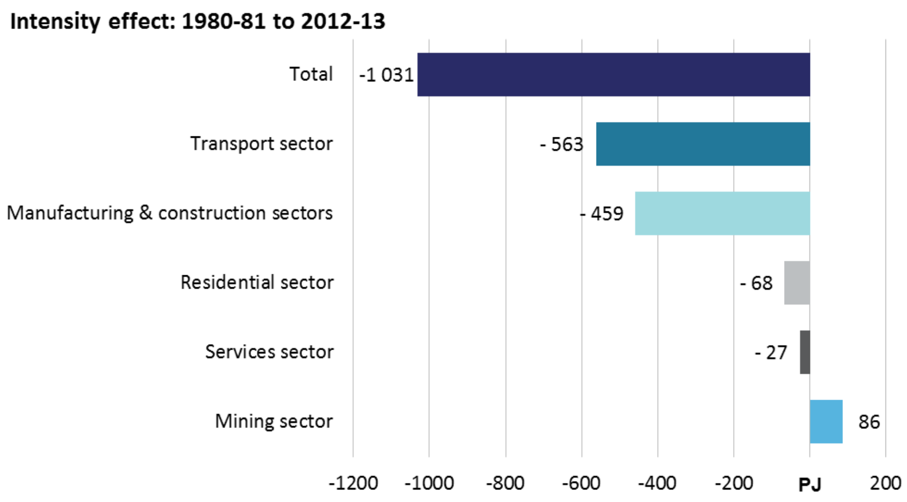
Figure 1.3: Final energy consumption with and without changes in energy intensity



Source: Department of Industry and Science 2015.

Figure 1.4 summarises the changes in energy consumption in end-use sectors of the Australian economy due to the intensity effect over the period 1980–81 to 2012–13. The transport sector exhibited the largest decline in energy intensity, followed by the manufacturing and construction sectors. Users are shifting away from road transport to relatively less-energy intensive rail and air transport modes, and road engine technologies are also improving. Declining energy intensity was partly offset by increased energy intensity in the mining sector. Recent higher commodity prices have provided incentives for firms to extract from more marginal resource deposits, which use relatively more energy to extract the same level of output.

Figure 1.4: Changes in energy consumption due to the intensity effect, by sector, 1980–81 to 2012–13



Source: Department of Industry and Science 2015.

2. Introduction

The Australian Government Energy White Paper, released in April 2015, outlines a vision for the Australian energy sector of competitively priced and reliable energy supply to households, business and international markets. Part of that vision is to be achieved through the more productive use of energy to lower costs and stimulate economic growth. It includes development of a National Energy Productivity Plan, covering the built environment, equipment and appliances, and vehicles. A national energy productivity improvement target will be determined as part of the plan.

Benefits of using less energy include lower energy costs for businesses and households, improved competitiveness, improved energy security, reduced investment required in developing energy resources and infrastructure, and lower energy-related greenhouse gas emissions. With sharp increases in electricity and gas prices over the past five years, and until mid-2014 historically high oil prices, energy use and opportunities to save energy have come into focus.

The Australian economy is using relatively less energy as it grows than in the past. Until the mid-1980s, growth in Australia's energy consumption generally moved in tandem with growth in the economy. Since then, growth in Australia's energy consumption has slowed and has generally remained below the rate of economic growth.

The decline in the ratio of energy use to economic activity is often referred to as a decline in Australia's energy intensity. It can also be considered an improvement in Australia's energy productivity. This trend has been partly the result of improvements in energy efficiency, including through new technologies, minimum performance standards for appliances and buildings, as well as changes in behaviour by businesses and households. It has also been underpinned by a shift in economic structure away from heavy industry towards less energy-intensive sectors such as services.

The report analyses historical trends in final energy consumption and energy intensity in the Australian economy, and identifies the key factors affecting energy consumption in individual end-use sectors such as transport, services and households. It excludes energy used in conversion activities such as electricity generation, petroleum refining and coal product manufacturing. In particular, the report quantifies the contribution of energy efficiency improvements and structural changes to Australia's energy consumption over the past three decades, and provides a deeper analysis of specific effects within sub-sectors over the decade since 2002–03.

This is done by decomposing the change in energy consumption over time into an activity effect (the level of economic activity), a structural effect (the sectoral composition of the economy) and an intensity effect (the productivity of energy use). A change in energy consumption can be expressed as the sum of these three effects. This approach provides a better approximation of energy intensity and productivity trends because the influence of other factors not related to efficiency, such as changes in structure of the economy, can be identified.

The report presents two decomposition analyses of energy use in Australia:

- Part I: long-run analysis of changes in aggregate final energy consumption and intensity over the period 1980–81 to 2012–13; and
- Part II: analysis of changes in energy consumption and intensity in the main end-use sectors over the period 2002–03 to 2012–13. Sectors covered are transport, manufacturing and construction, mining, residential, and services.

3. Energy intensity indicators

3.1 Energy efficiency and energy intensity

Energy efficiency is measured as the ratio of activity or output to energy inputs. Improvements in energy efficiency can be achieved by using less energy for the same level of activity, or increasing the level of activity from the same amount of energy. At an appropriate level of sectoral disaggregation and accounting for other structural elements not related to efficiency in energy use, there is an inverse relationship between energy efficiency and energy intensity.

Energy intensity is measured as the ratio of energy used per unit of activity. Energy intensity is often used as an indicator to measure changes in energy productivity and efficiency over time. A decline in energy intensity can be considered an improvement in energy productivity.

Changes in energy intensity are explained by a number of factors including energy prices, technology use and innovation, choice of production processes, fuel mix and government policies (Sun 1998). Structural shifts in the economy or changes within energy-intensive sectors of the economy can lead to changes in energy intensity.

At the individual process or equipment level, energy intensity can simply be calculated as the change in energy use per unit of output. However, this measure may not be as informative at the aggregate level as there are other factors, such as structural changes, which could contribute to the economy-wide changes in energy intensity. For example, if the composition of the economy changes over time from the more energy-intensive industrial sector to the less energy-intensive service sector, energy intensity can decline without any change in energy efficiency.

3.2 Decomposition method

Energy decomposition analysis attempts to breakdown changes in energy use over time into various determinants bringing about the change, most importantly the contributions of true energy intensity changes and changes in the structure of an economy or a sector.

This analysis of energy intensity uses a form of index decomposition analysis called the Log-Mean Divisia Index Method I (LMDI-I), presented in detail in Appendix A. The approach is well developed in the literature and has been previously adopted by Ang and Liu (2001), Ang et al. (2003), Sandu and Petchey (2009), Petchey (2010), and Che and Pham (2012).

Decomposition analysis using the LMDI-I method allows changes in energy consumption to be broadly explained in terms of three different effects:

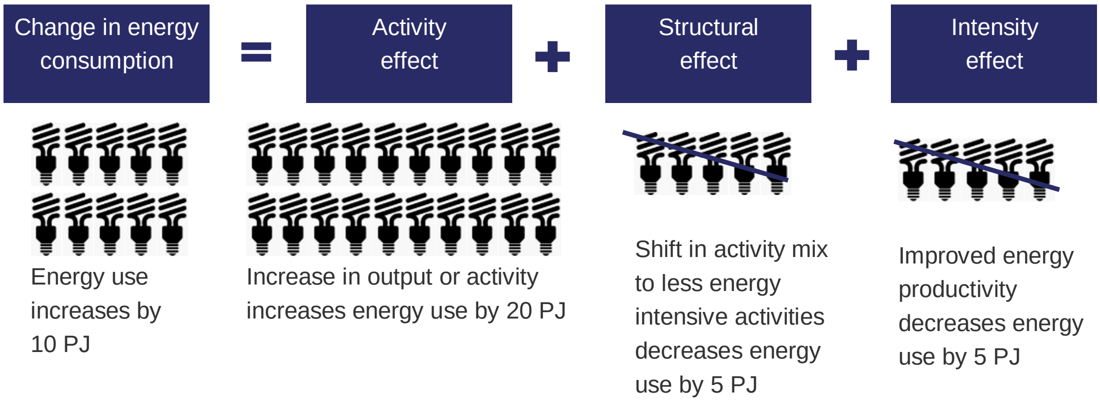
- changes in the level of overall economic activity (the **activity effect**);
- changes in the activity mix in economic sectors of the economy (the **structural effect**); and

- changes in the productivity of energy use (the **intensity effect**) (Ang 2005).

A change in energy consumption can be expressed as the sum of these three effects and movements in each of these effects over time can be examined individually. This is illustrated in Figure 3.1. The LMDI-I method captures how the relative economic performance of individual sectors, structural change in the economy and within sectors, and patterns of energy use may be used to account for changes in energy consumption.

The decomposition analyses are presented over two periods: 1980–81 to 2012–13, and a more detailed sectoral analysis for 2002–03 to 2012–13. Data availability at the subsectoral level, as well as structural breaks in the data for some series, constrains the ability to undertake the more detailed sectoral decomposition analysis over the longer time period.

Figure 3.1: Decomposition of change in energy consumption



Source: Department of Industry and Science 2015.

3.3 Energy intensity indicators: energy/output ratio and composite index

There are two common measures of energy intensity:

- the energy/output ratio, and
- the composite index, which uses the decomposition method outlined above.

Energy/output ratio

The energy/output ratio measures energy intensity as the relationship between energy consumption and economic activity at the aggregate level. Because this study is focussed on end-use sectors, final energy consumption is used to calculate the energy/output ratio.

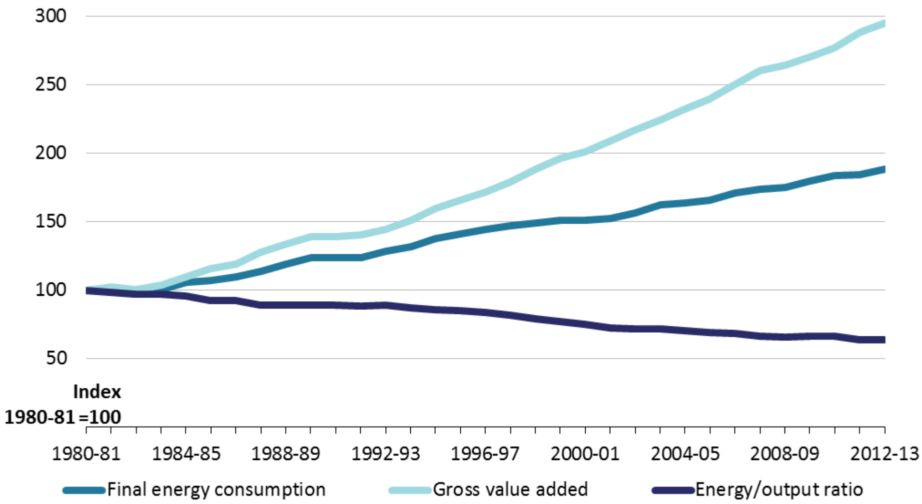
Calculation of the energy/output ratio is relatively straight forward. For the end use sectors covered in this study, the energy/output ratio is calculated by dividing their final energy consumption by industry gross value added.

The sectors included in this study are transport, manufacturing and construction, mining, residential, and services. Together, these sectors accounted for more than two-thirds of Australia's total energy consumption in 2012–13 and 98 per cent of total final energy consumption.

This study uses industry gross value added to measure activity for the transport, manufacturing, construction, mining, and services sectors. Broadly speaking, value added is the difference between an industry's revenue and its costs. Industry gross value added measures the value of output at basis prices less the value of total intermediate consumption at purchasers' prices. It excludes energy and other intermediate inputs used in the production of goods and services. 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.

Energy intensity in Australia, calculated using the energy/output ratio, declined at an average annual rate of 1.4 per cent over the period 1980–81 to 2012–13 (Figure 3.2).

Figure 3.2: Energy intensity in end-use sectors of the Australian economy, energy/output ratio



Notes: Includes transport, mining, manufacturing, construction, residential and services sectors.

Source: Department of Industry and Science 2015; BREE 2014; ABS 2015b.

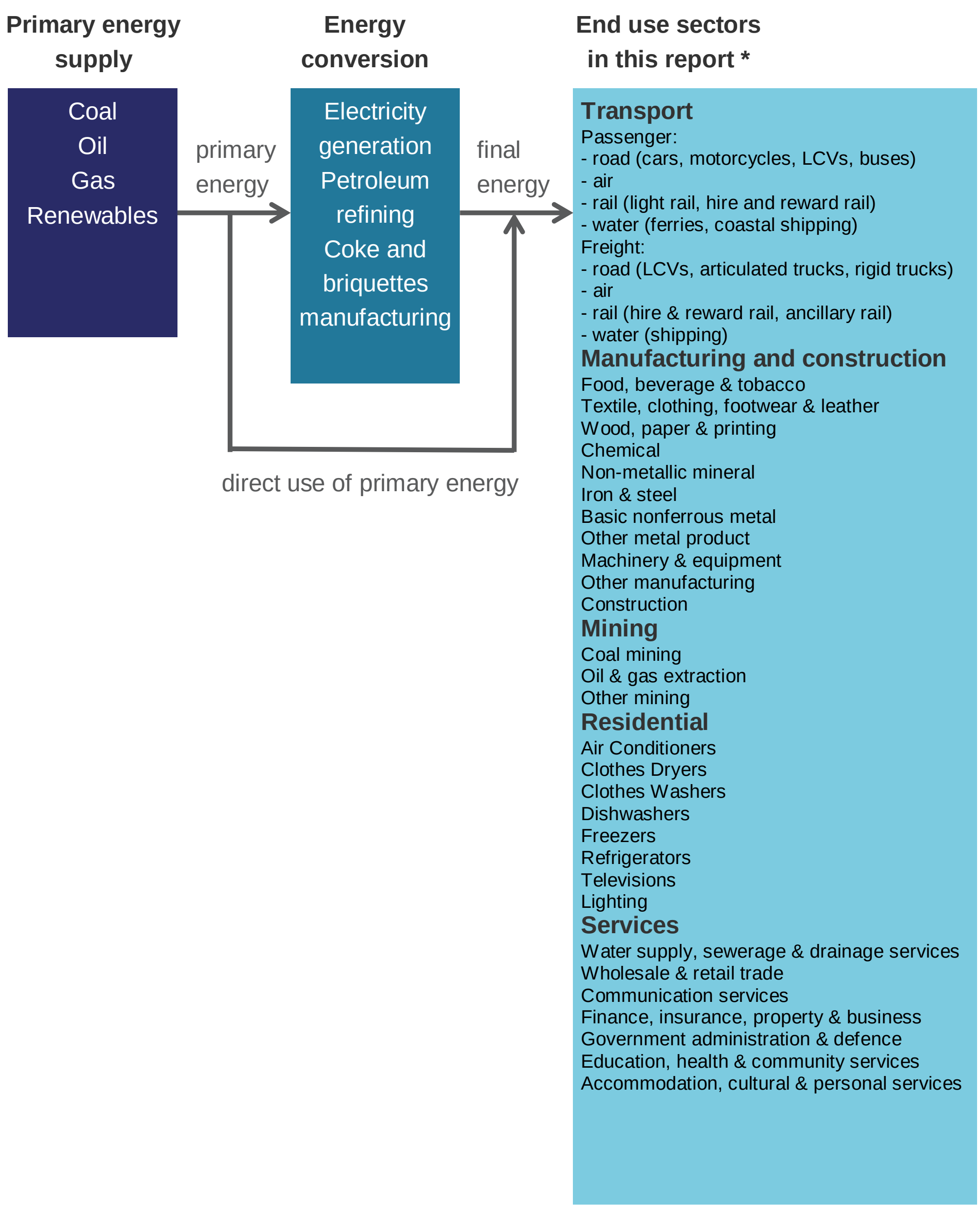
While relatively easy to calculate, the energy/output ratio is an aggregate measure and only provides information about general or economy-wide trends in energy intensity. It is difficult to determine the causes of trends in energy intensity without further disaggregated analysis. To do this requires going to the sectoral or subsectoral level to identify the factors causing the observed trends, such as changes in the structure of the economy, and actual improvements in energy efficiency.

Composite index method

The composite index is an alternative method to the energy/output ratio for calculating energy intensity. It is calculated based on a bottom up approach by aggregating energy intensities derived for individual sectors. The sectoral energy intensities are calculated using the LMDI-I decomposition method described in the previous section and Appendix A. The individual end-use sectors used to calculate this index are listed in Figure 3.3. Agriculture, which accounts for 2 per cent of total final energy consumption, has been excluded due to lack of subsectoral energy use data.

As previously mentioned, this method accounts for structural changes in the Australian economy. Another advantage is that it allows a high degree of flexibility in the choice of activity measures used.

Figure 3.3: Sectors included in the report

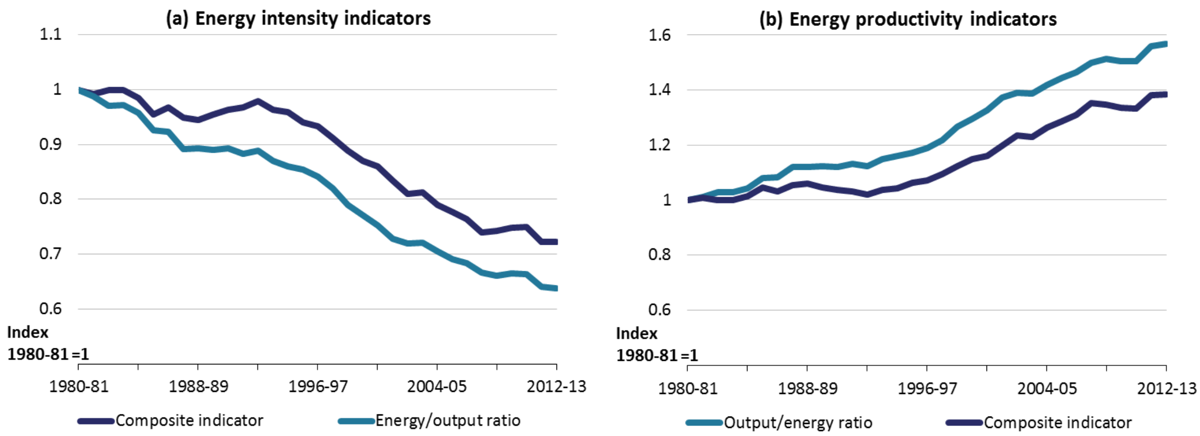


Source: Department of Industry and Science 2015.

Energy intensity in the Australian economy as measured by the composite index declined at an average rate of 1.0 per cent a year over the period 1980–81 to 2012–13, compared with 1.4 per cent as measured by the energy/output ratio (Figure 3.4a). The difference between these two measures is largely a result of a change in the composition of and changes in energy use patterns in the Australian economy. In particular, energy-intensive manufacturing has been displaced by growth of the services economy over the period 1980–81 to 2012–13. Further, since 2002–03, strong growth in mining energy consumption combined with the deterioration in energy efficiency in the sector has partly offset the long-term decline in energy intensity of the economy.

The decline in energy intensity can also be shown as an increase in energy productivity (Figure 3.4b). Energy productivity grew by 1.4 per cent a year over the period 1980–81 to 2012–13, as measured by the inverse of the energy/output ratio shown in Figure 3.4a. Similarly, the inverse of the composite indicator can be used to show the contribution of real changes in Australia's energy productivity.

Figure 3.4: Indicators for energy intensity and energy productivity in end-use sectors of the Australian economy



Notes: Includes final energy consumption transport, manufacturing, construction, mining, residential and services sectors.

Source: Department of Industry and Science 2015; BREE 2014; ABS 2015b.

4. Part I: Energy intensity in the Australian economy: 1980–81 to 2012–13

4.1 Key findings

- Final energy consumption in end-use sectors of the Australian economy increased by 88 per cent or 1 853 petajoules from 1980–81 to 2012–13.
- The majority of changes in energy consumption over the past three decades may be attributed to the expansion in economic activity. On its own, the activity effect would have led to an increase in energy consumption of 3 205 petajoules, nearly twice the actual increase.
- The structural effect from changes in the economy towards less energy-intensive sectors such as services have partly offset growth in energy consumption, reducing energy consumption by 17 per cent (or 321 petajoules) over the period 1980–81 to 2012–13.
- The intensity effect contributed a reduction of 1 031 petajoules in energy consumption, or 56 per cent of the change in energy consumption, over the past three decades.
- Energy intensity declined by 1.0 per cent a year over the past three decades when measured using a composite index accounting for structural changes in the economy, compared with a decline of 1.4 per cent a year when measured using the energy/output ratio.

4.2 Introduction

Apart from two economic recessions in the early 1980s and 1990s, the Australian economy has experienced largely uninterrupted growth over the past three decades. Until the mid-1980s, the rate of economic growth moved in parallel with growth in energy consumption. Since then, growth in Australia's energy consumption has slowed and has generally remained below the rate of economic growth. Changes in the composition of energy use associated with structural shifts in the Australian economy have contributed to a relative slowdown in the growth in energy use. Energy efficiency activity in individual sectors has also played a role.

Part I examines changes in energy consumption and energy intensity at the macro level by analysing key end-use sectors of the Australian economy: the transport, mining, manufacturing and construction, residential, and services sectors (Table 4.1). Using index decomposition analysis, changes in aggregate energy consumption are decomposed into the activity effect, structural effect and intensity effect. A more detailed analysis of energy intensity in each end-use sector is presented in Part II of this study.

Table 4.1: Coverage and variables used for decomposition of energy consumption in the Australian economy

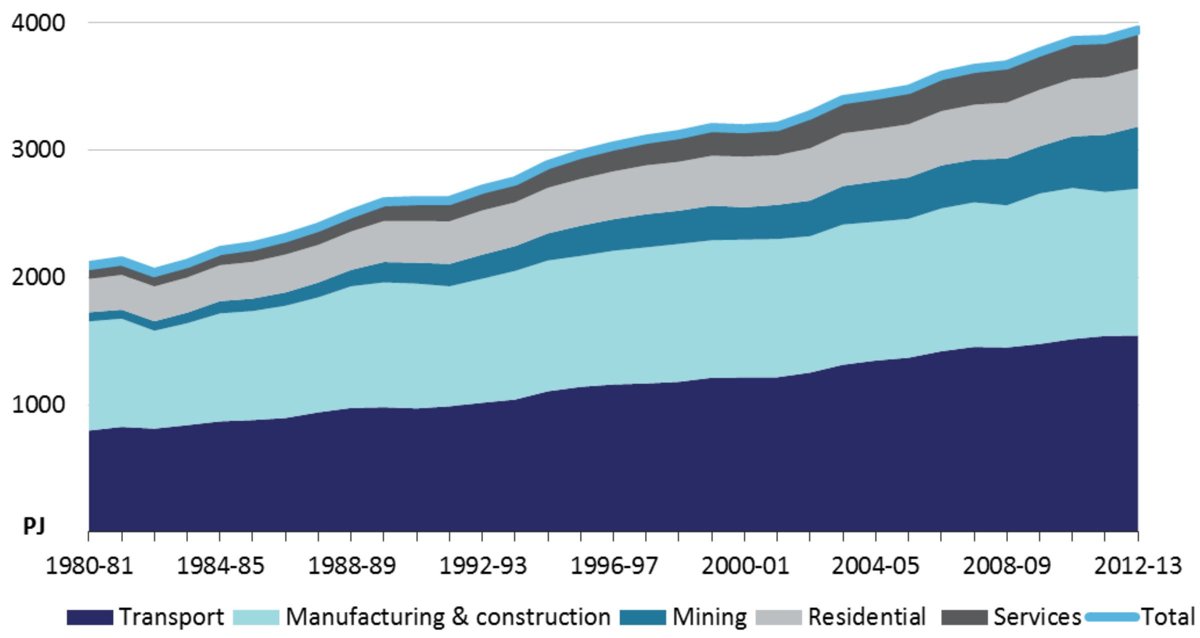
Economic segment	*Activity variables*	*Structure variables*	*Intensity variables*
Transport	value-added	share of total output	energy/ value-added
Manufacturing and construction	value-added	share of total output	energy/ value-added
Mining	value-added	share of total output	energy/ value-added
Residential	household final consumption expenditure	share of total output	energy/ household final consumption expenditure
Services	value-added	share of total output	energy/ value-added

Notes: Activity in the residential sector is measured by household final consumption expenditure (FCE) on electricity, gas and other fuel.

4.3 Trends in energy consumption

Final energy consumption in key end-use sectors of the Australian economy increased by 2.0 per cent a year from 1980–81 to 2012–13 (Figure 4.1). The highest rate of energy consumption growth occurred in the mining and services sectors, which increased by 6.2 per cent and 3.4 per cent a year respectively over the period. While energy consumption in the manufacturing and construction sectors constitutes a relatively large share of total energy consumption, their share declined from 1980–81 to 2012–13. In contrast, the shares of energy consumption in the mining, services and transport sectors all increased over the period.

Figure 4.1: Energy consumption in the Australian economy, selected end-use sectors



Source: Department of Industry and Science 2015; BREE 2014.

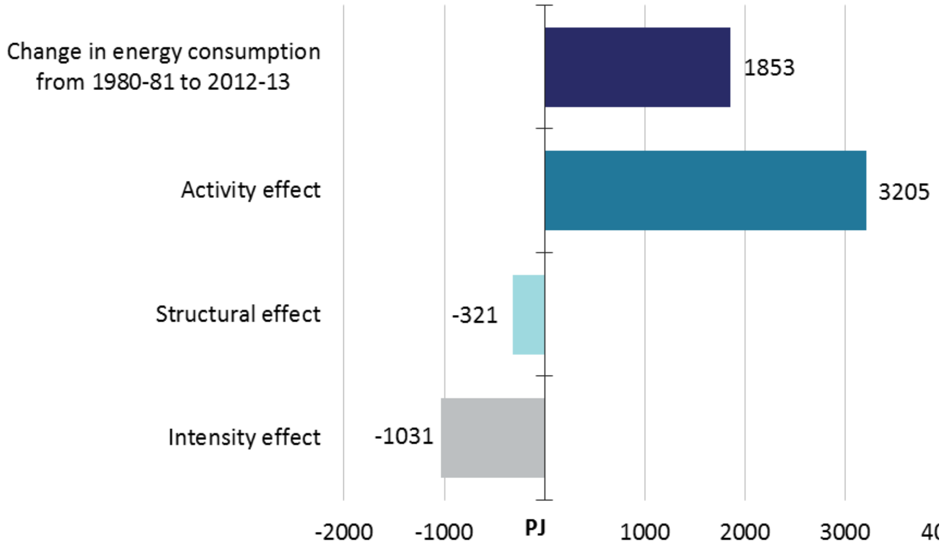
4.4 Decomposition of changes in energy consumption

The results of the decomposition analysis show changes in final energy consumption in the Australian economy attributable to the activity effect, structural effect, and intensity effect over the period 1980–81 to 2012–13. Figure 4.2 summarises the changes in energy consumption explained by each of these effects.

Final energy consumption in the end-use sectors increased by 1 853 petajoules from 1980–81 to 2012–13. Growth in economic activity is the major determinant of the change in energy consumption over this period. The activity effect indicates that the amount of energy consumed would have been nearly twice the realised energy consumption in the absence of the other effects.

The structural and intensity effects partly offset the changes in energy consumption attributable to the activity effect, reducing energy consumption by 321 petajoules and 1 031 petajoules respectively.

Figure 4.2: Decomposition of the change in final energy consumption in end-use sectors of the Australian economy, 1980–81 to 2012–13



Source: Department of Industry and Science 2015.

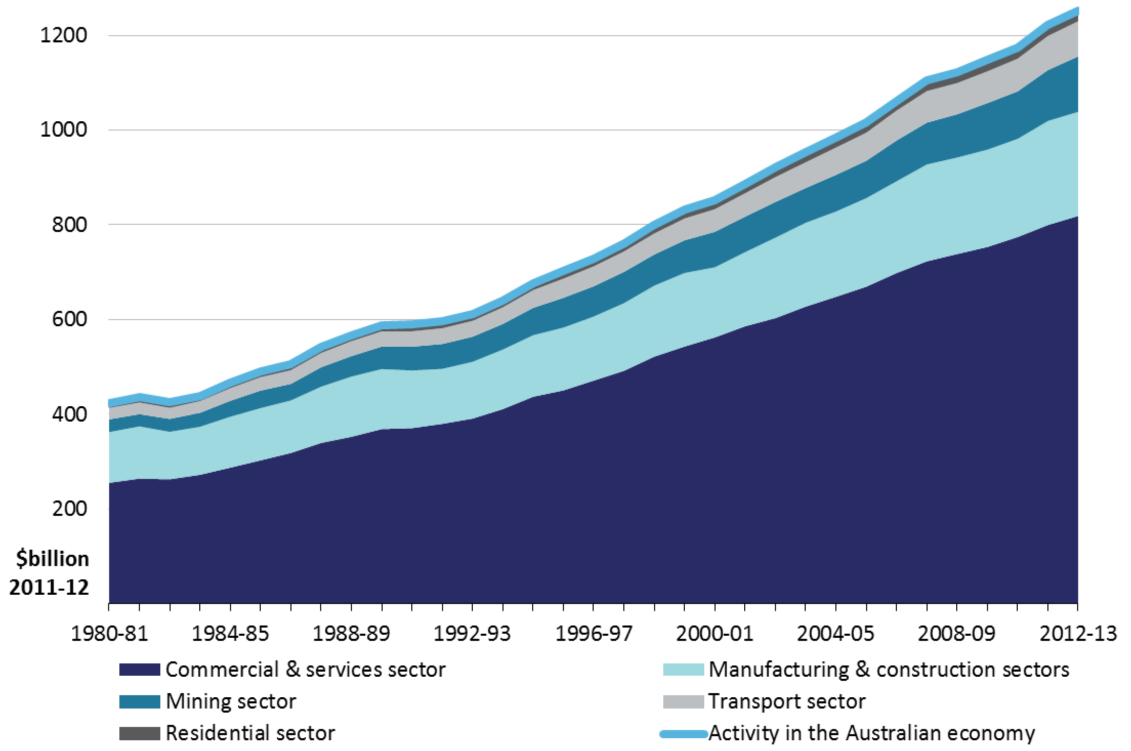
4.5 Changes in the scale of activity in the Australian economy – the activity effect

In the absence of the structural and intensity effects, the activity effect would have increased energy consumption by 3 205 petajoules over the period 1980–81 to 2012–13.

Economic activity in the key end-use sectors of the Australia economy increased at an annual average rate of 3.4 per cent from 1980–81 to 2012–13 (Figure 4.3), nearly tripling over the period. All sectors grew at an annual average rate greater than 2.0 per cent over this period. The services, mining and transport sectors contributed the most to growth in industry gross value added (gva).

The absolute size of the mining sector, measured in industry gva terms, more than quadrupled over the period 1980–81 to 2012–13, with the services and transport sectors more than tripling. Economic activity in the residential sector, measured by household final consumption expenditure on electricity, gas and other fuel, also exhibited considerable growth (Table 4.2).

Figure 4.3: Economic activity in end-use sectors of the Australian economy



Note: Residential sector activity measured by household final consumption expenditure (FCE) on electricity, gas and other fuel.

Source: Department of Industry and Science 2015; ABS 2015b.

Table 4.2: Activity in end-use sectors of the Australian economy, by sector

Activity	*1980–81*	*2012–13*		*1980–81 to 2012–13*
	$billion	$billion	% change	Annual growth (%)
Gross value added a				
Total GVA for key end-use sectors	423.5	1251.6	195.5	3.4
Services	255.2	818.7	220.8	3.7
Manufacturing and construction	107.1	219.9	105.3	2.3
Mining	26.9	117.0	335.8	4.7
Transport	24.0	74.3	209.2	3.6
Total household final consumption expenditure a, b				
Residential	10.3	21.7	110.8	2.4

Notes: a Chain volume measures. Reference year for chain volume measures is 2011-12; b Activity in the residential sector measured by household final consumption expenditure (FCE) on electricity, gas and other fuel.

Source: Department of Industry and Science 2015; ABS 2015b.

4.6 Structural change in the Australian economy – the structural effect

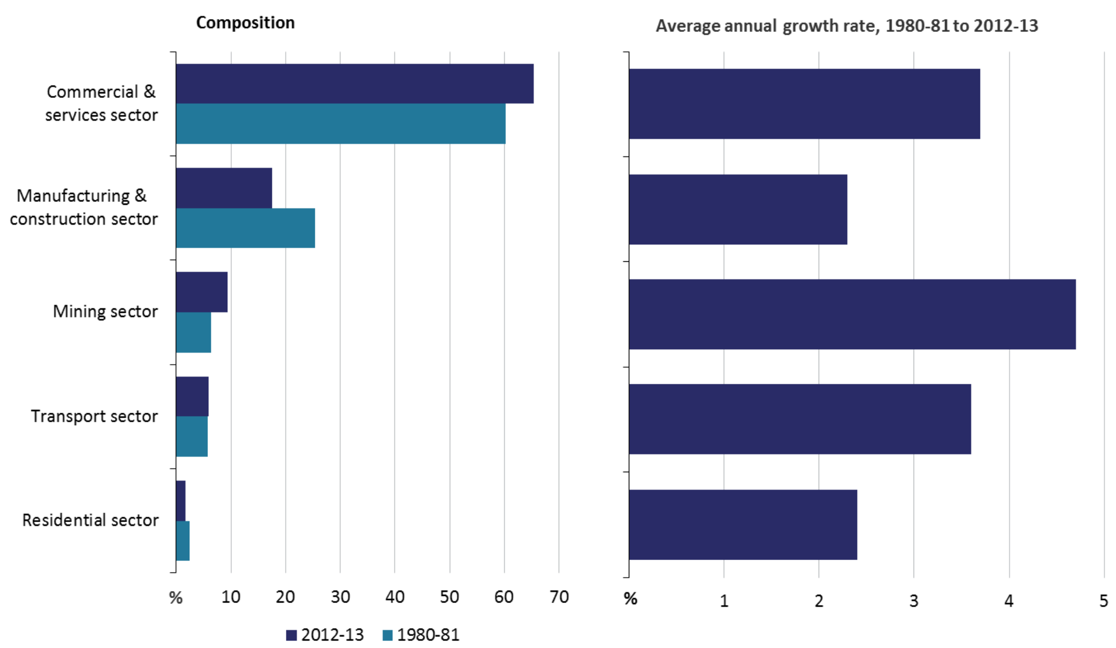
While economic activity increased over the period 1980–81 to 2012–13 in all sectors, rates of economic growth varied across the sectors. In particular, annual growth in activity in the mining, transport and services sectors was considerably greater than the rate of growth in the manufacturing and construction sectors. A decline in the share of total economic activity of the manufacturing and construction sectors and the increasing shares of the services and mining sectors indicate a change in the structure of Australian economy over the period.

The key factors driving structural change in the economy include economic reform, technological innovation, high commodity prices and increasing demand for services. Technological improvements are changing how and where products are produced. A richer and older population is demanding more health care, more tourism and more education. Globalisation, including tariff reduction, has exposed industries to highly competitive international markets (Department of Industry 2014).

Expansion in mining production and exports has been driven by the fast pace of urbanisation and industrialisation of emerging economies in Asia. This has underpinned the commodity booms in the early 1980s and from 2002–03, which have increased the contribution of the mining sector (Bishop et al. 2013).

The structural effect reduced energy consumption by 321 petajoules, or around 17 per cent of the change in energy consumption over the period 1980–81 to 2012–13.

Figure 4.4: Activity in end-use sectors of the Australian economy, 1980–81 to 2012–13



Source: Department of Industry and Science 2015; ABS 2015b.

4.7 Changing energy intensity – the intensity effect

Over the period 1980–81 to 2012–13, the mining sector had the highest rate of annual growth in energy consumption, increasing by 6.2 per cent. Energy consumption in the transport sector increased the most in absolute terms but at a relatively moderate rate compared with the mining and services sectors. The annual average growth rates of the residential, and manufacturing and construction sectors were 1.7 per cent and 0.9 per cent, respectively (Table 4.3 and Figure 4.5). While the manufacturing and construction sectors together were the second largest final energy user in 1980–81, their share of the total declined from 41 to 29 per cent of energy consumption over the period 1980–81 to 2012–13.

Energy intensity reflects not only how much energy is used in the economy but also the changes in energy consumption across sectors. Energy intensity in the Australian economy declined by 1 031 petajoules from 1980–81 to 2012–13, or around 56 per cent of the change in energy consumption. Figure 4.6 and Figure 4.7 summarise changes in energy consumption in the Australian economy due to the intensity effect, which also provides a proxy measure of energy efficiency activity at the sectoral level.

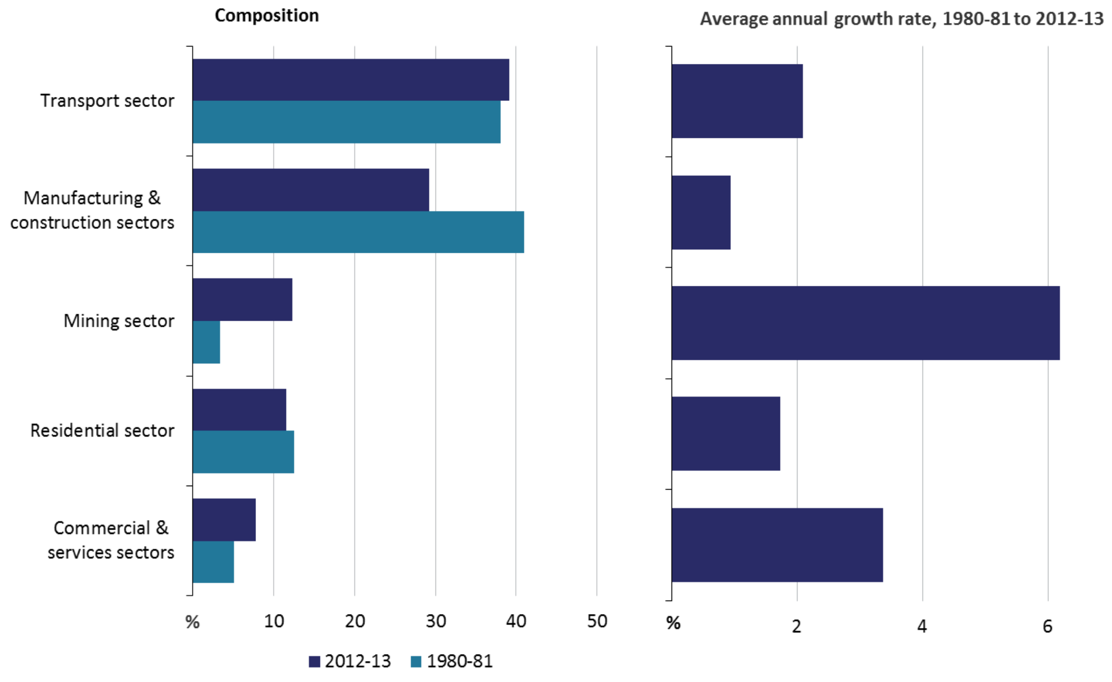
The transport sector exhibited the largest decline in energy intensity, followed by the manufacturing and construction sectors and residential sectors. The decline in energy intensity in the Australian economy from 1980–81 to 2012–13 was partially offset by increased energy intensity in the mining sectors. Energy intensity trends in each of these sectors are examined in further detail in Part II.

Table 4.3: Total final energy consumption

Energy consumption	*1980–81*	*2012–13*		*1980–81 to 2012–13*
	PJ	PJ	% change	Annual growth (%)
TFEC of key end-use sectors	2096	3949	88.4	2.0
Transport	798	1545	93.7	2.1
Manufacturing and construction	858	1154	34.5	0.9
Mining	71	488	584.8	6.2
Residential	263	454	72.9	1.7
Services	107	308	189.1	3.4

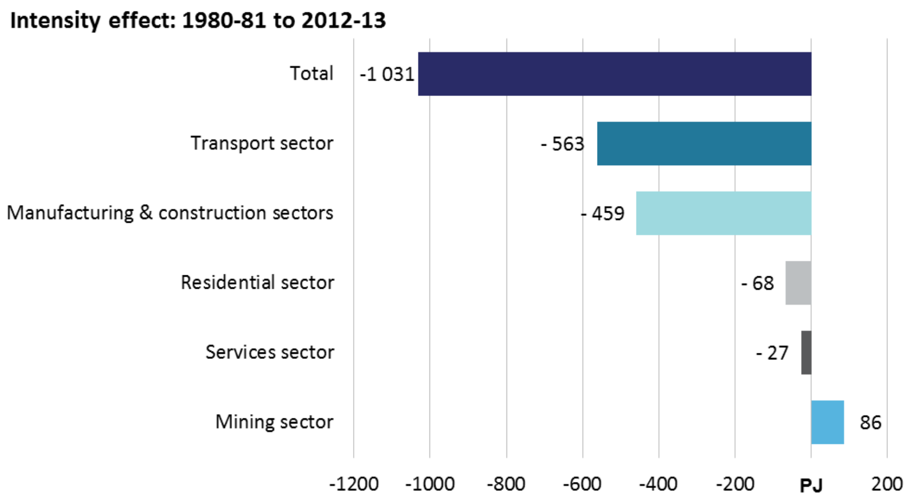
Source: Department of Industry and Science 2015; BREE 2014.

Figure 4.5: Final energy consumption in end-use sectors of the Australian economy, 1980–81 to 2012–13



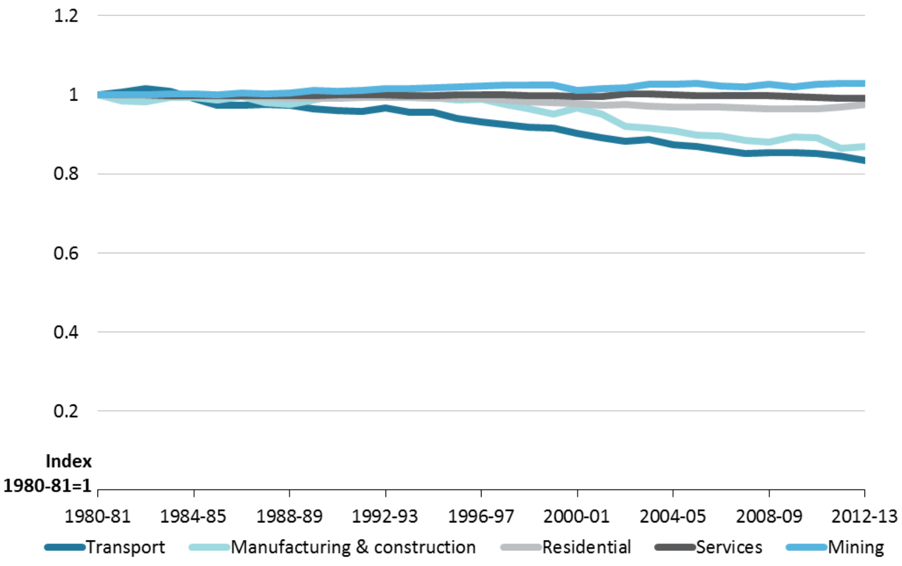
Source: Department of Industry and Science 2015; BREE 2014.

Figure 4.6: Changes in energy consumption due to the intensity effect, by sector, 1980–81 to 2012–13



Source: Department of Industry and Science 2015.

Figure 4.7: Composite indicators of energy intensity in end-use sectors of the Australian economy

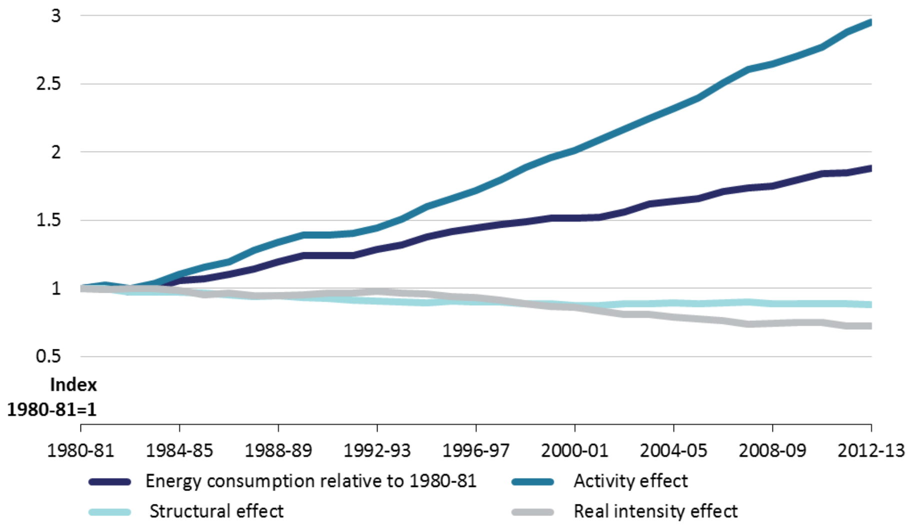


Source: Department of Industry and Science 2015.

4.8 Factored trends in energy consumption

Trends in each factored component, relative to 1980–81, are shown in Figure 4.8. Structural shifts in the composition of the end-use sectors contributed to reducing energy consumption although this effect has diminished over time. The contribution of the intensity effect was relatively small during the 1980s, but has increased in the 1990s. This is likely to reflect greater energy efficiency activity in many sectors, including improved fuel efficiency in vehicles and improved efficiency and standards for buildings and appliances.

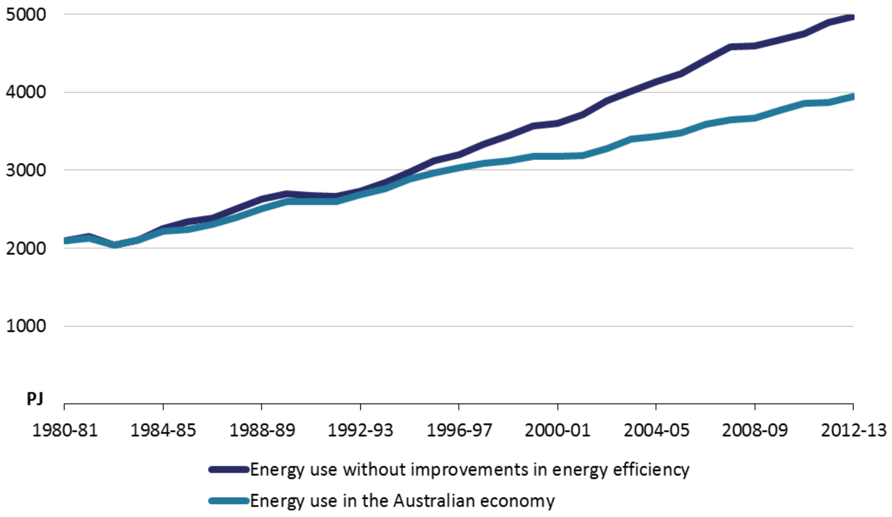
Figure 4.8: Decomposition of the change in energy consumption in end-use sectors of the Australian economy



Source: Department of Industry and Science 2015.

Final energy consumption would have been 5 301 petajoules in 2012–13, instead of actual consumption of 3 949 petajoules, if reductions in energy use associated with the intensity effect and structural effect had not been achieved. Changes in energy consumption in end-use sectors explained by the intensity effect are compared to actual energy consumption in Figure 4.9. The intensity effect contributed an estimated 1 031 petajoules of energy savings over the past three decades.

Figure 4.9: Changes in final energy consumption in end-use sectors of the Australian economy and energy efficiency



Notes: Shows cumulative changes in energy efficiency.

Source: Department of Industry and Science 2015.

4.9 Concluding remarks

In Part I, economy-wide changes in energy consumption were analysed over the longer term with particular emphasis on how the intensity effect explains improvements in energy productivity in the end-use sectors of the Australian economy.

Part II of the report builds on the analysis in Part I to investigate further changes in final energy consumption in the Australian economy in more detail using data at the sub-sectoral level. The availability of sub-sectoral level data from 2002–03 provides further detail on energy consumption and enables analysis of the effects of structural changes as well as changes in patterns of energy use within sectors.

Subsector data is not available for all of the sectors prior to 2002–03, which constrains the ability to replicate the more detailed analysis in Part II over the longer term. There are also some structural breaks in 2002-03 in some series, which would affect longer term sub sectoral analysis.

5. Part II: Energy intensity in end-use sectors, 2002–03 to 2012–13

Part II investigates the key explanatory factors for changing energy consumption in the main end-use sectors of the Australian economy for the period 2002–03 to 2012–13. Sectors covered in the decomposition analysis are transport, manufacturing and construction, mining, residential, and services. Agriculture is excluded due to lack of subsectoral energy use data.

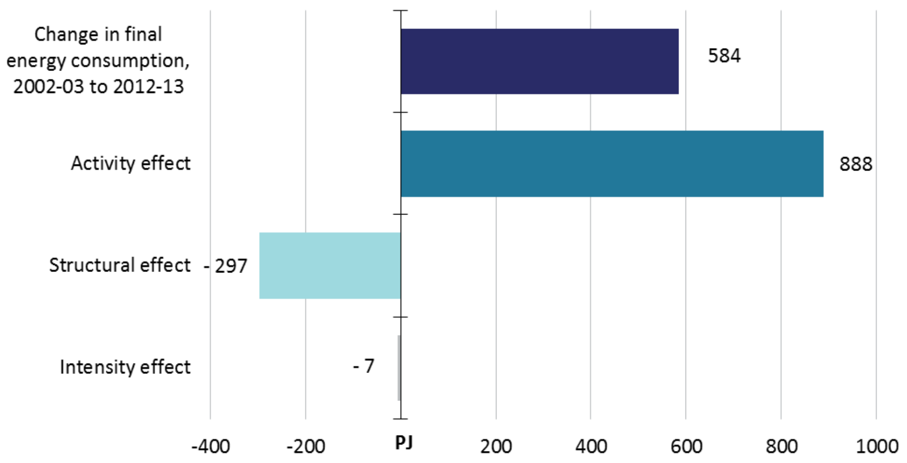
Since 2002-03, Australia's economic performance has been underpinned by the contribution of the mining boom. The rapid expansion of Australia’s extractive industries has led to strong growth in final energy consumption and in patterns of energy use. However, the compositional change in the Australian economy is not limited solely to the effects of the expansion of the mining sector. The analysis in Part II shows that changes in the activity mix within other end-use sectors have also contributed strongly to changes in energy consumption.

Decomposition of changes in energy consumption

The results of the decomposition analysis show changes in final energy consumption in the end-use sectors attributable to the activity effect, structural effect, and intensity effect over the period 2002–13 to 2012–13 (Figure 5.1). Final energy consumption in the end-use sectors increased by 584 petajoules from 2002–03 to 2012–13. The activity effect indicates that the amount of energy consumed would have been around 152 per cent more than the realised energy consumption in the absence of the other effects.

The structural and intensity effects partly offset the increase in energy consumption attributable to the activity effect, reducing energy consumption by 297 petajoules and 7 petajoules respectively.

Figure 5.1: Decomposition of changes in energy consumption in end-use sectors, 2002–03 to 2012–13

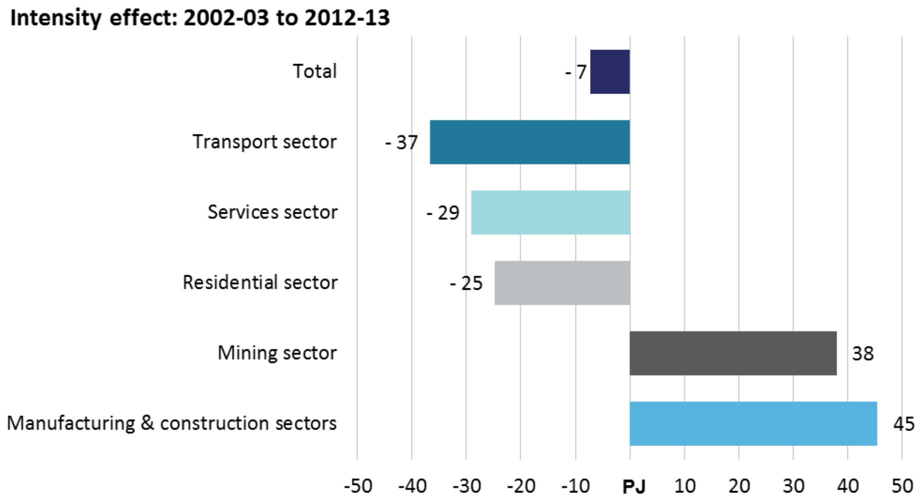


Source: Department of Industry and Science 2015.

The analysis of the relative change in energy consumption within the end-use sectors demonstrates a different story to the aggregate and long-run analysis in Part I of the study. A key difference is that structural changes are shown to have a greater impact on changes in energy use over the period 2002-03 to 2012-13 than the impact of energy efficiency activity.

Figure 5.2 summarises changes in energy consumption in each of the end-use sectors due to the intensity effect. The intensity effect contributed to a decline of 7 petajoules from 2002-03 to 2012-13, or around 1 per cent of the change in energy consumption. This proxy measure of energy efficiency activity at the sectoral level indicates an improvement in the transport, services and residential sectors from 2002-03 to 2012-13. This was largely offset by the deterioration in energy productivity in the mining and manufacturing and construction sectors over the last decade.

Figure 5.2: Changes in energy consumption due to the intensity effect, by sector, 2002-03 to 2012-13



Source: Department of Industry and Science 2015.

The LMDI-I approach used in Part II of this study explains changes in energy consumption relative to 2002-03 and these results may vary compared with longer-run results that rely on a different base year. The decomposition method takes a bottom up approach and takes into account structural shifts and changing patterns of energy use at the subsector level to explain changes in end-use sectors.

Transport

5.1 Key points

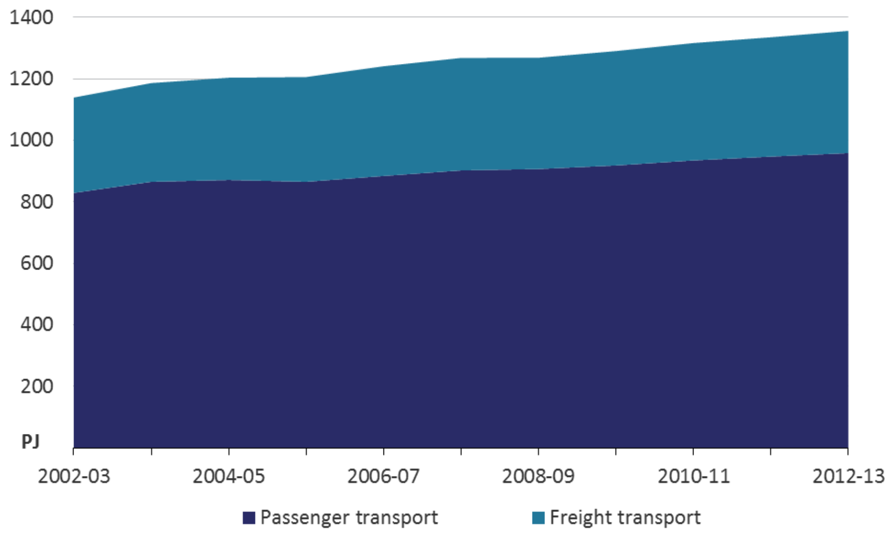
- The transport sector is the largest end-user of energy in Australia, accounting for 39 per cent of final energy consumption in 2012–13. It contributed 6 per cent of industry gross value added in the same year.
- Final energy consumption in the transport sector increased by 217 petajoules between 2002–03 and 2012–13, an increase of 1.8 per cent a year.
- Energy use in passenger transport increased by 1.5 per cent a year from 2002–03 to 2012–13, underpinned by growth in air transport and light commercial vehicles.
- Energy use in freight transport rose by 2.5 per cent a year over the same period, attributable to growth in trucking and light commercial vehicles.
- Decomposition of changes in energy consumption shows that the activity effect contributed 299 petajoules to growth in energy use in the transport sector from 2002–03 to 2012–13.
- Structural changes within the sector contributed to a decline of 45 petajoules in energy consumption over the period.
- Energy intensity in the transport sector fell by modestly by 0.3 per cent a year over this period, with the intensity effect reducing energy consumption by 37 petajoules.

5.2 Introduction

The transport sector is the largest user of final energy in Australia, accounting for 39 per cent of final energy consumption in 2012–13 (BREE 2014). Unleaded petrol, diesel and aviation turbine fuel represented 92 per cent of transport energy use in 2012–13. More than two-thirds of energy consumption in the transport sector is for passenger transport, mainly road but also increasingly in air transport. Energy consumption in freight transport mainly comprises trucking.

Energy consumption in the transport sector grew by 1.8 per cent a year between 2002–03 and 2012–13. Energy use in passenger transport increased by 1.5 per cent a year over this period, supported by growth in air and light commercial vehicles. Over the same period, energy consumption in freight transport increased by 2.5 per cent, underpinned by growth in energy use in trucking and light commercial vehicles (Figure 5.3).

Figure 5.3: Final energy consumption in the transport sector, by subsector



Source: BITRE 2015.

5.3 Coverage, variables used and data sources

The transport sector is split into two transport tasks, passenger and freight, and then into a range of transport modes such as road, rail, air and shipping (Table 5.1). Estimates of passenger kilometres and tonne kilometres, used to measure activity, were provided by the Bureau of Infrastructure, Transport and Regional Economics (BITRE 2015).

Estimates of energy use in the transport sector by task and mode were also sourced from BITRE. The BITRE estimates enable a more detailed examination of energy use and intensity within the transport sector compared with data available in the Australian Energy Statistics (BREE 2014), which has less disaggregation. While similar in magnitude, total energy use for the transport sector differs between the two data sets, and care should be taken when comparing these results.

The energy/output ratios for the transport tasks are measured by energy use per passenger kilometre travelled (one passenger being moved one kilometre), and energy use per tonne kilometre travelled (one tonne of freight being moved one kilometre). The activity measures for the transport tasks are not directly comparable and aggregating passenger and freight transport can sometimes be difficult to interpret. Given this disparity between activity measures, a log average weighting of the share of energy use of each transport task is calculated in the decomposition analysis to estimate the change in energy consumption in the transport sector overall. Changes in energy consumption are decomposed in terms of the activity effect, structural effect, and intensity effect using the relative contribution of the passenger and freight transport tasks.

Table 5.1: Coverage and variables used in the transport sector

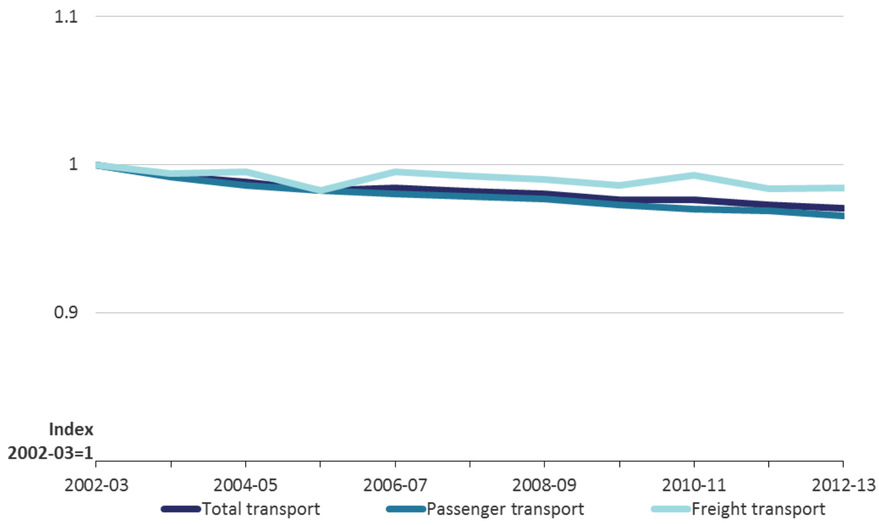
Subsector	*Transport mode*	*Activity variables a*	*Structure variables*	*Intensity variables*
Passenger				
	Air	Passenger-kms	Share of total pass-km	Energy/pass-km
	Light rail	Passenger-kms	Share of total pass-km	Energy/pass-km
	Hire and reward rail	Passenger-kms	Share of total pass-km	Energy/pass-km
	Ferries	Passenger-kms	Share of total pass-km	Energy/pass-km
	Coastal	Passenger-kms	Share of total pass-km	Energy/pass-km
	Cars	Passenger-kms	Share of total pass-km	Energy/pass-km
	Motorcycles	Passenger-kms	Share of total pass-km	Energy/pass-km
	Trucks	Passenger-kms	Share of total pass-km	Energy/pass-km
	Buses	Passenger-kms	Share of total pass-km	Energy/pass-km
	Light commercial vehicles	Passenger-kms	Share of total pass-km	Energy/pass-km
Freight				
	Hire and reward rail	Tonne-kms	Share of total tonne-km	Energy/tonne-km
	Ancillary rail	Tonne-kms	Share of total tonne-km	Energy/tonne-km
	Shipping	Tonne-kms	Share of total tonne-km	Energy/tonne-km
	Light commercial vehicles	Tonne-kms	Share of total tonne-km	Energy/tonne-km
	Articulated trucks	Tonne-kms	Share of total tonne-km	Energy/tonne-km
	Rigid trucks	Tonne-kms	Share of total tonne-km	Energy/tonne-km
	Air	Tonne-kms	Share of total tonne-km	Energy/tonne-km

Notes: a Passenger-kilometre (pass-km) refers to the task undertaken by passenger transport modes and is equivalent to one passenger being moved one kilometre. Tonne-kilometre (tonne-km) refers to the task undertaken by the freight transport modes and is equivalent to one tonne being moved one kilometre.

5.4 Indicators of energy intensity in the transport sector

Energy intensity of the transport sector declined steadily over the decade to 2012–13 by 0.3 per cent a year on average (Figure 5.4). Energy intensity in passenger transport has fallen by 0.4 per cent a year while freight transport has fallen by 0.2 per cent a year.

Figure 5.4: Energy intensity of the transport sector



Notes: Log average weights of energy consumption by transport task are used to calculate total transport energy intensity.

Source: Department of Industry and Science 2015.

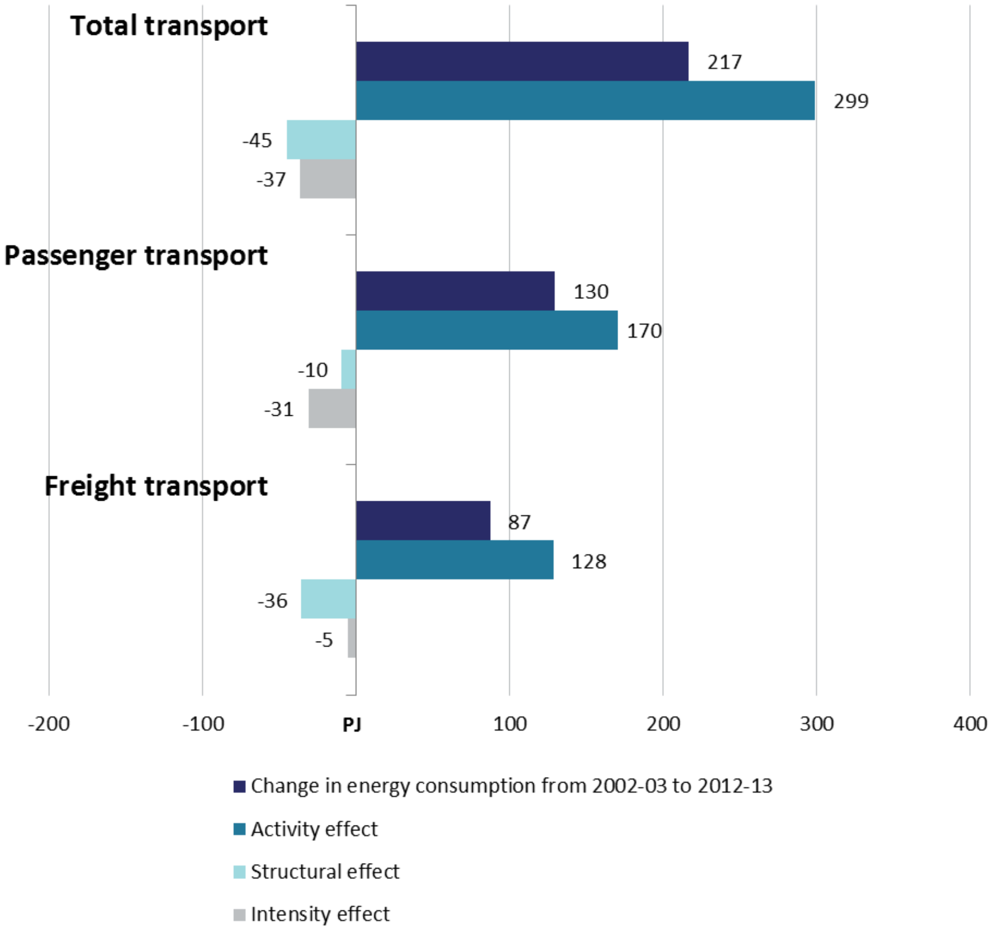
5.5 Decomposition of changes in energy consumption

Final energy consumption in the transport sector rose by 217 petajoules between 2002–03 and 2012–13 (Figure 5.5). Over the period, energy consumption attributable to the activity effect increased by 299 petajoules. However, this was largely offset by the structural effect, which contributed a decline of 45 petajoules in energy consumption, and the intensity effect, which led to a decline of 37 petajoules.

In passenger transport, final energy consumption increased by 130 petajoules over the period 2002–03 to 2012–13, with growth in activity contributing 170 petajoules. The reduction in energy consumption due to the structural effect (10 petajoules) and the intensity effect (31 petajoules) partly offset the increase in energy use explained by the activity effect.

Final energy consumption in freight transport rose by 87 petajoules between 2002–03 and 2012–13. Most of the increase in energy consumption was attributable to the activity effect which was partly offset by decreases due to the structural effect (by 36 petajoules) and the intensity effects (by 5 petajoules). Without the structural effect and the intensity effect, activity in freight transport would have contributed to an increase of 128 petajoules in energy consumption over the period.

Figure 5.5: Decomposition of changes in energy consumption in the transport sector



Source: Department of Industry and Science 2015.

5.6 Changes in the scale of activity

Activity increased in both passenger and freight transport. The activity effect alone would have increased energy consumption in the transport sector by 299 petajoules over the period 2002–03 to 2012–13. Activity in freight transport grew more rapidly than passenger transport over the same period, by 3.7 per cent and 1.9 per cent a year respectively (Table 5.2 and Table 5.3).

Domestic aviation was the fastest growing passenger transport mode, increasing by 6.9 per cent a year from 2002–03 to 2012–13 (Table 5.2). Activity in other passenger transport modes also expanded, except for coastal shipping which declined over the period. Cars remain the most common passenger transport mode.

Table 5.2: Activity in passenger transport

Activity	*2002–03*	*2012–13*	*2002–03 to 2012–13*	
Passenger-kilometre	million	million	% change	Annual growth (%)
Cars	249,454	269,031	7.8	0.8
Air	35,833	69,702	94.5	6.9
Light commercial vehicles	27,191	37,570	38.2	3.3
Buses	17,685	21,397	21.0	1.9
Hire and reward rail	11,184	14,465	29.3	2.6
Motorcycles	1,599	3,081	92.7	6.8
Light rail	630	772	22.5	2.0
Trucks	275	379	38.2	3.3
Ferries	141	163	15.7	1.5
Coastal	225	144	-36.0	-4.4
Total	344,216	416,704	21.1	1.9

Source: BITRE 2015.

Rail was the most common means for moving freight in 2012–13 (Table 5.3). Transport activity in ancillary rail grew strongly over the past decade, supported by growth in the mining sector. Transport activity in the hire and reward rail, articulated trucks, rigid trucks and light commercial vehicle transport modes also increased over the period. In contrast, freight shipping activity declined, reflecting a decline in petroleum shipping associated with the closures of a number of Australian refineries since 2002–03.

Table 5.3: Activity in freight transport

Activity	*2002–03*	*2012–13*	*2002–03 to 2012–13*	
Tonne-kilometre	million	million	% change	Annual growth (%)
Ancillary rail	67,222	180,695	168.8	10.4
Articulated trucks	117,673	160,734	36.6	3.2
Hire and reward rail	93,358	131,855	41.2	3.5
Shipping	114,814	96,860	-15.6	-1.7
Rigid trucks	27,306	35,178	28.8	2.6
Light commercial vehicles	3,939	4,686	19.0	1.8
Air	300	291	-3.1	-0.3
Total	424,612	610,299	43.7	3.7

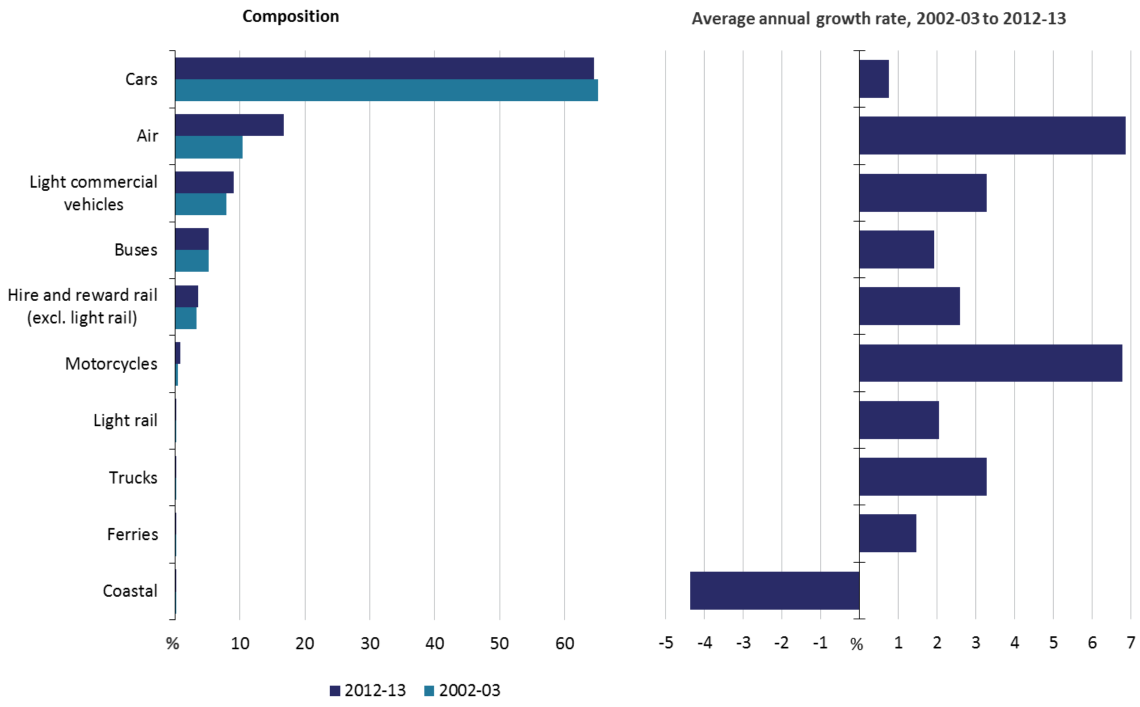
Source: BITRE 2015.

5.7 Changes in the structure of the transport sector

Structural change has had a negative effect on energy use in the transport sector over the last decade. The structural effect contributed a 45 petajoules reduction in energy consumption from 2002–03 to 2012–13.

Passenger air travel increased by 6.9 per cent a year from 2002–03 to 2012–13. The absolute change in air travel activity, almost double the increase in car transport, suggests consumers are increasingly choosing to fly than drive (Figure 5.6). Along with air travel, light commercial vehicles have gained an increasing share of the passenger transport market over the last decade at the expense of cars. The share of cars fell from 72 per cent to 65 per cent of total passenger activity over the past decade.

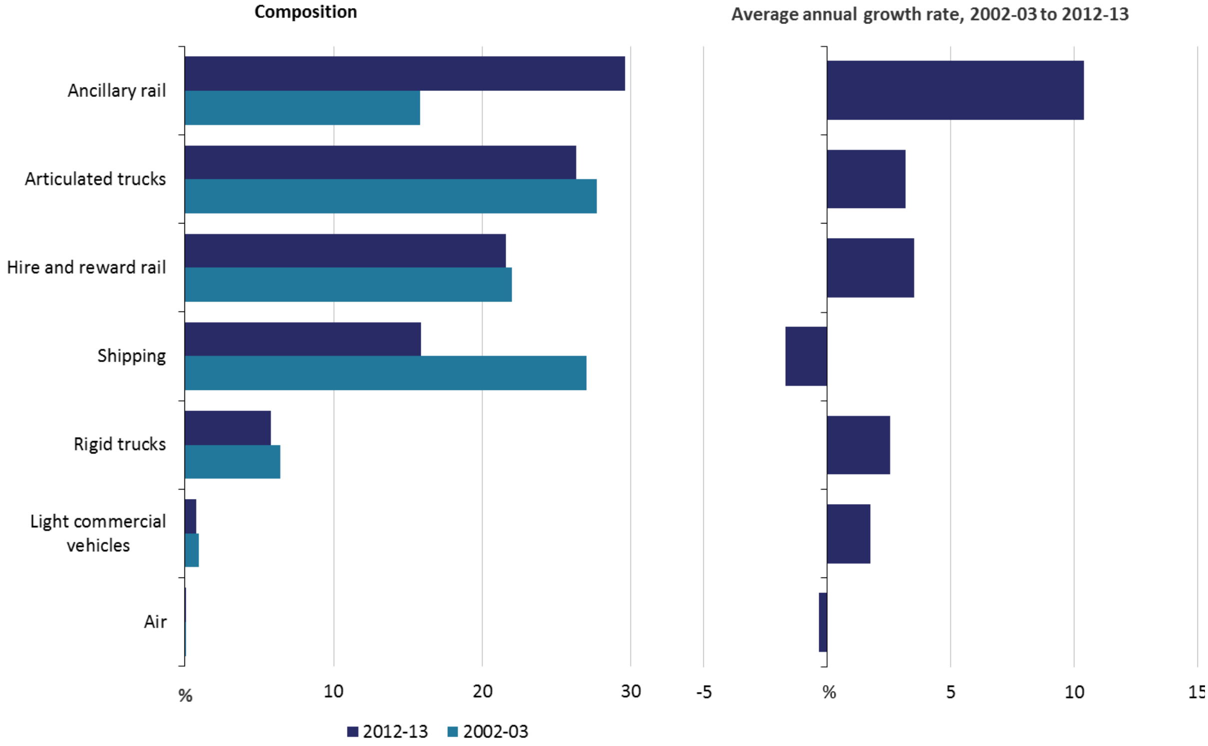
Figure 5.6: Change in composition of passenger transport, by transport mode



Source: Department of Industry and Science 2015; BITRE 2015.

In freight transport, activity in ancillary rail transport increased at an annual average rate of 10.4 per cent from 2002–03 to 2012–13. The share of ancillary rail in freight transport almost doubled over the last decade, supported by growth in coal, iron ore and other commodities. Freight tasks carried out by shipping fell, with the market share of shipping declining from 27 per cent to 16 per cent over the decade (Figure 5.7). This reflects a fall in oil production and domestic refining.

Figure 5.7: Change in composition of freight transport, by transport mode



Source: Department of Industry and Science 2015; BITRE 2015.

5.8 Changes in energy intensity

The intensity effect contributed to a decline of 37 petajoules in energy consumption in the transport sector between 2002–03 and 2012–13, reducing energy use in both passenger and freight transport.

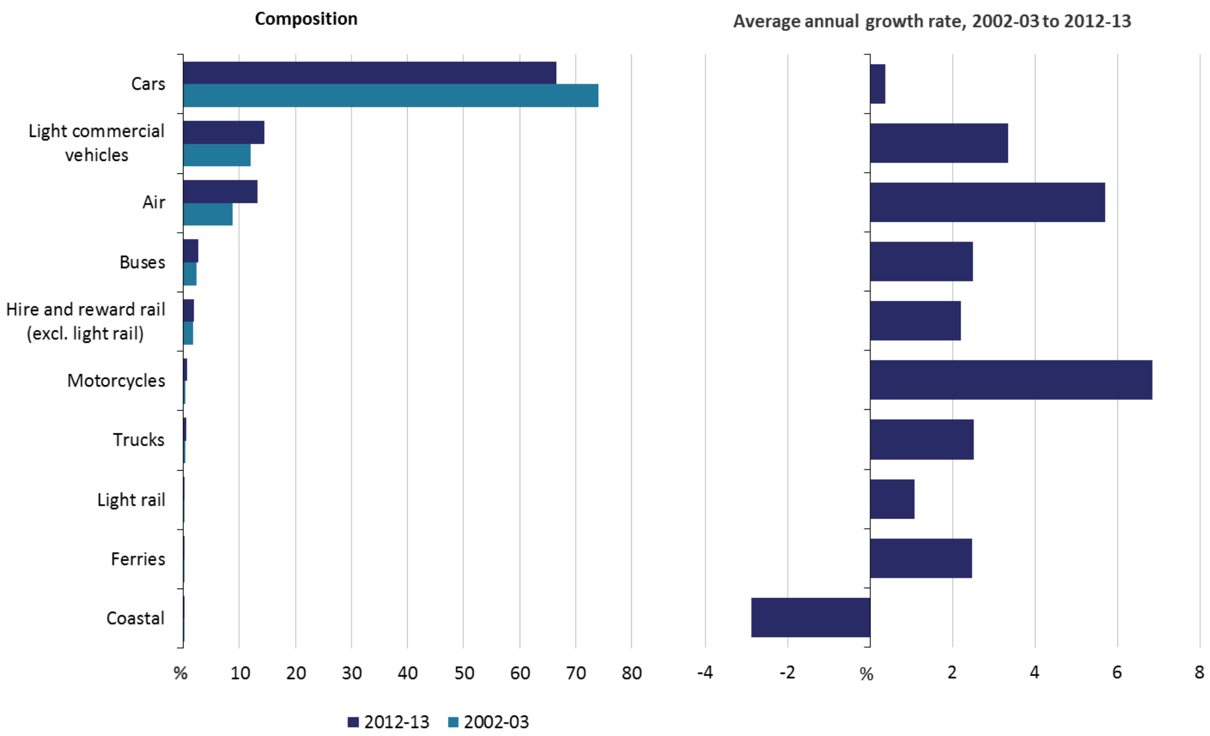
In passenger transport, the intensity effect contributed to a decline of 31 petajoules in energy consumption over the period, supported by energy efficiency improvements in cars, the largest mode of passenger transport. Energy consumption increased in passenger transport by 1.5 per cent a year from 2002–03 to 2012–13. Cars, light commercial vehicles and air travel contributed most of this growth. However, the share of energy use in car transport declined over the period 2002–03 to 2012–13, in contrast with increasing shares of energy consumption in air transport and light commercial vehicles (Table 5. 4 and Figure 5.8).

Table 5.4: Energy consumption in passenger transport

Energy consumption	*2002–03*	*2012–13*	*2002–03 to 2012–13*	
	PJ	PJ	% change	Annual growth (%)
Cars	614.3	637.8	3.8	0.4
Light commercial vehicles	99.9	138.9	39.0	3.4
Air	72.8	126.8	74.2	5.7
Buses	19.5	24.9	27.9	2.5
Hire and reward rail (excl. light rail)	14.6	18.2	24.4	2.2
Motorcycles	3.1	6.0	94.0	6.9
Trucks	3.3	4.3	28.3	2.5
Light rail	1.1	1.2	11.4	1.1
Ferries	0.5	0.7	27.6	2.5
Coastal	0.4	0.3	-25.4	-2.9
Total	829.6	959.1	15.6	1.5

Source: BITRE 2015.

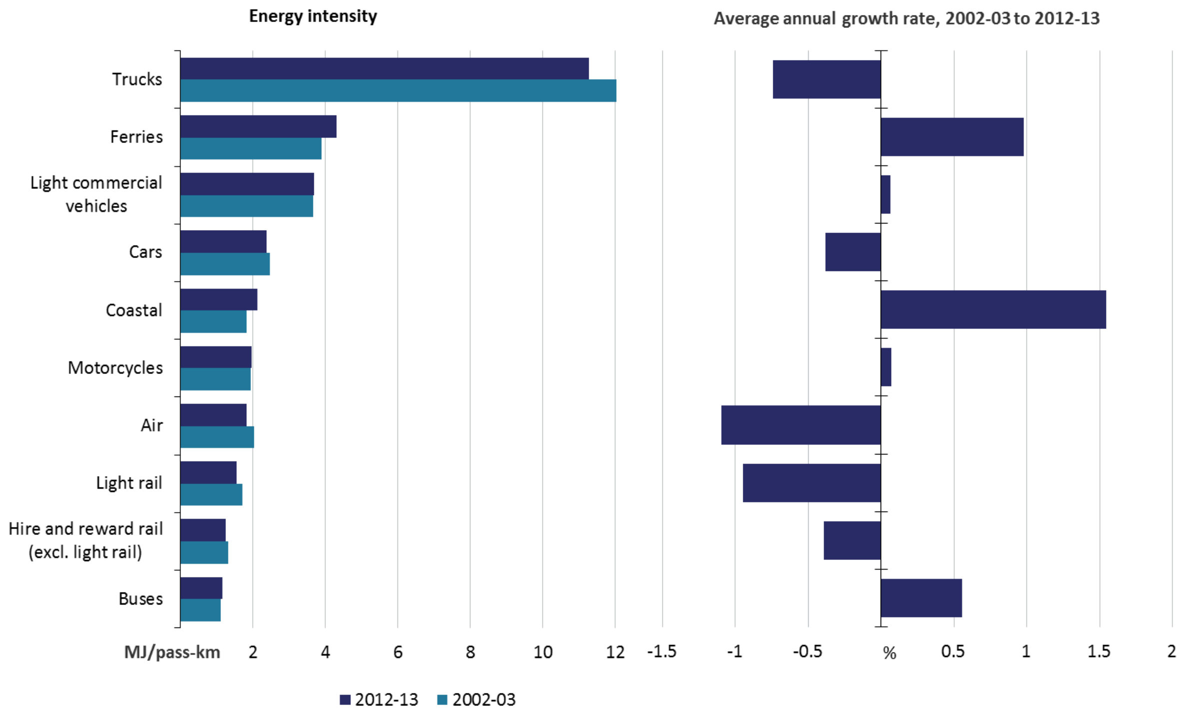
Figure 5.8: Energy consumption in passenger transport, by transport mode



Source: BITRE 2015.

Trucks, ferries and light commercial vehicles are the most energy-intensive passenger transport modes. Energy intensity, measured by the ratio of energy/output, in both passenger car and air travel declined over this period (Figure 5.9).

Figure 5.9: Energy intensity in passenger transport



Source: Department of Industry and Science 2015.

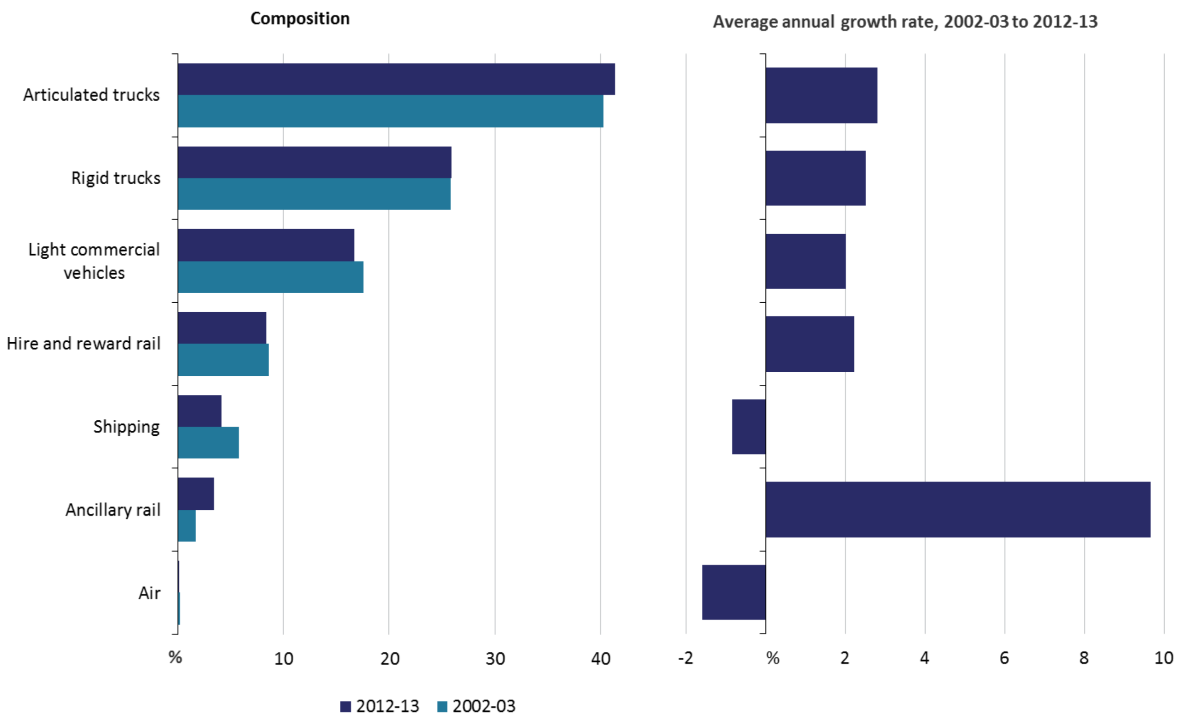
In freight transport, energy consumption rose by 2.5 per cent a year between 2002–03 and 2012–13 (Table 5.5). This was largely attributable to increased energy consumption in the truck, light commercial vehicle and rail transport modes (Figure 5.10). In contrast, energy consumption declined in air freight and freight shipping.

Table 5.5: Energy consumption in freight transport

Energy consumption	*2002–03*	*2012–13*	*2002–03 to 2012–13*	
	PJ	PJ	% change	Annual growth (%)
Articulated trucks	124.5	164.2	31.8	2.8
Rigid trucks	80.0	102.6	28.3	2.5
Light commercial vehicles	54.3	66.2	22.1	2.0
Hire and reward rail	26.6	33.1	24.4	2.2
Shipping	17.9	16.4	-8.1	-0.8
Ancillary rail	5.3	13.5	151.8	9.7
Air	0.7	0.6	-14.8	-1.6
Total	309.2	396.5	28.2	2.5

Source: BITRE 2015.

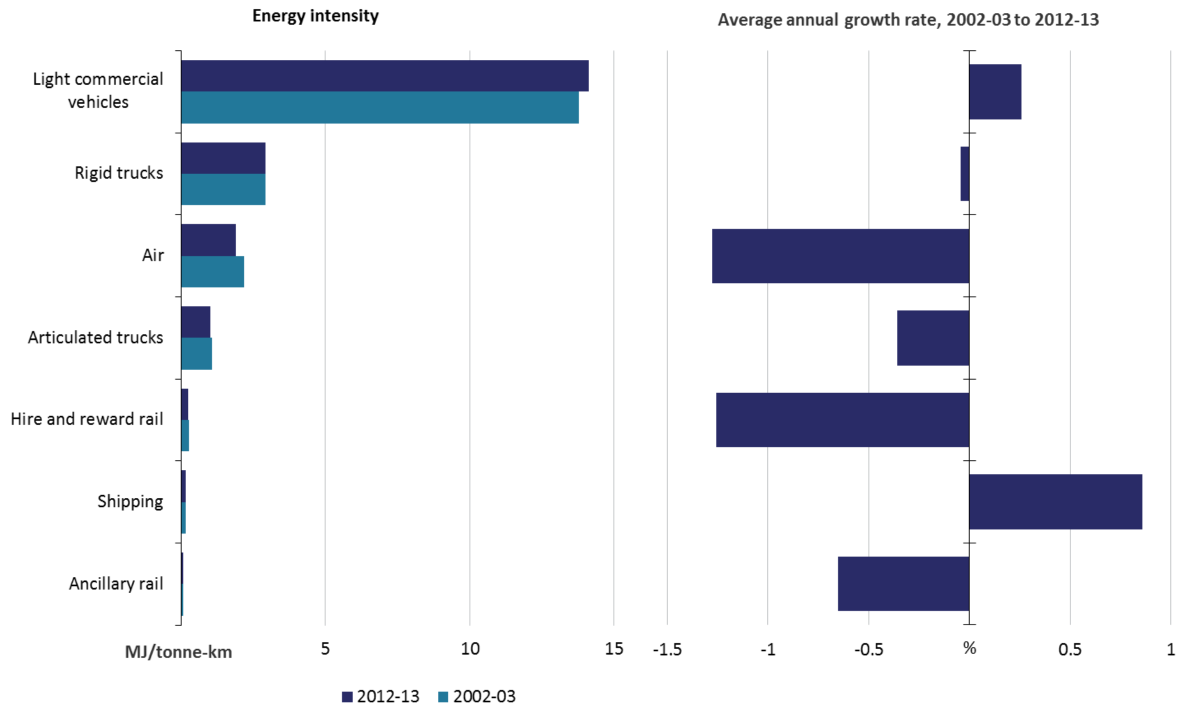
Figure 5.10: Energy consumption in freight transport, by transport mode



Source: BITRE 2015.

Light commercial vehicles are typically the most energy intensive out of the freight movement modes. The fall in energy intensity in freight transport was mainly attributable to the declines in energy intensity of truck, rail and air freight transport modes (Figure 5.11). Increasing energy intensity in the light commercial vehicle and freight shipping transport partly offset this fall.

Figure 5.11: Energy intensity in freight transport

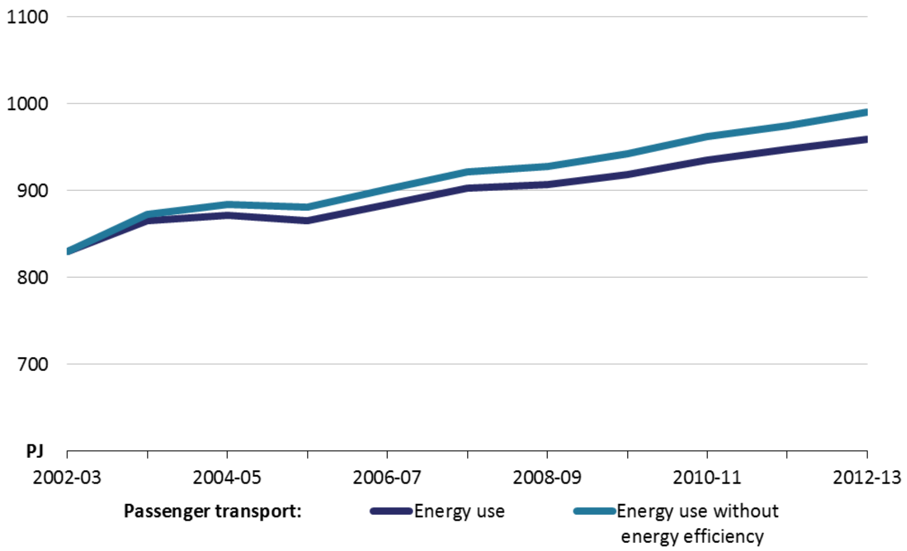


Source: Department of Industry and Science 2015.

5.9 Energy efficiency in the transport sector

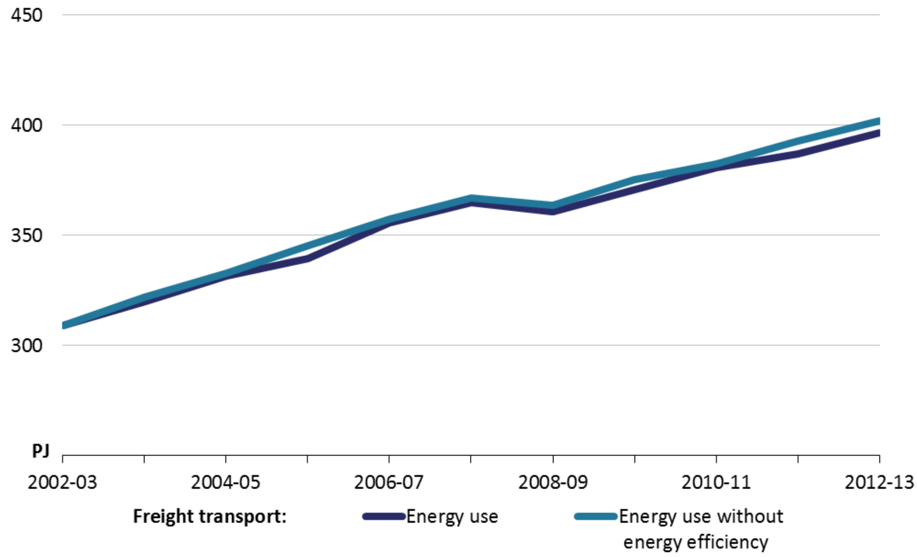
Without the intensity effect, energy consumption in the transport sector would have been 3 per cent higher in 2012–13. This trend in energy intensity is consistent with improvements in energy efficiency in the sector. The rate of improvements in energy efficiency in passenger transport is relatively greater compared with freight transport (Figure 5.12 and Figure 5.13). In the absence of the intensity effect, energy consumption in passenger transport and freight transport would have been 3 per cent and 1 per cent higher, respectively, than actual energy consumption over the period 2002–03 to 2012–13.

Figure 5.12: Energy consumption in passenger transport, with and without intensity effect



Source: Department of Industry and Science 2015; BITRE 2015.

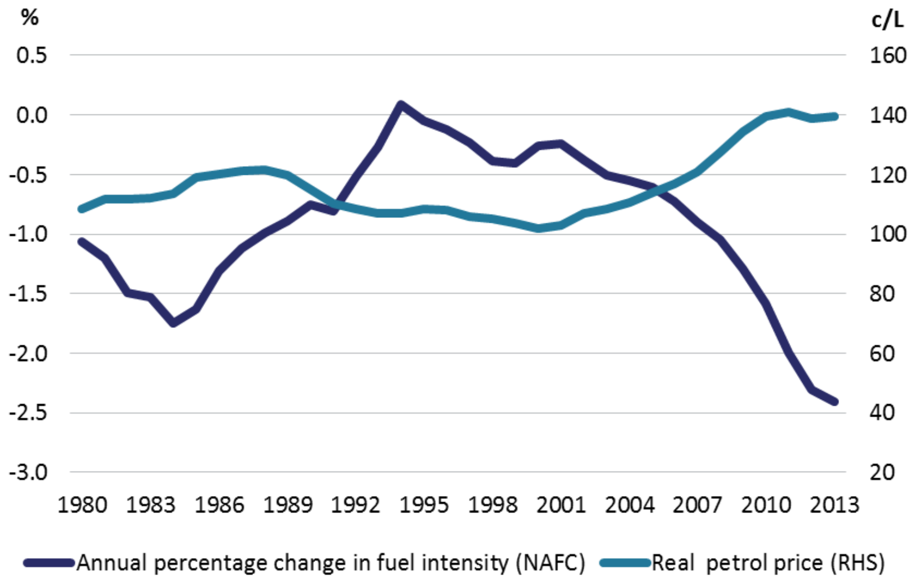
Figure 5.13: Energy consumption in freight transport, with and without intensity effect



Source: Department of Industry and Science 2015; BITRE 2015.

Energy prices have been one of the most important factors affecting energy intensity in the transport sector. Often, higher energy prices can induce improvements in energy efficiency, thereby lowering energy intensity. Figure 5.14 shows a period of declining energy intensity in the transport sector is associated with a period of high energy prices between 2002–03 and 2008–09. However, there is also a period of declining energy intensity despite the fall in energy prices after 2008–09. This suggests other factors such as technologies are playing an important role in reducing energy intensity in the sector.

Figure 5.14: Annual change in average rated fuel consumption and trends in prices

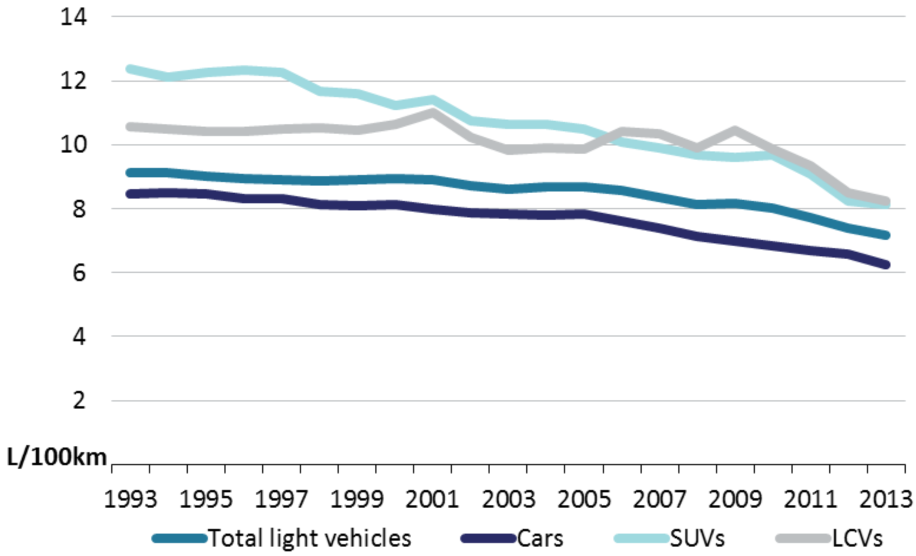


Notes: Percentage changes related to National Average Fuel Consumption (NAFC) L/100km, sales weighted across all fuel types. Petrol prices 5 year moving average in 2011-12 prices.

Source: BITRE 2014.

Engine technologies have also been advancing (BITRE 2014). Up to 2005, advances in engine technology for new passenger vehicles, which improved fuel efficiency, were partly offset by increases in power, weight and the popularity of four wheel drive vehicles, which tend to increase fuel consumption. Since then, changes in preferences toward smaller, more fuel efficient vehicles have been evident, which is a behavioural response by consumers to petrol price rises. This has resulted in an accelerated downward trend in the rated fuel consumption of new vehicles sold (Figure 5.15).

Figure 5.15: Rated national average fuel consumption by Australian new light vehicles



Notes: Sports Utility Vehicle (SUVs); Light commercial vehicles (LCVs).

Source: BITRE 2014.

Manufacturing and Construction

5.10 Key points

- The manufacturing and construction sectors accounted for 27 per cent of final energy consumption in 2012–13.
- Final energy use in the manufacturing and construction sectors increased by 83 petajoules over the period 2002–03 to 2012–13 (0.7 per cent a year).
- Without changes to sectoral structure and intensity, increased activity in the manufacturing and construction sectors would have caused an increase in energy consumption of 289 petajoules between 2002–03 and 2012–13, more than triple its actual increase.
- Structural shifts away from energy intensive subsectors such as metal product manufacturing are estimated to have reduced energy consumption by 251 petajoules between 2002–03 and 2012–13.
- The intensity effect contributed to growth in energy use of 45 petajoules over the period 2002–03 to 2012–13, underpinned by increases in non-ferrous metals and chemicals, which are very energy intensive.

5.11 Introduction

In 2012–13 the manufacturing and construction sectors accounted for 15 per cent of Australia's GDP and 27 per cent of total final energy consumption. Energy consumption in the manufacturing and construction sectors rose by 0.7 per cent a year over the past decade to 1154 petajoules in 2012–13.

Gas is the largest source of energy in the sector, followed by electricity and petroleum products. The major users of energy are the non-ferrous metal and the chemical subsectors. The sector is also a large user of renewable energy, particularly of bagasse to produce heat in food manufacturing.

5.12 Coverage and variables used

The manufacturing and construction sectors have been grouped for this analysis. Subsectors that perform energy conversion activities such as the petroleum refining and other petroleum and coal product manufacturing subsectors of the manufacturing sector are excluded. The subsector coverage and variables used for energy intensity are outlined in Table 5.6.

Except for the iron and steel and the non-ferrous metal subsectors, which use the value of production for the estimation of activity and intensity variables, the gross value added as a measure of economic output are used for the remaining subsectors. Energy use is based on the 2014 Australian Energy Statistics (BREE 2014).

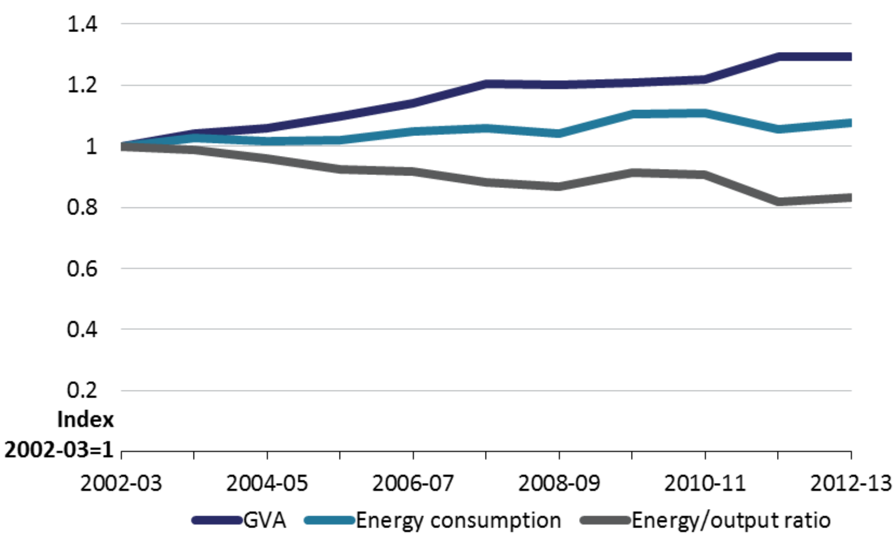
Table 5.6: Subsector coverage and variables used in the manufacturing and construction sectors

Subsector	*Activity variables*	*Structure variables*	*Intensity variables*
Food, beverage and tobacco	value-added	share of sector output	energy/ value-added
Textile, clothing and leather	value-added	share of sector output	energy/ value-added
Wood, paper and printing	value-added	share of sector output	energy/ value-added
Chemical	value-added	share of sector output	energy/ value-added
Non-metallic mineral	value-added	share of sector output	energy/ value-added
Iron and steel	value of production	share of sector output	energy/output
Non-ferrous metal	value of production	share of sector output	energy/output
Other metals	value-added	share of sector output	energy/ value-added
Machinery and equipment	value-added	share of sector output	energy/ value-added
Other manufacturing	value-added	share of sector output	energy/ value-added
Construction	value-added	share of sector output	energy/ value-added

5.13 Comparison of energy intensity indicators

Energy intensity in the manufacturing and construction sectors has fluctuated but shows an overall decreasing trend during 2002–03 to 2012–13 (Figure 5.16), when measured using the ratio of energy to output. The ratio of energy consumption to output over the period 2002–03 to 2012–13 fell by 2.0 per cent a year on average.

Figure 5.16: Energy intensity in the manufacturing and construction sectors, energy/output ratio

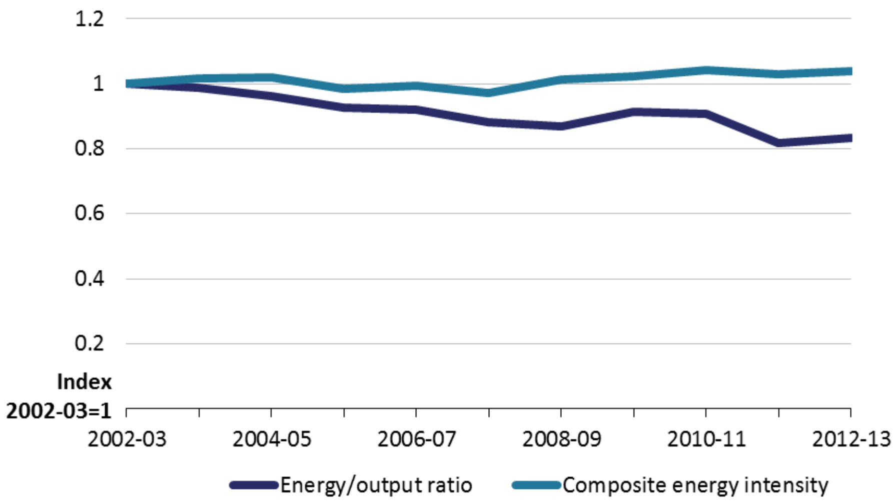


Source: Department of Industry and Science 2015; BREE 2014; ABS 2015b.

The composite energy intensity index, as calculated using decomposition analysis, rose slightly by 0.4 per cent a year over the period 2002–03 to

2012–13 (Figure 5.17). This is underpinned by increased activity in the most energy-intensive non-ferrous subsector and the largest energy user of the manufacturing and construction sectors. In particular, Australian alumina production increased by 32 per cent over the past decade, which requires a significant amount of energy to support production.

Figure 5.17: Comparison of energy intensity indicators in the manufacturing and construction sectors

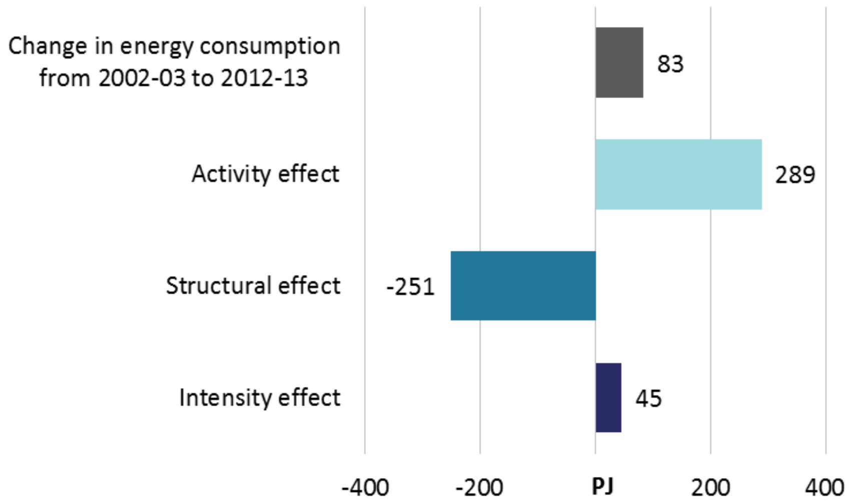


Source: Department of Industry and Science 2015.

5.14 Decomposition of changes in energy consumption

Final energy consumption in the manufacturing and construction sectors rose by 83 petajoules between 2002–03 and 2012–13. Increasing activity alone over the period would have resulted in an increase of 289 petajoules in total final energy consumption. However, the structural changes within the sector led to energy savings of 251 petajoules (Figure 5.18). The intensity effect contributed 45 petajoules to the increase in energy consumption over the period.

Figure 5.18: Decomposition of changes in energy consumption in the manufacturing and construction sectors



Source: Department of Industry and Science 2015.

5.15 Changes in the scale of activity

Economic output of the manufacturing and construction sectors, measured by industry gross value-added, rose by 2.6 per cent a year on average during 2002–03 to 2012–13 (Table 5.7). The other metal subsector recorded the strongest growth over the period, but accounted for only 2 per cent of the sector's gross value-added. In contrast, the food, beverage and tobacco subsector showed the slowest growth but accounted for the largest share of gross value-added over the period. Decreases in the value-added of the iron and steel; the textile, the clothing and leather; and the wood, paper and printing subsectors partly offset this growth.

When considered on its own, the overall increase in activity in the manufacturing and construction sectors would have resulted in a 289 petajoules increase in energy consumption from 2002–03 to 2012–13, around triple the actual increase in energy consumption.

Table 5.7: Activity in the manufacturing and construction sectors

Activity	*2002–03*	*2012–13*		*2002–03 to 2012–13*
Gross value added	$billion	$billion	% change	Annual growth (%)
Construction	71.5	119.7	67.5	5.3
Food, beverage and tobacco	24.0	25.3	5.5	0.5
Machinery and equipment	18.3	21.5	17.7	1.6
Chemical	11.1	13.5	21.8	2.0
Wood, paper and printing	13.5	9.6	-28.6	-3.3
Non-ferrous metal	6.7	8.1	21.5	2.0
Non-metallic mineral	5.0	5.9	17.1	1.6
Textile, clothing and leather	9.6	5.4	-43.8	-5.6
Other metals	0.6	4.5	610.6	21.7
Iron and steel	7.4	3.8	-48.4	-6.4
Other manufacturing	2.3	2.6	9.3	0.9
Total	169.9	219.9	29.4	2.6

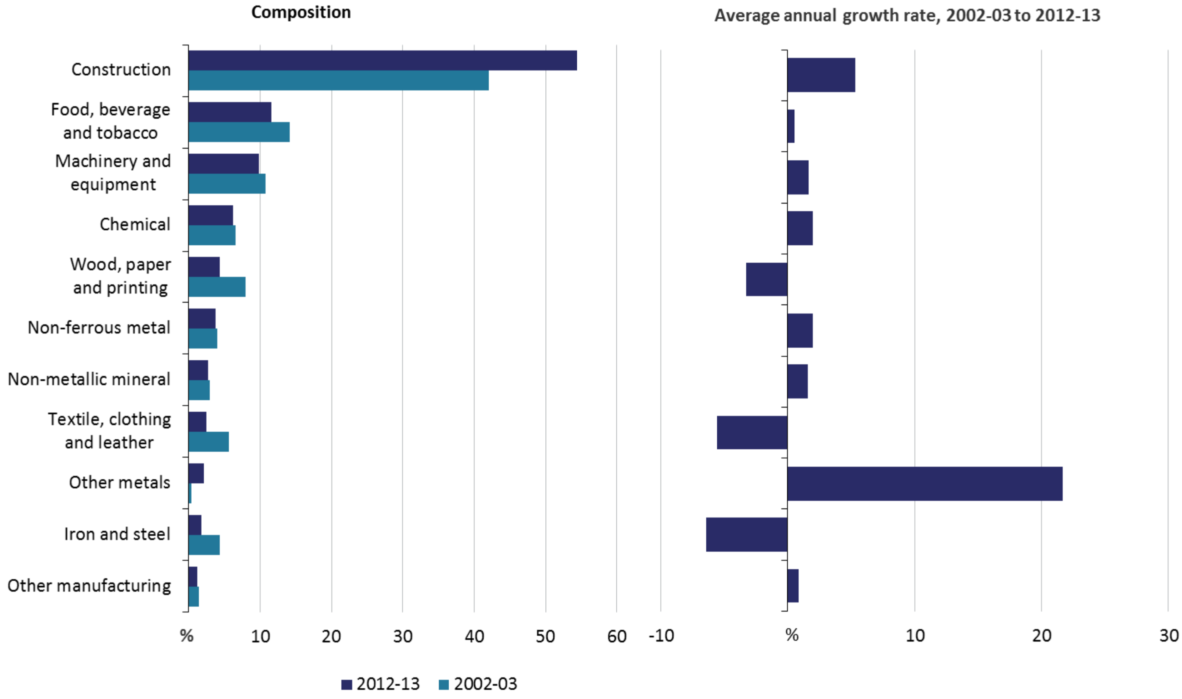
Notes: Chain volume measures. Reference year is 2011-12.

Source: Department of Industry and Science 2015; ABS 2015b.

5.16 Changes in structure

Structural changes in the manufacturing and construction sectors partly offset the growth in energy consumption over the decade to 2012–13. This includes a shift away from energy-intensive manufacturing activities such as metal products manufacturing, particularly iron and steel (Figure 5.7). The food, beverages and tobacco subsector has also significantly decreased its share of gross value added over the past decade. In contrast, the construction sector has strongly increased its share of gross value added, supported by large scale projects such as LNG plants.

Figure 5.19: Activity in the manufacturing and construction sectors

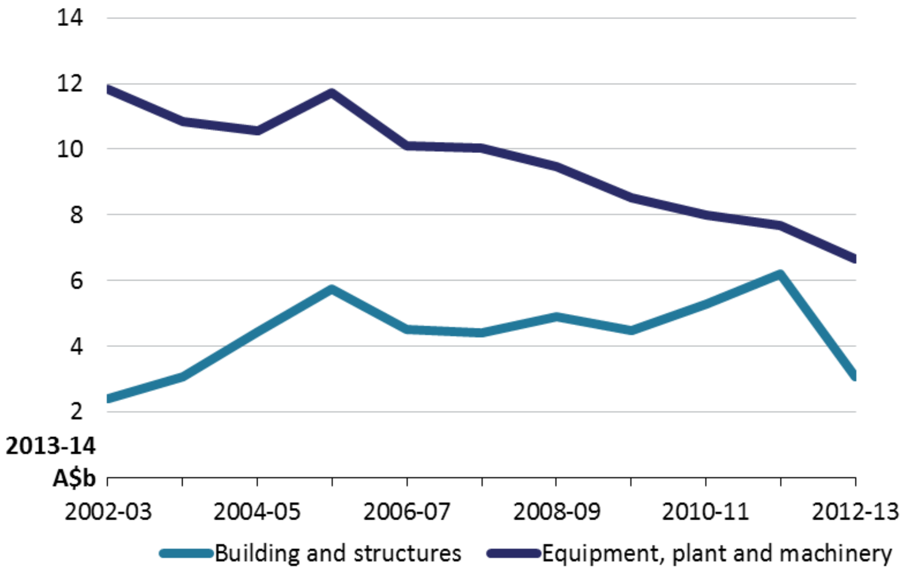


Source: Department of Industry and Science 2015; ABS 2015b.

The structural changes have resulted in a reduction in energy use of 251 petajoules from 2002–03 to 2012–13, largely offsetting the effects of the increase in economic activity over the same period.

Additionally, due to the relatively lower cost of manufacturing in emerging Asian economies Australian manufacturers increasingly sourced labour- and energy-intensive production offshore to remain competitive. In line with reducing onshore production, investment in manufacturing production processes particularly in equipment, plant and machinery, have continually decreased since the mid-2000s (Figure 5.20). Offshoring and declining investment in capital equipment in the manufacturing and construction sectors have contributed to the fall in energy consumption, from 2002–03 to 2012–13, explained by the structural effect.

Figure 5.20: Capital investment in the manufacturing sector



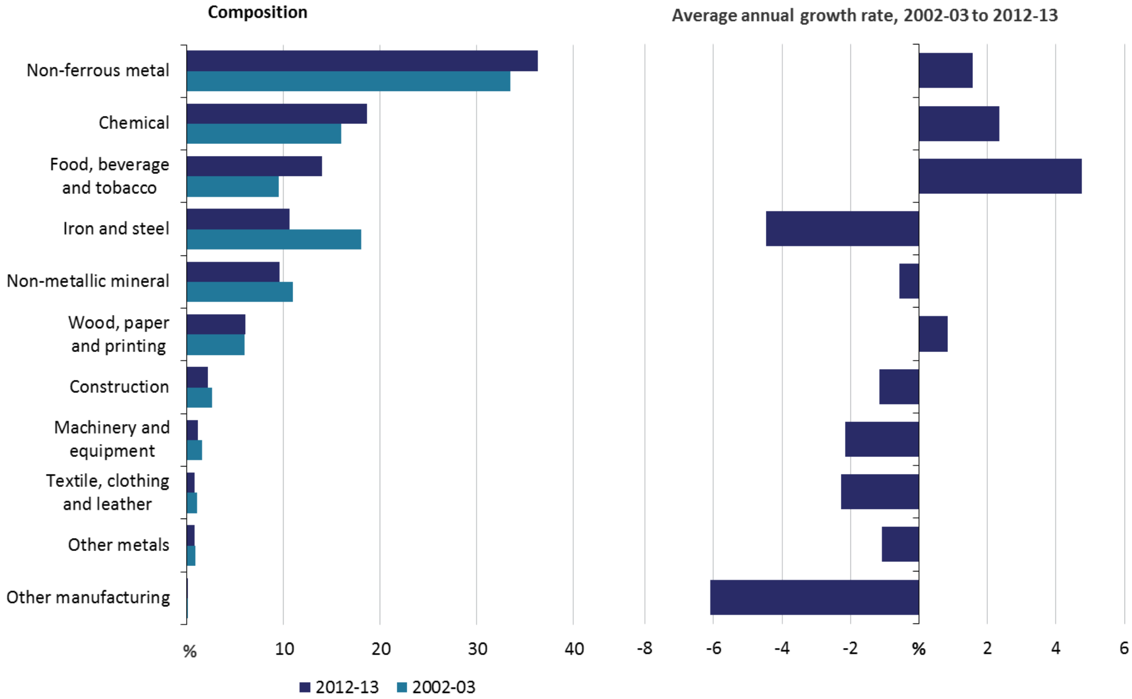
Source: ABS 2015a.

5.17 Changes in energy intensity

The intensity effect increased energy consumption by 45 petajoules from 2002–03 to 2012–13. Energy consumption in the manufacturing and construction sectors grew by 0.7 per cent a year on average over this period. Most of the growth in energy use occurred in large energy using sectors. Within the manufacturing and construction sectors, the non-ferrous metal subsector (including alumina and aluminium) was the largest energy user, followed by chemicals, while the food, beverage and tobacco subsector was the fastest growing energy user (Figure 5.21).

Over the period 2002–03 to 2012–13 energy consumption increased in the food, beverage and tobacco; the non-ferrous metal; the chemical; and the wood, paper and printing subsectors. In contrast, energy consumption fell in the other manufacturing, the iron and steel, the textile, clothing and leather and the machinery subsectors. The shares in the sector’s energy consumption of those subsectors also declined during 2002–03 to 2012–13. Energy consumption in the construction subsector fell by 1.1 per cent per year over the same period while its share in total energy consumption also decreased (Figure 5.21 and Table 5.8).

Figure 5.21: Energy consumption in the manufacturing and construction sectors



Source: Department of Industry and Science 2015; BREE 2014.

Table 5.8: Energy consumption in the manufacturing and construction sectors

Energy consumption	*2002–03*	*2012–13*	*2002–03 to 2012–13*	
	PJ	PJ	% change	Annual growth (%)
Non-ferrous metal	358.9	419.5	16.9	1.6
Chemical	170.6	215.1	26.1	2.3
Food, beverage and tobacco	101.4	161.1	59.0	4.7
Iron and steel	193.3	122.5	-36.6	-4.5
Non-metallic mineral	117.0	110.5	-5.5	-0.6
Wood, paper and printing	63.8	69.4	8.7	0.8
Construction	27.7	24.7	-10.9	-1.1
Machinery and equipment	16.2	13.1	-19.5	-2.1
Textile, clothing and leather	11.4	9.1	-20.6	-2.3
Other metals	9.6	8.6	-10.4	-1.1
Other manufacturing	1.4	0.8	-46.7	-6.1
Total	1071.2	1154.2	7.8	0.7

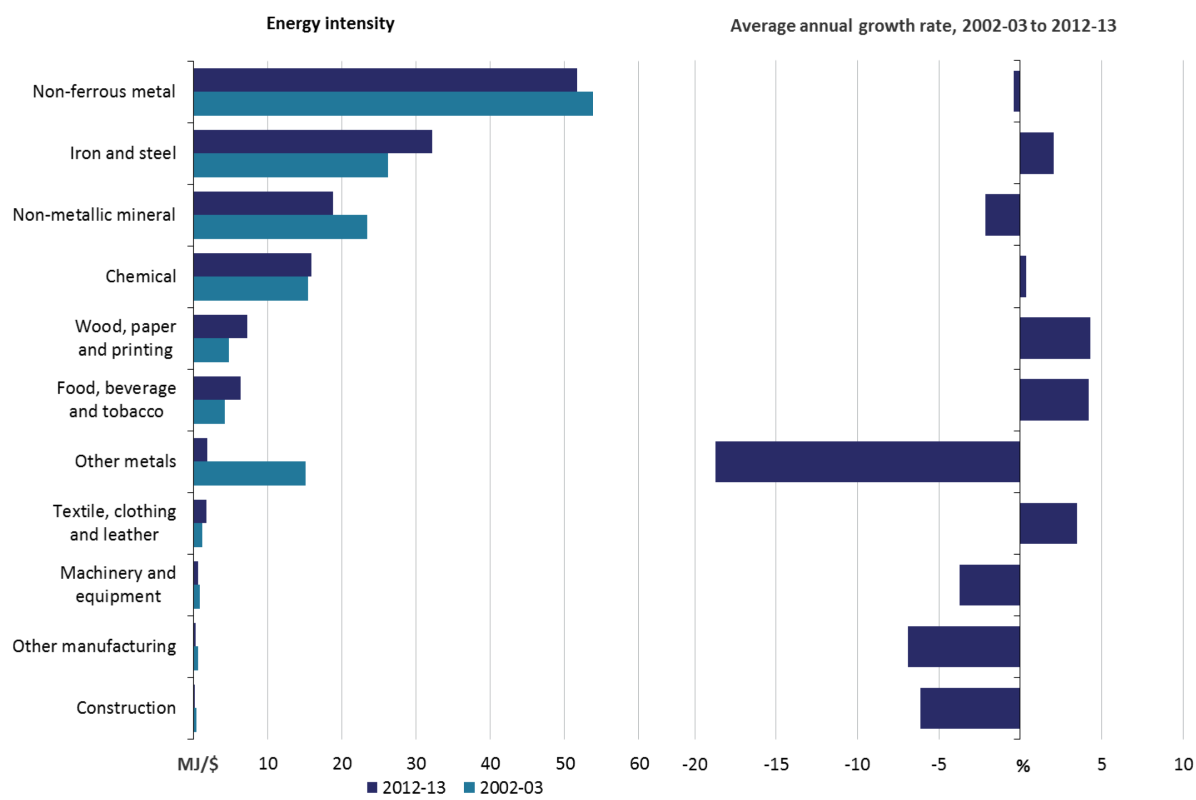
Source: Department of Industry and Science 2015; BREE 2014.

By subsector, the most energy-intensive subsectors are the non-ferrous metal, the iron and steel, the non-metallic mineral and the chemical subsectors (Figure 5.22). Energy intensity increased in the iron and steel and the chemical subsectors in 2012–13, while energy intensity declined in the non-metallic mineral and the non-ferrous metal subsectors.

Between 2002–03 and 2012–13 energy intensity grew strongly in the less energy-intensive food, beverage and tobacco; the wood, paper and printing and; the textile, clothing and leather subsectors. In contrast, the construction subsector was the least energy-intensive subsector in 2012–13, with energy intensity decreasing during 2002–03 to 2012–13.

The increase in energy intensity of the manufacturing and construction sectors was underpinned by increasing energy consumption in some of its most energy-intensive subsectors: the chemical and the non-ferrous metal subsectors.

Figure 5.22: Energy intensity in the manufacturing and construction sectors

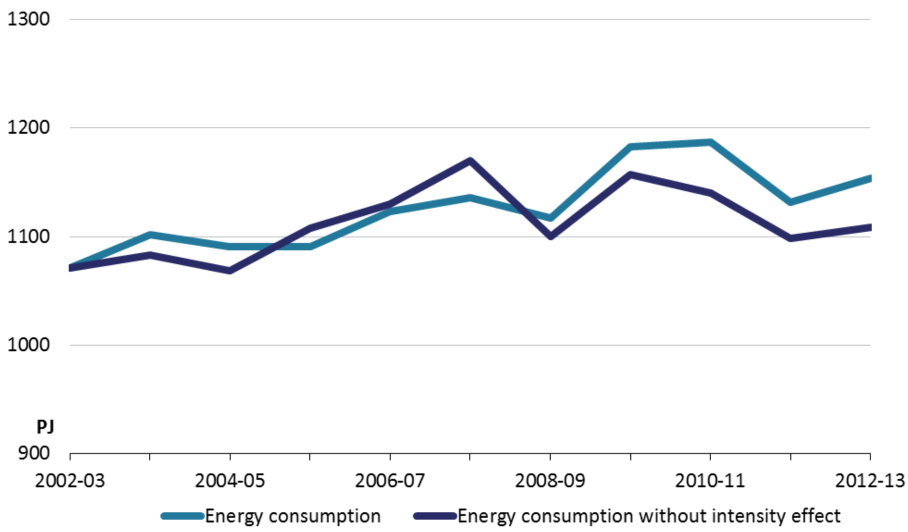


Source: Department of Industry and Science 2015.

5.18 Energy efficiency in the manufacturing and construction sectors

While energy intensity increased over the decade as a whole, Figure 5.23 shows that some energy savings were achieved in the manufacturing and construction sectors during the mid-2000s.

Figure 5.23: Energy consumption in the manufacturing and construction sectors, with and without intensity effect



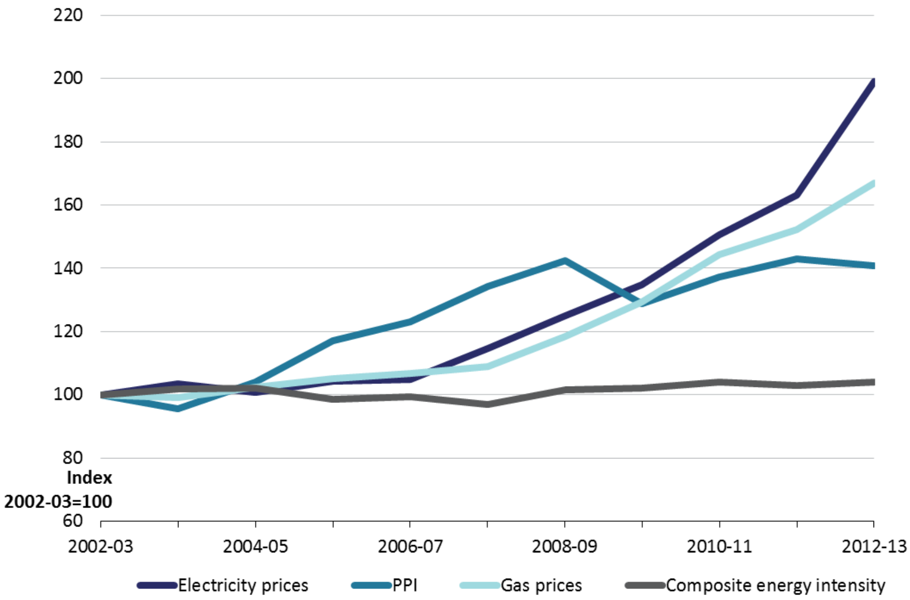
Source: Department of Industry and Science 2015; BREE 2014.

Energy prices may have been one factor affecting energy intensity (Figure 5.24). Higher prices encourage manufacturers to look for ways to reduce costs, improve competitiveness, and reduce energy intensity: including, upgrades to production lines and investing in new technologies to improve energy productivity (or reduce energy use per unit of output).

From 2008–09 to 2012–13 notwithstanding the sharp increases in industrial energy prices, the overall energy intensity of the manufacturing and construction sectors still increased. The increase in energy intensity does not necessary imply that energy efficiency of the sectors has worsened. Some production processes require more energy (or more energy-intensive) than others; and increased activity in these processes will increase the overall energy intensity of the sector.

For example, during 2008–09 to 2012–13 increased activity in its most energy-intensive subsector and the largest energy user—the non-ferrous metal subsector— has contributed to the increase in energy intensity of the manufacturing and construction sectors. Most of the growth in activity in the non-ferrous metal subsector was due to increased alumina production, by 32 per cent over the past decade, supported by capacity expansions at Worsley Alumina refinery and Rio Tinto Alcan Yarwun refinery. This outweighed the efficiency gains by other subsectors over the period such as the non-metallic mineral and the other metal subsectors where energy consumption has decreased despite increases in economic activities.

Figure 5.24: Energy prices and energy intensity in the manufacturing and construction sectors



Source: Department of Industry and Science 2015; ABS 2014c.

Mining

5.19 Key points

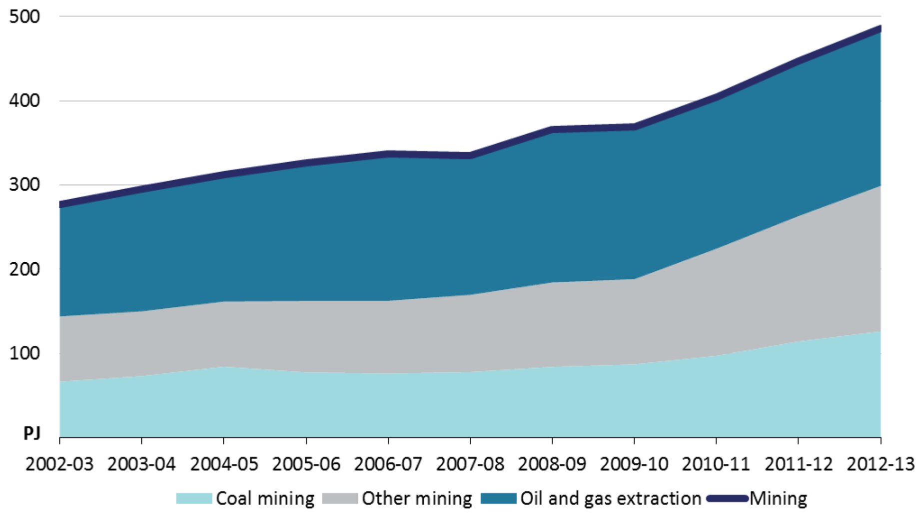
- Energy consumption in the mining sector increased by 75 per cent or 209 petajoules from 2002–03 to 2012–13.
- Energy use in the mining sector is strongly associated with changes in the scale and composition of activity in the sector.
- Decomposition of energy consumption indicates the activity effect contributed 194 petajoules to the increase in energy consumption from 2002–03 and 2012–13.
- The structural effect shows energy consumption decreased by 23 petajoules, attributed to a decline in the share of mining activity in the oil and gas extraction subsector. The results suggest a change in the composition of the mining sector towards lower value-added subsectors.
- Energy use in the mining sector has become relatively more energy intensive over the period 2002–03 to 2012–13. The intensity effect contributed 38 petajoules to the increase in final energy consumption, largely attributed to greater energy use in iron ore and coal mining subsectors, which are relatively more energy intensive.
- Higher commodity prices over this period may also have provided incentives for firms to extract from more marginal deposits, which require more energy to produce the same level of output.

5.20 Introduction

The remarkable performance of the Australian mining sector since 2002–03 is well-known. The fast pace of urbanisation and industrialisation of emerging economies in Asia underpinned a rapid expansion of Australia's mining industry. From 2002–03 to 2012–13, Australian production of resources and energy commodities increased by 40 per cent, including an 45 per cent increase in black coal production, 58 per cent rise in gas production, and 179 per cent expansion in iron ore production.

The expansion of mining activity since 2002–03 has been accompanied by substantial changes in energy consumption. Over the past decade, mining energy consumption increased by 5.8 per cent a year, with the mining sector the fastest growing energy user in the Australian economy (Figure 5.25). The share of the mining sector in total final energy consumption increased from 8.6 per cent to 12 per cent from 2002–03 to 2012–13.

Figure 5.25: Energy consumption in the mining sector



Source: BREE 2014.

The oil and gas extraction subsector, which includes gas used to produce LNG, accounted for around 38 per cent of mining energy use in 2012–13, and is the largest energy using subsector. Coal mining accounts for around 26 per cent of final energy consumption, while the remaining share is attributed to the other mining. Diesel constitutes the main fuel source (42 per cent of energy fuels) used in the mining sector, followed by natural gas (31 per cent) and electricity (16 per cent).

5.21 Coverage and variables used

The available energy data for the mining sector includes three subsector categories: coal mining, oil and gas extraction, and other mining (Table 5.9). The other mining subsector covers a range of commodities, including iron ore, bauxite, copper ore, gold ore, mineral sands, nickel ore, silver-lead-zinc ore, and other metal ore mining, as well as exploration and mining support services. Energy consumption data is sourced from the 2014 Australian Energy Statistics (BREE 2014) and includes some unpublished subsector energy use data. Industry gross value added data (ABS 2015) is used to measure output in the mining sector.

Table 5.9: Subsector coverage and variables used in the mining sector

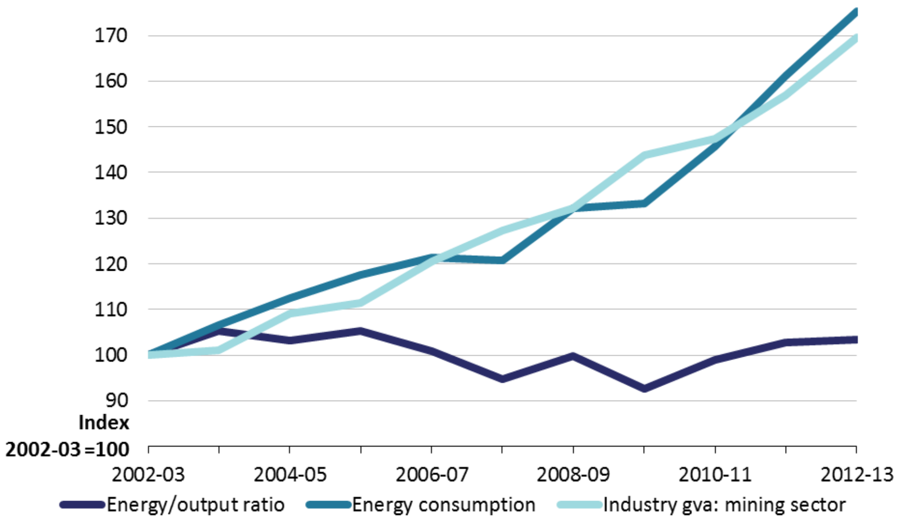
Subsector	*Activity variables*	*Structure variables*	*Intensity variables*
Coal mining	value-added	share of sector output	energy/ value-added
Oil and gas extraction	value-added	share of sector output	energy/ value-added
Other mining	value-added	share of sector output	energy/ value-added

Notes: 'Other mining' includes metal ore mining and exploration and mining support services.

5.22 Comparison of energy intensity indicators

Energy intensity in the Australian mining sector has fluctuated over the period 2002–03 to 2012–13. The energy/output ratio shows that energy intensity in the mining sector increased annually by 0.3 per cent, on average, from 2002–03 to 2012–13 (Figure 5.26). Further, the ratio indicates that energy intensity increased by 12 per cent from 2009–10 to 2012–13, suggesting that energy productivity in the sector has worsened more recently.

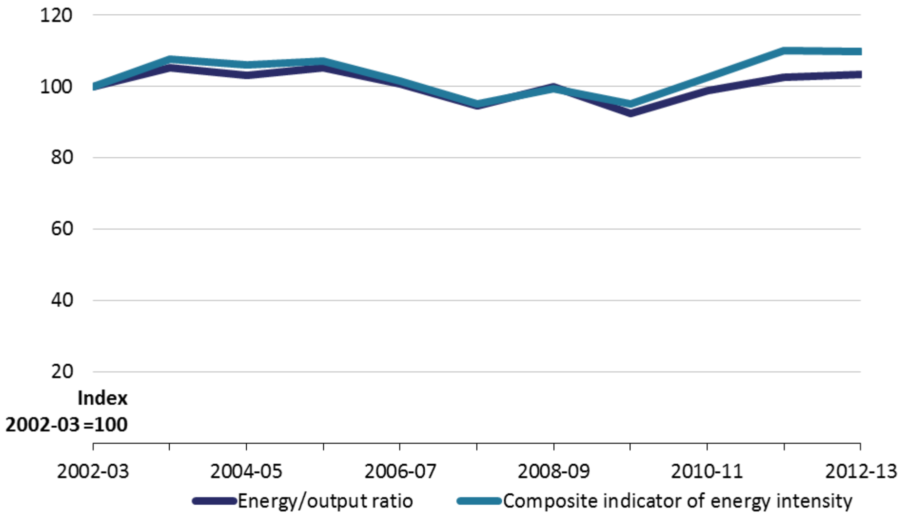
Figure 5.26: Energy intensity of the mining sector, energy/output ratio



Source: Department of Industry and Science 2015; BREE 2014; ABS 2015b.

The composite indicator shows relatively higher average growth in energy intensity in the mining sector of 1.0 per cent a year from 2002–03 to 2012–13. Figure 5.27 presents a comparison of the energy/output ratio and the composite indicator. The gap between the two indexes captures how the net effect of contributing factors, such as structural changes and energy efficiency, impact on changes in energy use over time.

Figure 5.27: Comparison of energy intensity indicators in the mining sector



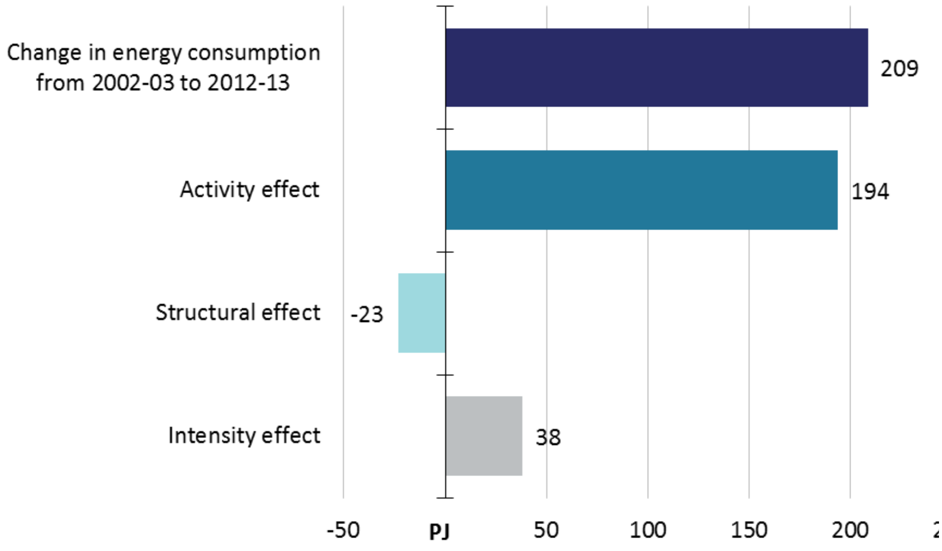
Source: Department of Industry and Science 2015; BREE 2014; ABS 2015b.

5.23 Decomposition of changes in energy consumption

Energy consumption in the Australian mining sector increased by 75 per cent or 209 petajoules from 2002–03 to 2012–13. Changes in energy consumption in the mining sector are strongly associated with changes in the scale of activity. Decomposition of energy consumption indicates the activity effect contributed 194 petajoules to the rise in energy consumption from 2002–03 and 2012–13 (Figure 5.28).

The negative impact of the structural effect on changes in energy consumption partly offset increasing energy consumption explained by the intensity effect. The analysis indicates a change in the composition of the mining sector towards lower value-added subsectors, whereas energy use has become relatively more energy-intensive.

Figure 5.28: Decomposition of changes in energy consumption in the mining sector



Source: Department of Industry and Science 2015.

Variations in energy intensity of each of the subsectors of the mining sector reflect the choice of production technology as well as how and in what and ways energy is used in production processes. Relatively more energy-intensive subsectors engaged in the physical transformation of raw materials use more energy than production processes in other mining subsectors. In this regard, the increasing energy intensity of the Australian mining sector can be attributed to a number of factors, including structural change within the mining sector towards more energy-intensive mining industries, production processes used more intensively and existing production technologies used less efficiently.

5.24 Changes in the scale of activity

Economic activity in the mining sector, as measured by industry gross value added (gva), increased at an average annual rate of 5.4 per cent from 2002–03 to 2012–13, to reach $117.0 billion in 2012–13 (Table 5.10) The expansion of the mining sector is associated with strong growth in global demand for commodity resources and increases in commodity prices.

Iron ore mining is included in industry gva for the other mining subsector to enable comparison with energy consumption statistics. Within the other mining subsector, iron ore mining more than doubled over the period 2002–02 to 2012–13 as measured by industry gva, while industry gva of the remaining commodities fell over the same period.

Table 5.10: Activity in the mining sector

Activity	*2002–03*	*2012–13*		*2002–03 to 2012–13*
Gross value added	$billion	$billion	% change	Annual growth (%)
Other mining	36.9	69.6	88.3	6.5
includes iron ore mining	14.5	45.7	215.3	12.2
Coal mining	12.9	19.0	47.7	4.0
Oil and gas extraction	19.2	28.5	48.1	4.0
Total	69.1	117.0	69.5	5.4

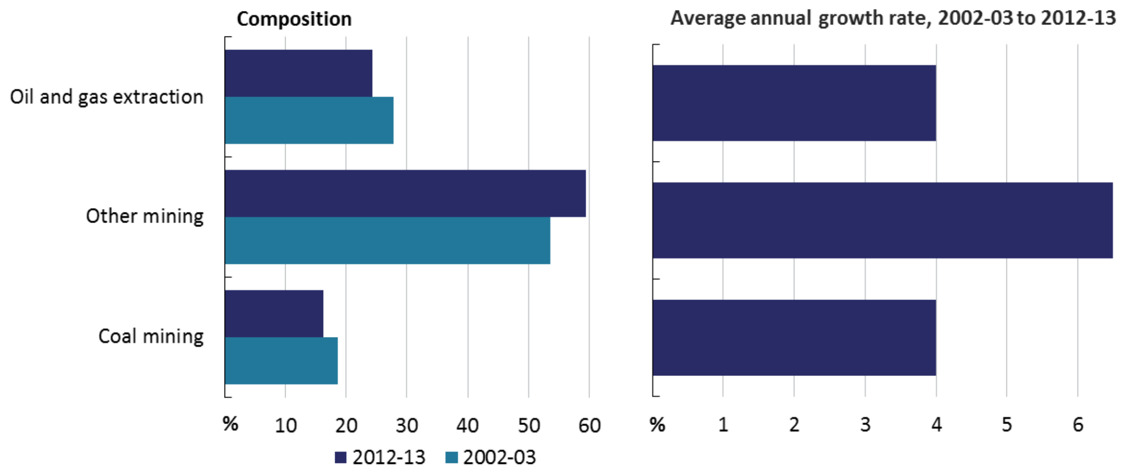
Notes: Chain volume measures. Reference year is 2011–12.

Source: Department of Industry and Science 2015; ABS 2015b.

5.25 Changes in structure

Activity increased in each of the mining subsectors, but at different annual growth rates over the period from 2002–03 to 2012–13 (Figure 5.29). Other mining, the largest mining subsector, increased at a much faster rate and comprised a relatively larger share of the mining sector from 2002–03 to 2012–13, compared with the coal mining, and oil and gas extraction subsectors.

Figure 5.29: Activity in the mining sector

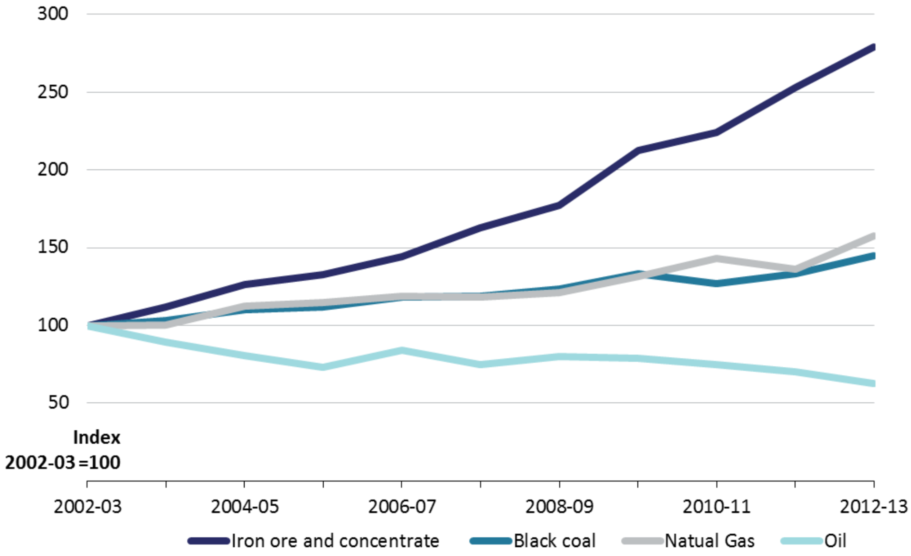


Source: Department of Industry and Science 2015; ABS 2014.

The increase in industry gva for other mining is largely attributed to the iron ore mining industry which more than doubled over the period 2002–03 to 2012–13 in response to higher prices and strong demand from China. While industry gva in the oil and gas extraction, and coal mining subsectors each increased by 4.0 per cent a year, the share of mining sector industry gva of each of these subsectors contracted from 2002–03 to 2012–13.

Figure 5.30 presents indexes for the production of mining commodities. The comparison shows that iron ore production has increased relatively more than production of coal and natural gas.

Figure 5.30: Production indexes of mining commodities



Source: Department of Industry and Science 2015.

5.26 Changes in energy intensity

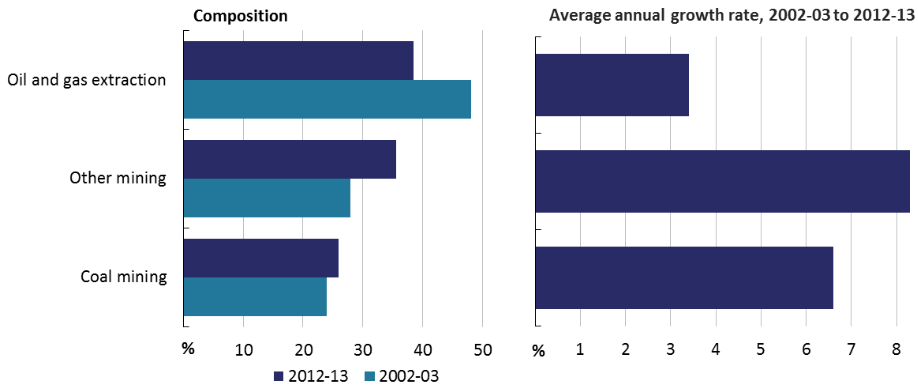
Energy consumption in the other mining subsector increased the most in absolute terms and at the fastest rate compared with the coal mining and oil and gas extraction subsectors. Over the period 2002–03 to 2012–13, annual growth in energy consumption in other mining increased by 8.3 per cent, on average. The annual average growth rates of the coal mining, and oil and gas extraction subsectors were 6.6 per cent and 3.4 per cent, respectively. While the oil and gas extraction subsector constitutes the largest energy user in the mining sector, its share of total final energy consumption was lower in 2012–13, relative to 2002–03 (Table 5.11 and Figure 5.31).

Table 5.11: Energy consumption in the mining sector

Energy consumption	*2002–03*	*2012–13*	*2002–03 to 2012–13*	
	PJ	PJ	% change	Annual growth (%)
Other mining	77.6	172.9	122.9	8.3
Coal mining	66.4	126.2	90.2	6.6
Oil and gas extraction	133.6	187.0	40.0	3.4
Total	277.5	486.1	75.2	5.8

Source: Department of Industry and Science 2015; BREE 2014 (unpublished data).

Figure 5.31: Energy consumption in the mining sector



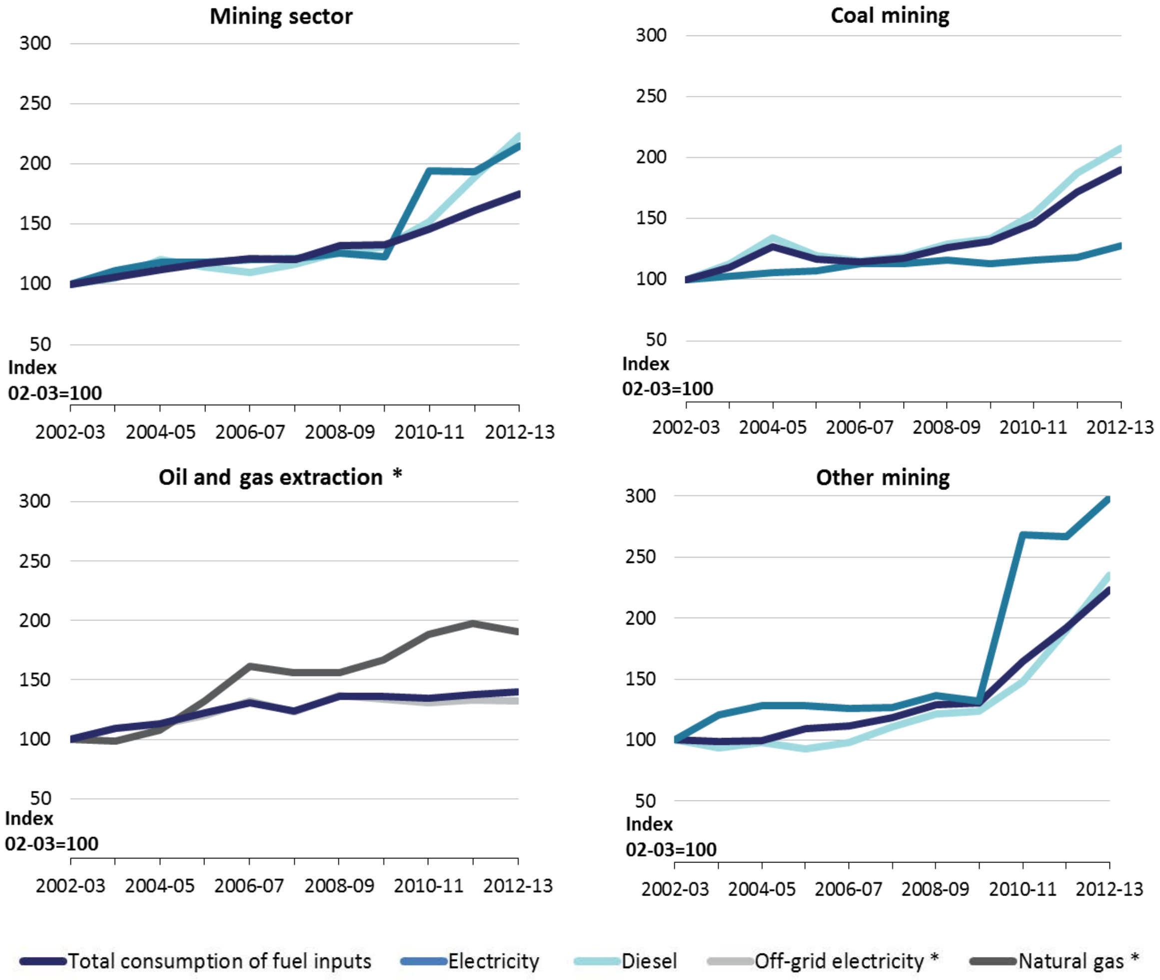
Source: Department of Industry and Science 2015; BREE 2014 (unpublished data).

Different production processes and the respective need for energy have implications for energy intensity of the mining sector. Fuel usage and the fuel mix may be used as a proxy for how increasing production and more energy-intensive processes contribute to changes in energy intensity in the mining sector during the period 2002–03 to 2012–13.

Measuring energy consumption in the mining sector comprises the amount and energy content of fuel inputs used. Activities associated with mining, including mine production, and the transportation and processing of material on-site, determine the fuel mix and amount of consumption. Diesel and electricity are the predominant fuels used in the coal mining and ‘other mining’ subsectors. Natural gas and electricity represent the main fuels used in the oil and gas extraction subsector. Figure 5.32 presents indexes of the main fuels used in energy consumption in the mining subsectors.

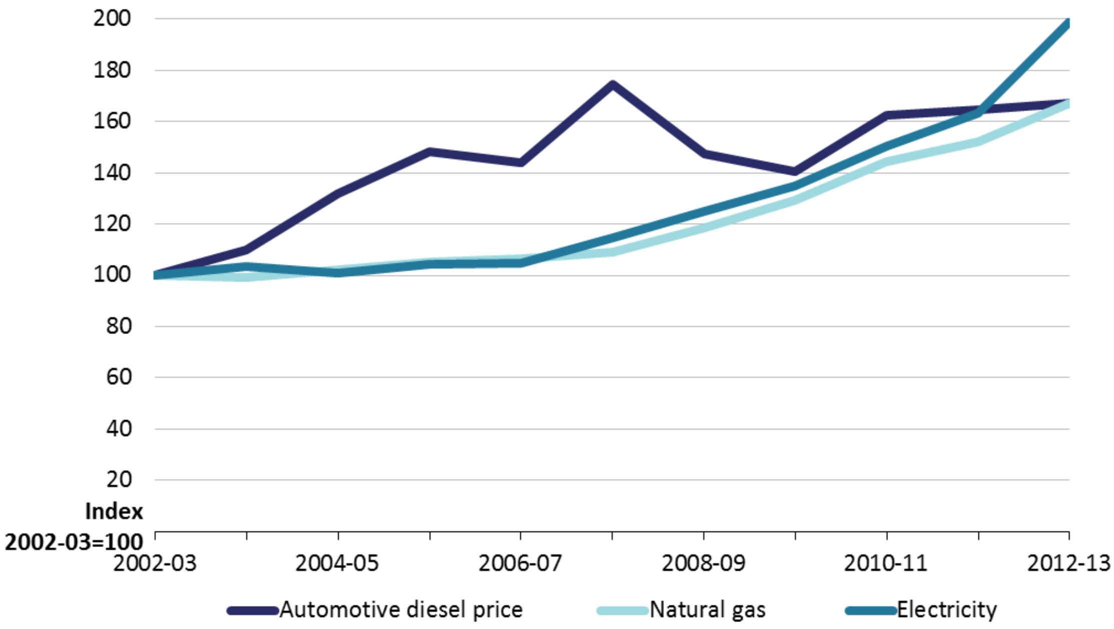
Fuel prices also influence patterns of energy consumption because demand for fuel inputs is responsive to changing prices. Prices for fuel inputs used in the mining sector have increased substantially since 2002–03 (Figure 5.53). Diesel prices increased sharply from 2002–03 to 2005–06 and continued to grow over the period to 2012–13. Gas and electricity prices increased strongly from 2006–07 to 2012–13.

Figure 5.32: Consumption of fuel inputs in the mining sector



Source: BREE 2014 (unpublished data); ABS 2015b.

Figure 5.33: Energy price indexes for fuels used in the mining sector

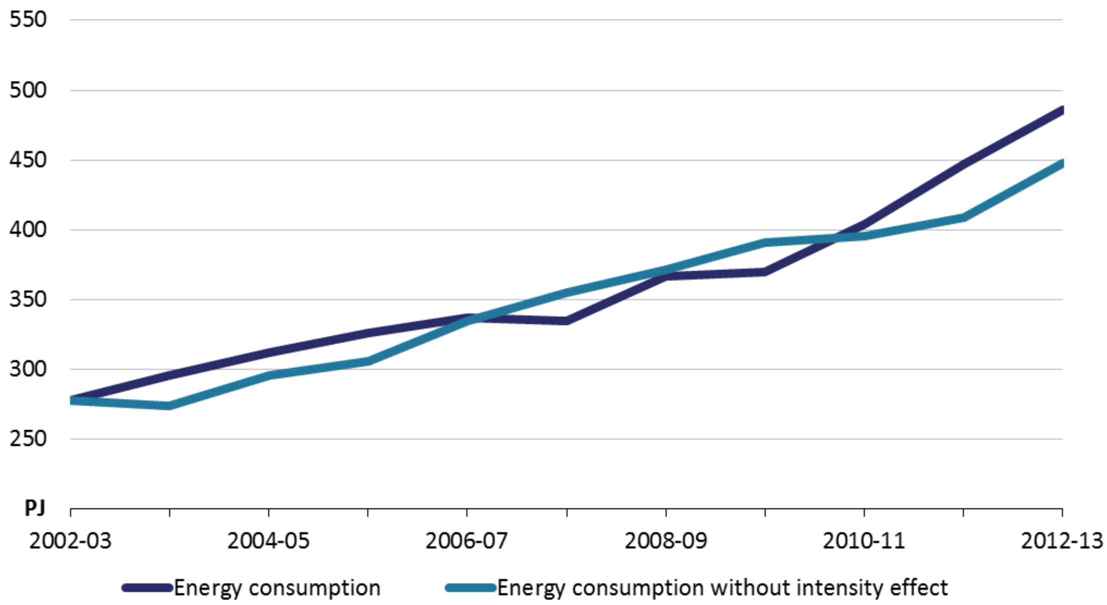


Source: Department of Industry and Science 2015; ABS 2014c; IEA 2014.

5.27 Energy efficiency in the mining sector

Figure 5.34 shows cumulative changes in energy savings and dissaving associated with energy efficiency in the mining sector compared to final consumption in the mining sector.

Figure 5.34: Energy consumption in the mining sector, with and without intensity effect



Notes: Shows cumulative changes in efficiency.

Source: Department of Industry and Science 2015; BREE 2014.

Energy consumption has increased but has been accompanied by a deterioration in energy efficiency over time, in particular from 2002–03 to 2006–07 and from 2010–11 to 2012–13. High commodity prices during the mining boom provided firms with incentive to extract from marginal resource deposits that were previously unprofitable due to high costs of extraction. Proportionally more energy inputs are used in mining operations to increase rates of extraction (Syed 2013). This can affect energy consumption, as more energy inputs are required to produce the same amount of saleable output.

The periods of energy dissaving may be associated with the amount of fuel inputs consumed in line with the aggregate effect of development of mining projects during the construction phase from 2002–03 and the ramp up in production from 2010–11.

Residential

5.28 Key points

- Energy consumption is measured for electricity use by households over the period 2002–03 to 2012–13 for electrical appliances, lighting and air-conditioners. The dataset used represents a subset of final energy consumption and activity in the residential sector.
- Annual electricity demand for the average household declined by 3.3 per cent between 2002–03 to 2012–13, from 7 080 kilowatt hours to 6 846 kilowatt hours.
- The analysis shows that energy consumption in the residential sector increased by 27 per cent or 29 petajoules from 2002–03 to 2012–13.
- A decomposition analysis of changes in energy consumption shows that the activity effect contributed 20 petajoules to the change in energy consumption.
- The structural effect contributed 34 petajoules to changes in energy consumption in the residential sector.
- The intensity effect shows a decrease in energy consumption of 25 petajoules. The intensity of residential energy demand has declined by 1.9 per cent a year from 2002–03 to 2012–13.
- Regulations implementing efficiency performance standards for appliances and buildings represent a key contributing factor in energy efficiency improvements in the residential sector.

5.29 Introduction

Households use energy for lighting, space cooling and heating, and to operate appliances such as washing machines, refrigerators and televisions. The main energy sources used in the residential sector include electricity, natural gas, wood, liquefied petroleum gas (LPG), and solar energy. In 2012–13, the residential sector accounted for 12 per cent of final energy consumption.

Residential energy demand may be explained by a large number of variables: energy prices; household incomes; demography; the building envelope; types of water heating, and space heating and cooling; number and type of appliances; and other characteristics of the residence such as house size and number of household members. In addition, local climatic conditions often determine patterns of energy use of and demand for energy-using equipment in households.

5.30 Coverage and variables used

In this study, energy consumption is measured for electricity use by households over the period 2002–03 to 2012–13 for numbers of household electrical appliances, lighting and air-conditioners. Estimates of household electricity use presented in this study constitute around 60 per cent of residential electricity consumption, on average, over the period 2002–03 to 2012–13 (BREE 2014).

The analysis of changes in energy consumption in the residential sector focuses on electricity use, because electricity represents the most common final form of energy used by households across Australia. It also reflects data availability. Data on energy use and activity in the residential sector is limited. Available data is often partial and based on estimation techniques. As a result, only data for certain household electrical equipment have been investigated.

While gas is a important component of residential energy use, data on gas consumption and ownership of gas-using appliances, such as space heating, water heating and cooking, is either not current or readily available.

Estimates of household energy use in this study are not directly comparable with residential energy consumption measured in the Australian Energy Statistics (BREE 2014); the data source used in the aggregate analysis in Part I. The data used in the study also differ from previous energy intensity studies by BREE and ABARES (Che and Pham 2012, Petchey 2010, and Sandu and Petchey 2009) which relied on the DEHWA (2008) study.

Energy and activity measures of household electrical appliances, air-conditioners and lighting are used to characterise changes in energy consumption in the residential sector. Energy consumption for household appliances is measured using comparative energy consumption (CEC), a measure of annual energy consumption determined for the assumed usage profile of specific appliances. CEC is also the measure of energy that appears on energy star labels. Input power is used as a measure of energy use for air-conditioners. Energy consumption in air-conditioners is calculated using estimated equivalent full load operational hours by state and measures of annual Heating Degree-Days and Annual Cooling Degree-Days, by state. Energy consumption in lighting is estimated using a bottom up approach that uses lighting power for each bulb type. Sales data for household appliances, lighting and air-conditioners is used to measure activity in the residential sector. While data used in the analysis is limited by availability, the data sample captures the majority of household electricity consumption.

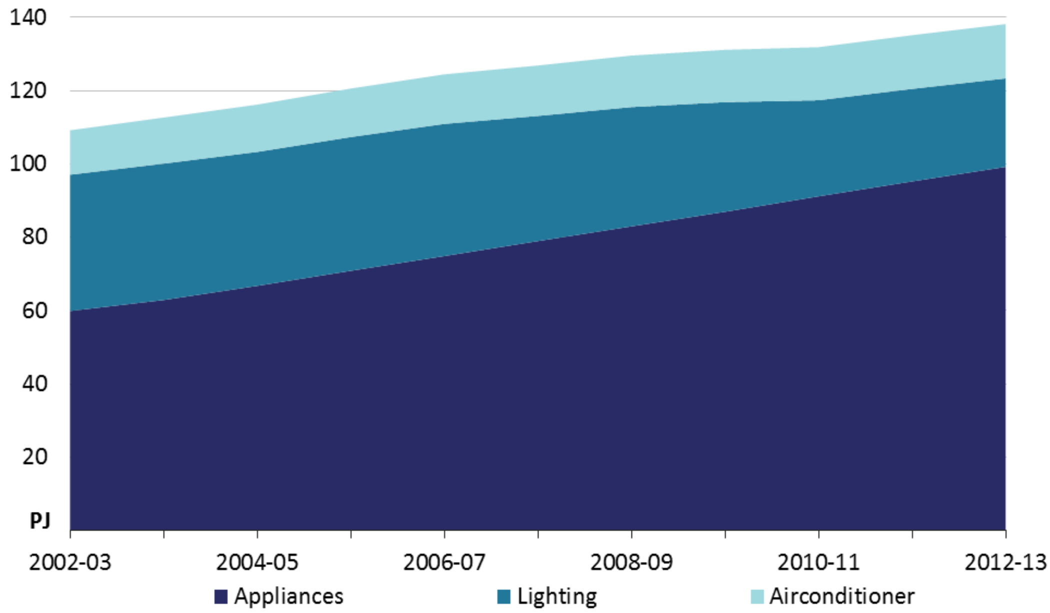
Table 5.12 provides a summary of coverage and variables used in the residential sector.

Table 5.12: Summary of coverage and variables used in the residential sector

End-use	*Activity variables*	*Structure variables*	*Intensity variables*
Electrical appliances			
Refrigerator	population	appliances/person	energy/appliance stock
Freezer	population	appliances/person	energy/appliance stock
Clothes washers	population	appliances/person	energy/appliance stock
Clothes dryer	population	appliances/person	energy/appliance stock
Dishwasher	population	appliances/person	energy/appliance stock
Television	population	appliances/person	energy/appliance stock
Lighting	population	floor area/person	energy/floor area
Air conditioners	population	floor area/person	energy/floor area

Figure 5.35 shows estimated annual energy consumption for household electrical appliances, lighting and air conditioners. Energy consumption in the residential sector increased by 29 petajoules over the period 2002–03 to 2012–13, or by 2.4 per cent a year. Growth in electricity use by appliances was partly offset by a fall in electricity use by lighting. Electricity use for air-conditioners grew by 2 per cent a year over the period. Appliances, mainly refrigerators, washing machines and televisions, accounted for 55 per cent of electricity use in households in 2002–03, with the share increasing to 72 per cent in 2012–13. Air conditioners accounted for 11 per cent of electricity use in both 2002–03 and 2012–13. The share of electricity use in lighting declined from 34 per cent in 2002–03 to 17 per cent in 2012–13.

Figure 5.35: Electricity consumption in the residential sector



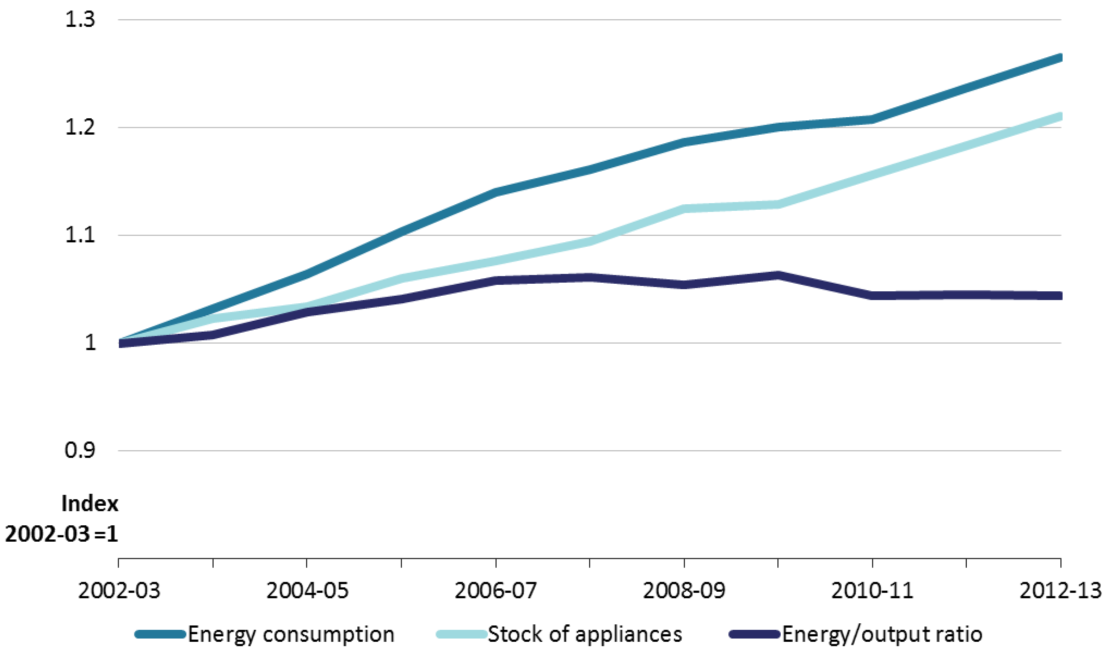
Notes: This represents only a subset of energy use in the residential sector.

Source: Department of Industry and Science 2015.

5.31 Indicators of energy intensity in the residential sector

Measuring activity or output in the residential sector is more complicated than other sectors. In this study, the stock of household energy-using equipment is used to represent output in the calculation of the energy/output ratio. The energy/output ratio indicates a 0.4 per cent per year increase in energy intensity in the residential sector from 2002–03 to 2012–13 (Figure 5.36).

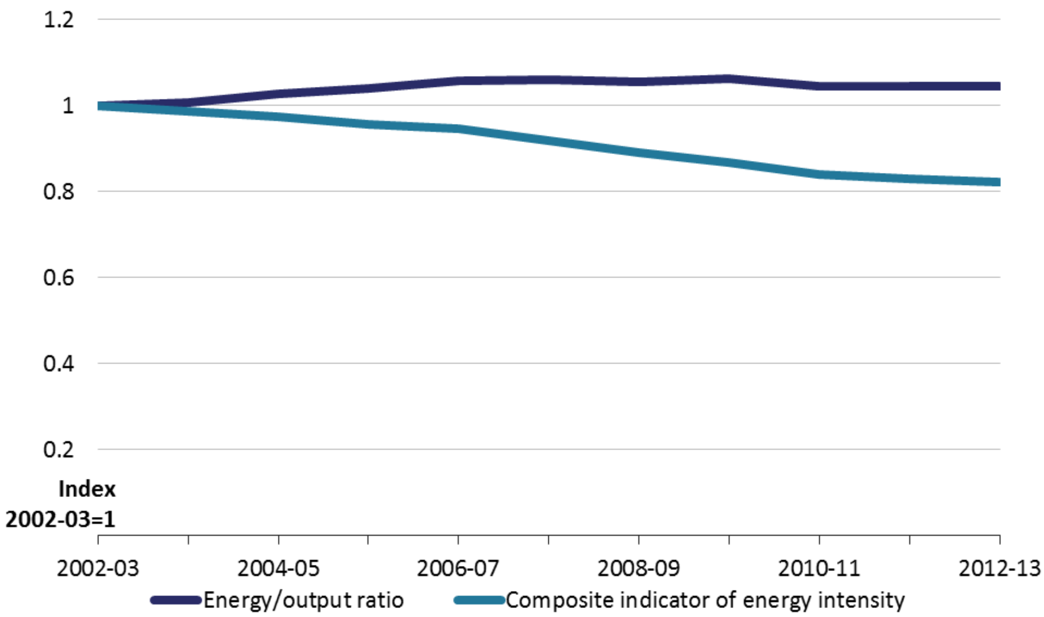
Figure 5.36: Energy intensity of the residential sector, energy/output ratio



Source: Department of Industry and Science 2015.

A composite indicator of energy intensity has also been calculated for the residential sector. Figure 5.37 illustrates how the effects of structural and behavioural influences can impact on measures of energy intensity in the residential sector. The composite indicator shows that energy intensity actually declined by 1.9 per cent a year over the period 2002–03 to 2012–13.

Figure 5.37: Comparison of energy intensity indicators in the residential sector



Source: Department of Industry and Science 2015.

The structural impacts captured in the composite indicator of energy intensity include the effect of population, the number of households, dwelling area, and stock of appliances on energy use in households. Behavioural influences on household energy consumption can differ in the short-term and over the long-run. In the short-run, residential households are typically locked into their existing stock of energy-consuming appliances, and cannot adjust their stock of appliance in response to variations in the price of energy. The short-run response of the household to an increase in energy prices may be limited to behavioural change, such as switching off lights when out of the room, shutting windows and doors, or adjusting the temperature of space heating and cooling units.

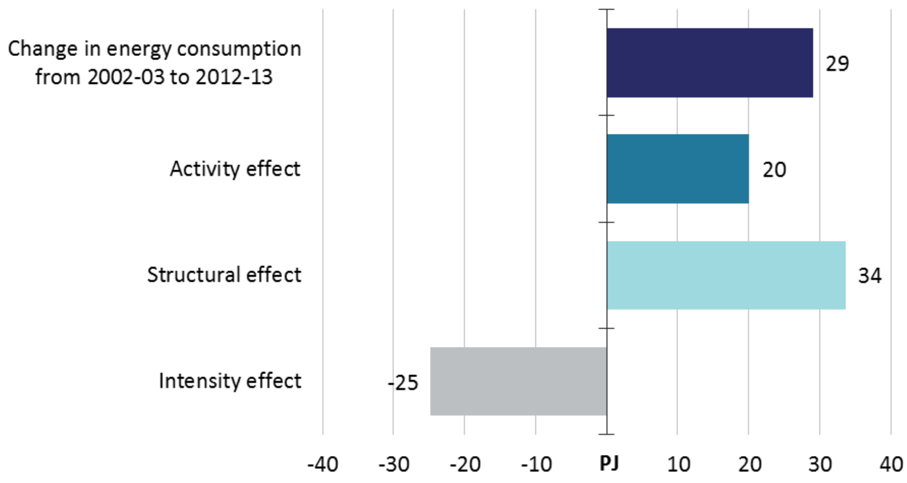
However, over the longer term, households are able to adjust the stock of capital, such as space cooling equipment, used in the home. These drivers for energy services in the residential sector can mask the effects of changes in energy intensity when measured using the energy/output ratio.

5.32 Decomposition of changes in energy consumption

Energy consumption in the residential sector increased by 29 petajoules over the period 2002–03 to 2012–13. Figure 5.38 summarises the changes in energy consumption in the residential sector as explained by the factored components, over the period 2002–03 to 2012–13. The activity effect indicates that the amount of energy consumed would have been 27 per cent lower than the realised energy consumption without taking into account the other explanatory factors for energy consumption.

The analysis demonstrates that changes in energy consumption in the residential sector are largely a result of the net effect of the structural effect and intensity effect. Behavioural and structural influences on energy use patterns have been partly offset by the intensity effect on changes in energy consumption due to energy efficiency improvements in the stock of energy-consuming equipment.

Figure 5.38: Decomposition of change in energy consumption in the residential sector



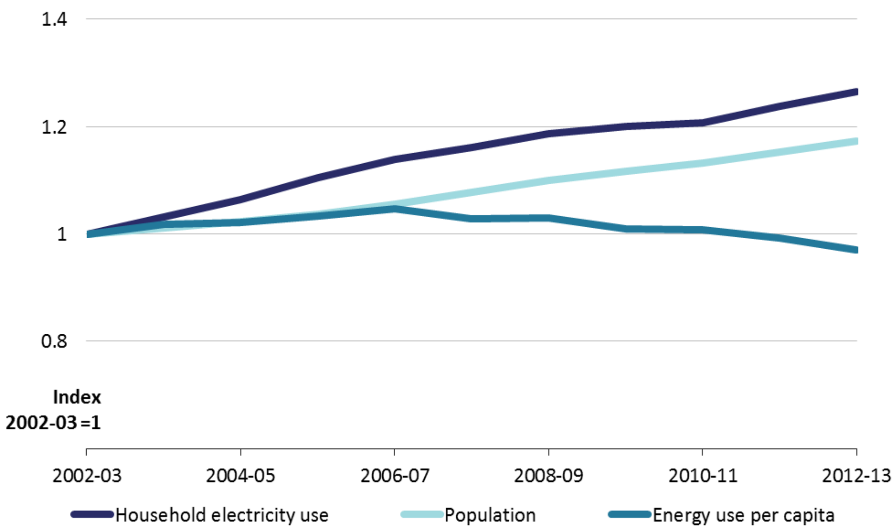
Source: Department of Industry and Science 2015.

5.33 Changes in the scale of activity

Population is a key determinant of how the activity effect contributes to changes in energy consumption in the residential sector. Population growth increases the number of energy users which contributes to changes in energy consumption. Australia's population increased by 3.4 million persons or by 1.6 per cent a year over the period 2002–03 to 2012–13 (Figure 5.39). The activity effect contributed 20 petajoules to the change in energy consumption in the residential sector from 2002–03 to 2012–13.

Energy use per capita, measured by the ratio of energy consumption to population, declined slowly at an average rate of 0.3 per cent per year from 2002–03 to 2012–13. However, energy use per capita has showed a particularly strong decline from 2010–11 to 2012–13, falling by 4.0 per cent.

Figure 5.39: Energy consumption per capita.



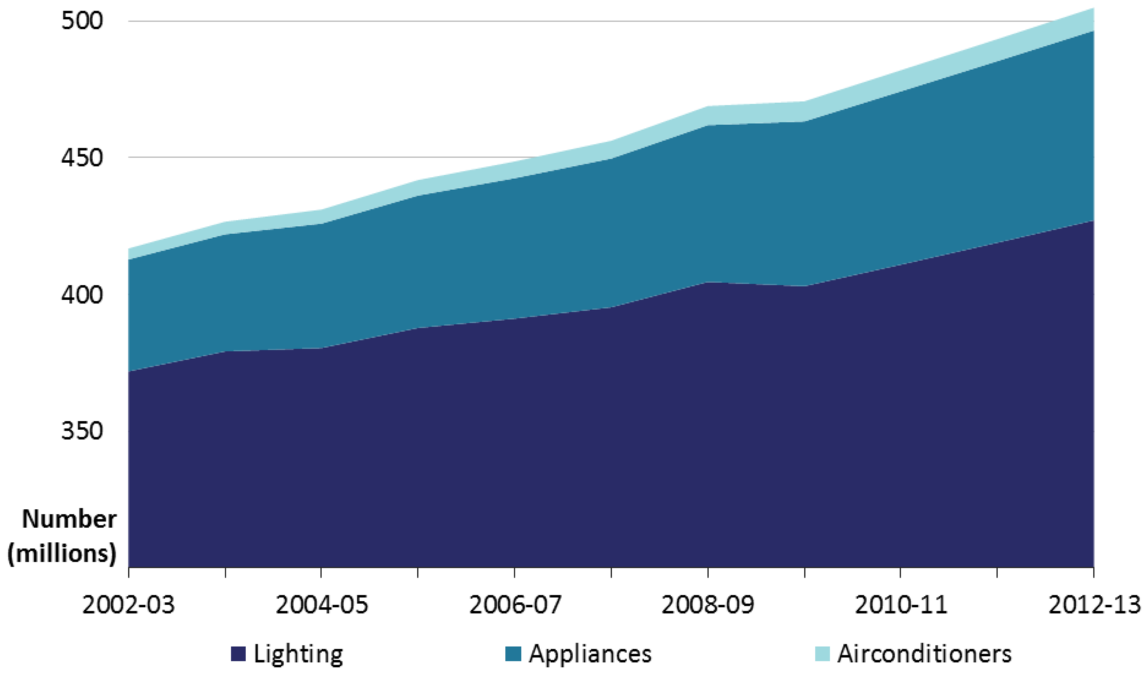
Source: Department of Industry and Science 2015; BREE 2014.

5.34 Structural change

The structural effect contributed 34 petajoules to changes in household energy consumption over the period 2002–03 to 2012–13. The structural effect of changes in energy consumption in the residential sector is determined by dwelling occupancy rates, size of household dwellings, and appliance ownership.

Figure 5.40 shows ownership of electrical appliances, air-conditioners and lighting in the residential sector from 2002–03 to 2012–13. The number of air-conditioners installed in households increased at an annual average rate of 7.6 per cent from 2002–03 to 2012–13. The stock of electrical appliances increased at an average rate of 5.4 per cent a year from 2002–03 to 2012–13 with televisions, refrigerators and clothes washers representing the most common electrical appliances in households. Lighting equipment increased by 14.9 per cent from 2002–03 to 2012–13 (Table 5.13).

Figure 5.40: Appliance ownership in the residential sector



Source: Department of Industry and Science 2015.

Table 5.13: Attributes of the appliance stock for the Australian residential sector

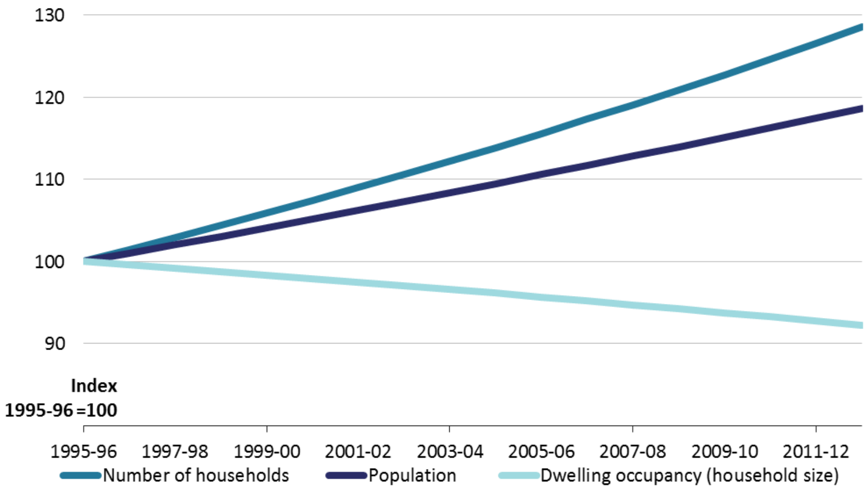
Ownership	*2002–03*	*2012–13*	*2002–03 to 2012–13*	
Stock (number)	million	million	% change	Annual growth (%)
Electrical appliances	40.9	69.4	69.7	5.4
of which				
Dishwashers	2.8	6.1	117.2	8.1
Refrigerators	8.0	17.1	113.3	7.9
Clothes washers	7.6	15.3	101.0	7.2
Clothes dryers	4.3	7.3	67.6	5.3
Freezers	2.9	4.8	64.4	5.1
Televisions	15.2	18.8	24.0	2.2
Air conditioners	4.0	8.3	108.3	7.6
Lighting	371.9	427.2	14.9	1.4

Source: Department of Industry and Science 2015.

Structural changes affecting energy consumption in the residential sector also include changes in the number of households, dwelling occupancy and the average amount of floor space per household. The Australian population increased slightly faster over the period 2002–03 to 2012–13 than growth in the number of households. As a result dwelling occupancy fell, with the average household size declining from 2.54 members per household in 2002–03 to 2.42 members per household in 2012–13 (Figure 5.41). Further, average floor space per household member increased from 82 square metres per household member in 2002–03 to 86 square metres in 2012–13.

Household demand for space cooling, lighting, and convenience appliances such as dishwashers has risen with increases in the number of households and average floor space per household member (Figure 5.42).

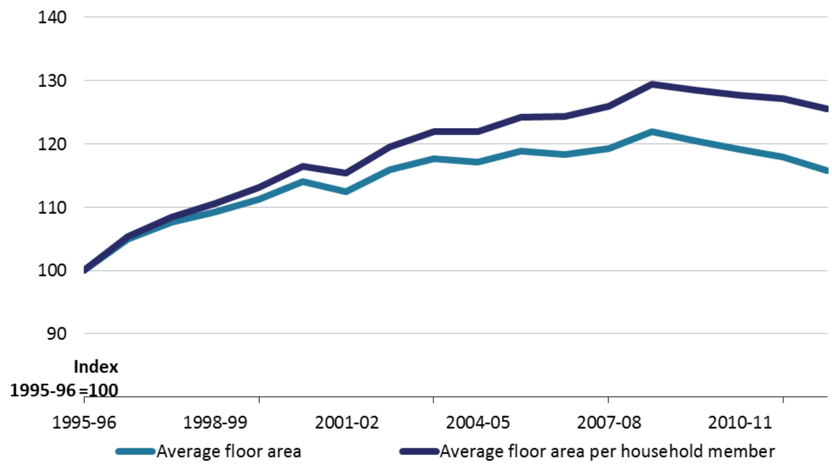
Figure 5.41: Household attributes and population



Source: Department of Industry and Science 2015; ABS 2015c.

The growing number of single-member households may also be having an impact on energy consumption in the residential sector. Declines in household size can result in more floor space per person. Households with fewer members will often acquire the same number and size of major appliances, and consume more energy per household member than a larger household. At the same time, though, single persons may spend less time at home than families, resulting in fewer hours demanding energy.

Figure 5.42: Average floor space in the residential sector

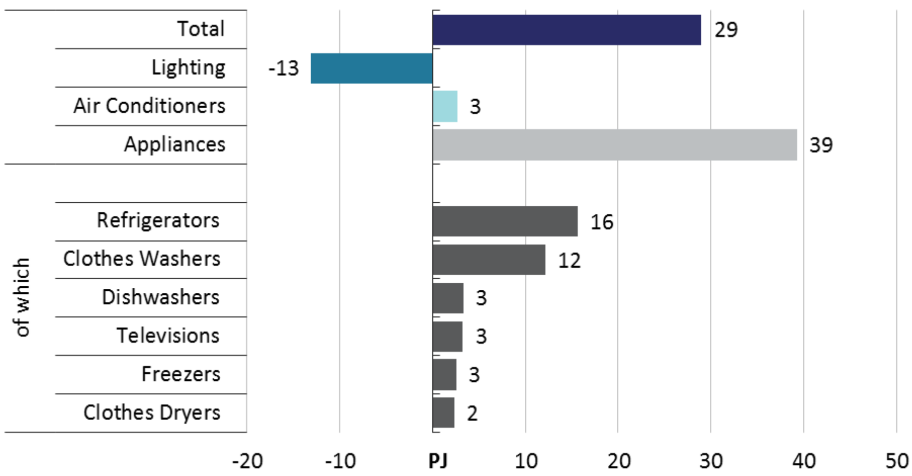


Source: Department of Industry and Science 2015; ABS 2015 (unpublished data).

5.35 Intensity effect

Energy intensity in the residential sector declined over the period 2002–03 to 2012–13, most likely as a result of improvements in the energy efficiency of household energy-using equipment. The intensity effect offset changes in energy consumption by 25 petajoules, which is equivalent to a reduction in household energy use of 1.9 per cent a year from 2002–03 to 2012–13.

Figure 5.43: Absolute change in energy consumption in the residential sector



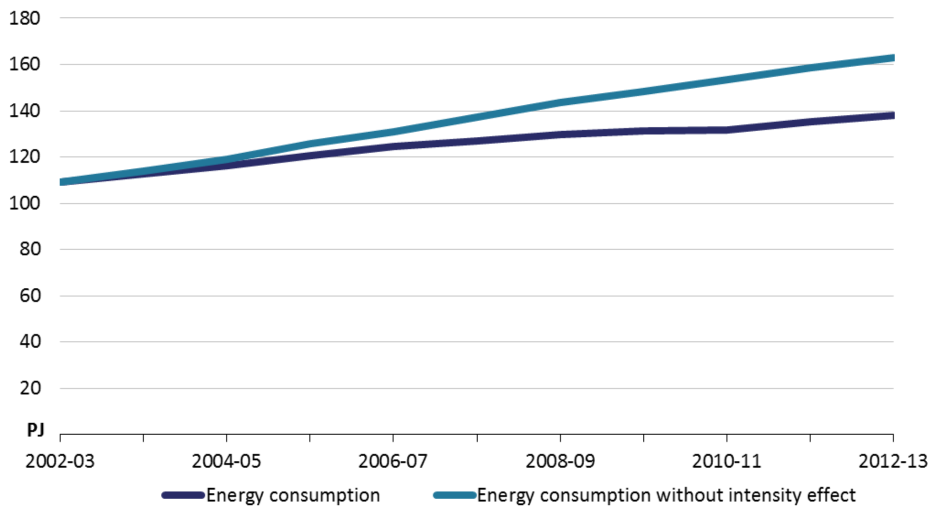
Source: Department of Industry and Science 2015.

Table 5.14: Energy consumption in the Australian residential sector

Energy consumption	*2002–03*	*2012–13*	*2002–03 to 2012–13*	
	PJ	PJ	% change	Annual growth (%)
Electrical appliances	59.9	99.2	65.7	5.2
of which				
Dishwashers	3.7	7.1	89.0	6.6
Freezers	6.0	8.5	43.0	3.6
Clothes dryers	3.7	6.0	63.1	5.0
Clothes washers	14.0	26.2	87.3	6.5
Refrigerators	18.9	34.5	82.8	6.2
Televisions	13.6	16.9	24.0	2.2
Air conditioners	12.1	14.8	22.3	2.0
Lighting	37.2	24.2	-35.1	-4.2

Source: Department of Industry and Science 2015.

Figure 5.44: Energy consumption in the residential sector, with and without intensity effect

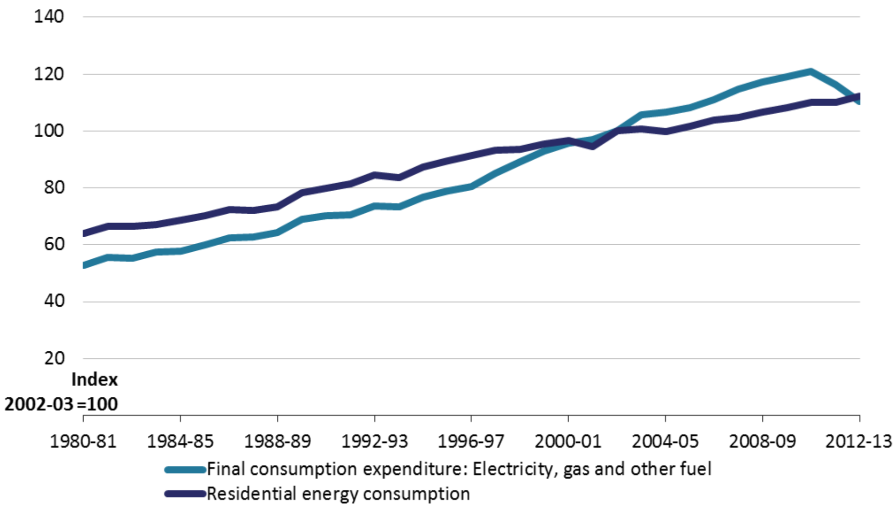


Notes: Shows cumulative changes in energy efficiency.

Source: Department of Industry and Science 2015.

Household income and energy prices are key factors affecting energy intensity in the residential sector. Household consumption expenditure on energy fuels has been increasing over the past decade (Figure 5.45). Since 2003-04, household expenditure on energy fuels has increased at a greater rate than growth in residential energy consumption despite the 7.9 per cent decrease in energy expenditure from 2010-11 to 2012–13.

Figure 5.45: Energy consumption and expenditure in the residential sector



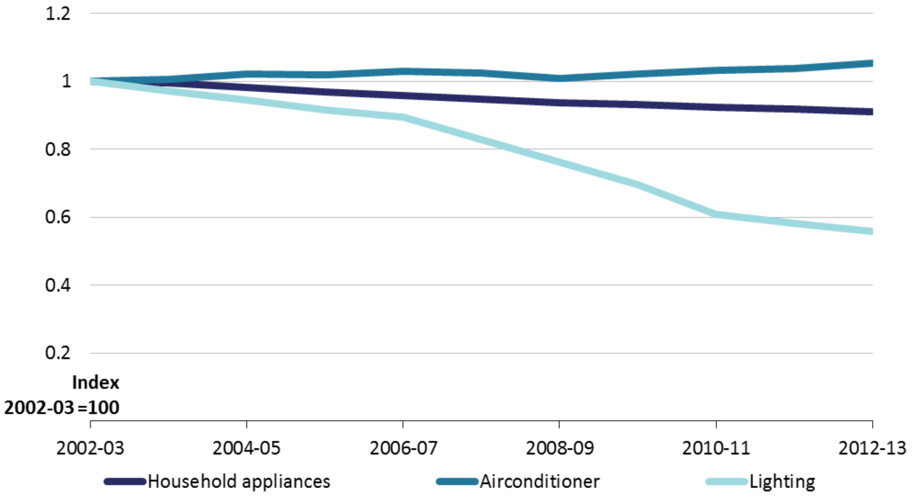
Source: Department of Industry and Science 2015; BREE 2014; ABS 2015b.

Even though households were purchasing more energy for appliances such as televisions and air-conditioners, many of the appliances were using less energy than older models. Further, although the quantity of lighting used in homes has increased since 2002–03, energy use for lighting has decreased because incandescent bulbs have been replaced with more efficient compact fluorescent lighting (CFL) and light-emitting diode (LED) lamps, and to some extent Mains Voltage halogen omnidirectional lamps (which are about 20-30 per cent more efficient than tungsten filament lamps).

The state and territory governments have mandated energy rating labelling for refrigerators and freezers since mid-1980s with the national scheme for minimum energy efficiency performance standards agreed to in 1992. Minimum performance standards have been amended over time to increase the coverage over a broader range of appliances and to tighten the minimum requirements for energy efficiency of appliances. Energy minimum performance standards have meant incandescent light bulbs were phased out from 2009 with sales restrictions imposed. A number of state-based lamp replacement schemes also operated from 2006.

Manufacturers have improved the energy efficiency of household appliances and lighting equipment in response to these mandatory performance standards. For example, air conditioners today are around one-third more efficient than a decade ago. However, despite the substantial improvement in technical efficiency of air-conditioners over the period 2002–03 to 2012–13, the intensity effect on changes in energy consumption for air-conditioners increased marginally by 0.5 per cent per year (Figure 5.46). The result suggests that household patterns of air-conditioner use have become less efficient over time.

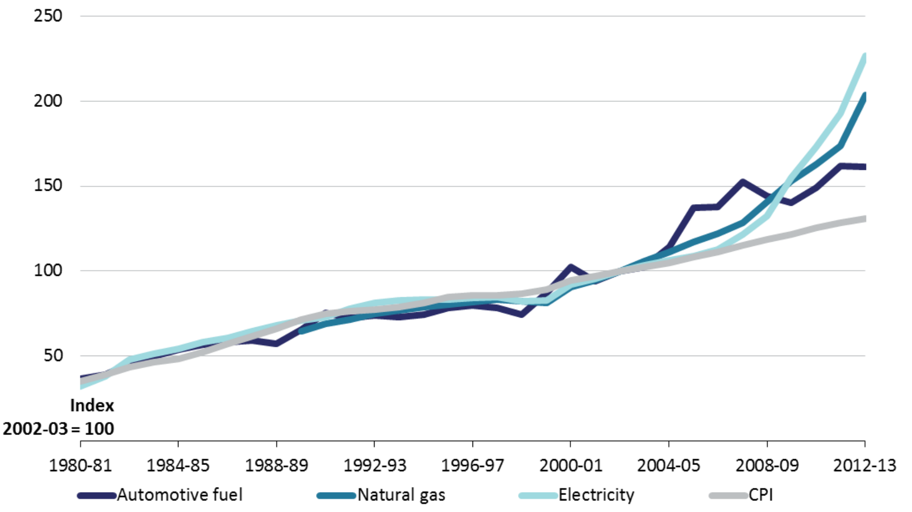
Figure 5.46: Increasing energy efficiency activity in the residential sector



Source: Department of Industry and Science 2015.

Energy prices are a key determinant of household decision making on the selection of the stock of appliances in the long-run because the choice to purchase an appliance can be dependent on the fuel used to operate the appliance. Energy prices also explain household behaviour and can influence changes in energy consumption. Figure 5.47 shows that the household fuel prices have increased more sharply since 2002–03 than the ABS Consumer Price Index (CPI). Electricity prices have increased strongly, relative to CPI, growing annually on average at a rate of 8.5 per cent from 2002–03 to 2012–13.

Figure 5.47: Price indexes of input fuel prices for the residential sector



Source: Department of Industry and Science 2015; ABS 2014b.

Services

5.36 Key points

- The services sector has relatively low energy intensity; accounting for more than half of GDP in 2012–13, and only 8 per cent of final energy consumption.
- Energy use in the services sector increased by 46 petajoules over the period 2002–03 to 2012–13, an average growth rate of 1.6 per cent a year.
- Without changes to sectoral structure and intensity, increased activity in the services sector would have caused an increase in energy consumption of 86 petajoules between 2002–03 and 2012–13, nearly double the actual increase in energy use.
- Structural shifts towards less-intensive services sectors such as finance, insurance, property and business are estimated to have reduced energy consumption by 11 petajoules between 2002–03 and 2012–13.
- The intensity effect resulted in a fall in energy use of 1.0 per cent a year over the period 2002–03 to 2012–13, leading to energy savings of 29 petajoules.
- Energy prices and government policies to enhance energy efficiency are key factors contributing to the decline in energy intensity in the services sector over the past decade.

5.37 Introduction

The services sector is the largest contributor to the Australian economy, accounting for more than half of Australia's GDP in 2012–13. The sector has grown by more than 3 per cent a year over the past decade.

In terms of energy use, the services sector accounted for around 8 per cent of Australia's final energy consumption in 2012–13. Electricity is the largest energy source for the sector, accounting for around three-quarters of its energy use in 2012–13, with some gas and petroleum products are also being consumed. Around two-thirds of energy use is in wholesale and retail trade; accommodation, cultural and personal services; and education, health and community services. Over the past decade, energy consumption in the services sector increased by around 1.6 per cent a year, to 308 petajoules in 2012–13.

5.38 Coverage and variables used

The subsectors and variables used in the services sector are presented in Table 5.15. The services sector includes ANZSIC divisions F, G, H, J, K, L, M, N, O, P, Q, R, S, and subdivision 28 of division D. Economic activity for each subsector and the services sector as a whole is measured by industry gross value added. Energy use in the services sector is based on the 2014

Australian Energy Statistics (BREE 2014). Sub-sectoral energy use is based on unpublished estimates from the 2014 Australian Energy Statistics.

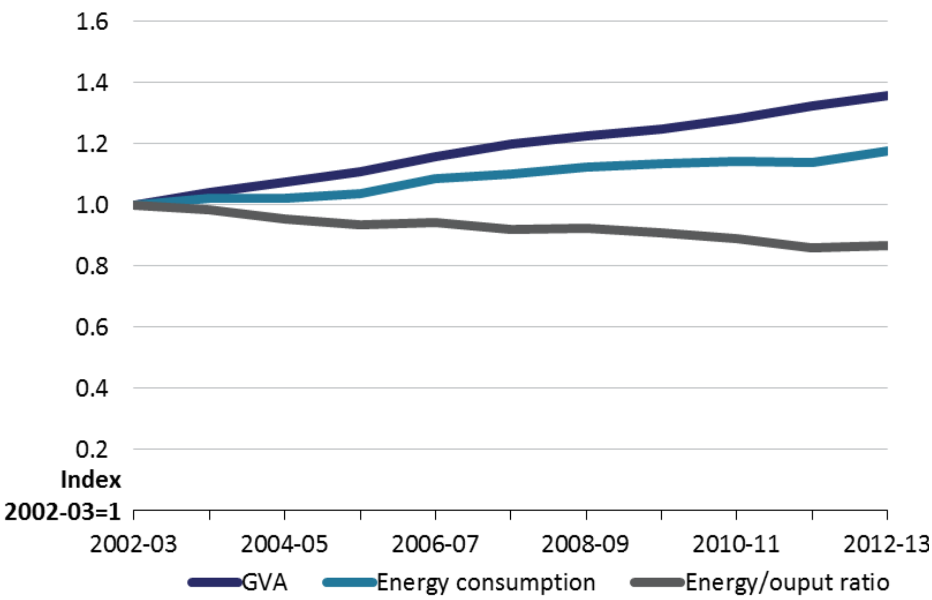
Table 5.15: Subsector coverage and variables used in the services sector

Subsector	*Activity variables*	*Structure variables*	*Intensity variables*
Wholesale and retail trade	value-added	share of sector output	energy/ value-added
Communication services	value-added	share of sector output	energy/ value-added
Finance, insurance, property and business	value-added	share of sector output	energy/ value-added
Government administration and defence	value-added	share of sector output	energy/ value-added
Education, health and community services	value-added	share of sector output	energy/ value-added
Accommodation, cultural and personal services	value-added	share of sector output	energy/ value-added
Water supply, sewerage and drainage services	value-added	share of sector output	energy/ value-added

5.39 Comparison of energy intensity indicators

Energy intensity in the services sector generally declined over the period 2002–03 to 2012–13, flattening towards the end of the period (Figure 5.48). Based on the ratio of energy use to output, energy intensity fell by 1.4 per cent a year during 2002–03 to 2012–13.

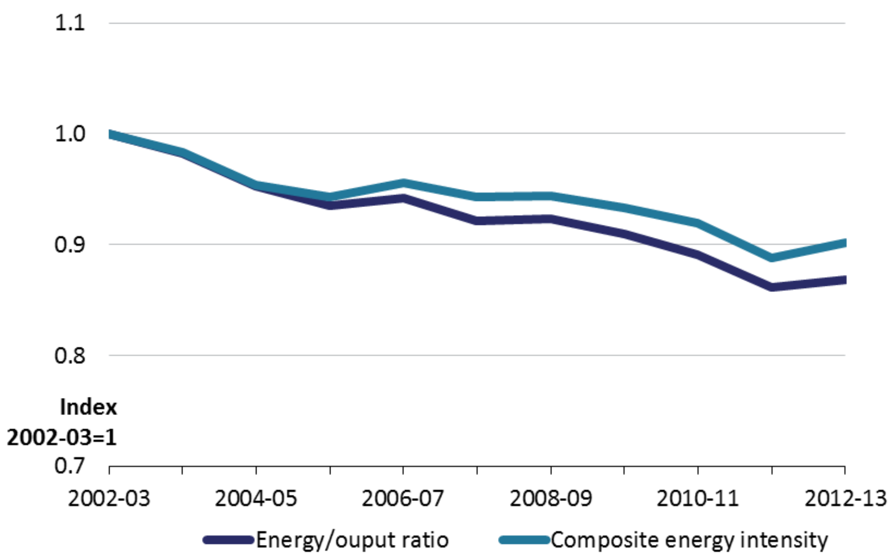
Figure 5.48: Energy intensity in the services sector, energy/output ratio



Source: Department of Industry and Science 2015; BREE 2014; ABS 2015b.

When calculated using the composite index to account for structural and intensity effects at the subsector level, energy intensity shows a similar trend, but at a slower pace of 1.0 per cent a year (Figure 5.49).

Figure 5.49: Comparison of energy intensity indicators in the services sector



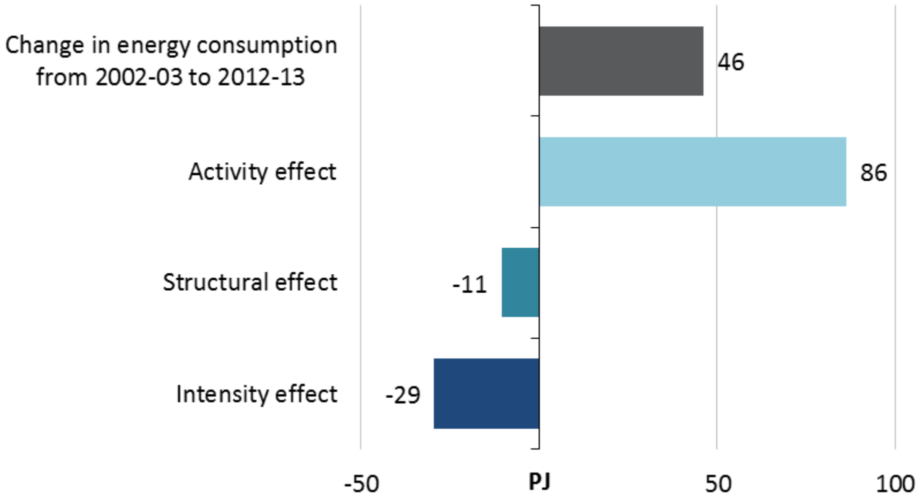
Source: Department of Industry and Science 2015; BREE 2014; ABS 2015b.

5.40 Decomposition of changes in energy consumption

Decomposition of changes in energy consumption in the services sector shows that the intensity and the structural effects have partially offset the increase in energy consumption due to the activity effect (Figure 5.50).

Increased activity in the services sector would have resulted in an 86 petajoules increase in final energy consumption between 2002–03 and 2012–13. However, final energy consumption in the services sector rose by only 46 petajoules over the period as the structural and the intensity effects partly offset the increase due to the activity effect. From 2002–03 to 2012–13 the structural effect and the intensity effect resulted in total energy savings of 40 petajoules.

Figure 5.50: Decomposition of changes in energy consumption in the services sector



Source: Department of Industry and Science 2015.

5.41 Changes in the scale of activity

During 2002–03 to 2012–13, gross value added in the services sector in Australia grew by 3.1 per cent a year, or around $216 billion in real terms. Within the services sector, the finance, insurance, property and business subsector recorded the strongest growth over this period (Table 5.16). It also accounted for the largest share in the services sector's gross value added. Increasing competition in the services sector as a result of continual deregulation of the Australian financial market and communication services from the 1980s and 1990s have driven down the cost of the sector. To take advantage of the low cost services, many businesses have outsourced their finance and communication needs, contributing to growth of the services sector. The value of Australian service exports has also increased over the past decade.

Table 5.16: Activity in the services sector

Activity	*2002–03*	*2012–13*	*2002–03 to 2012–13*	
Gross value added	$billion	$billion	% change	Annual growth (%)
Finance, insurance, property & business	216.6	308.8	42.5	3.6
Education, health & community services	120.0	165.9	38.2	3.3
Wholesale and retail trade	96.0	131.4	37.0	3.2
Government administration and defence	61.4	80.1	30.5	2.7
Accommodation, cultural and personal services	63.8	75.0	17.7	1.6
Communication services	31.7	42.5	34.1	3.0
Water supply, sewerage & drainage services	13.5	15.1	11.5	1.1
Total	603.0	818.7	35.8	3.1

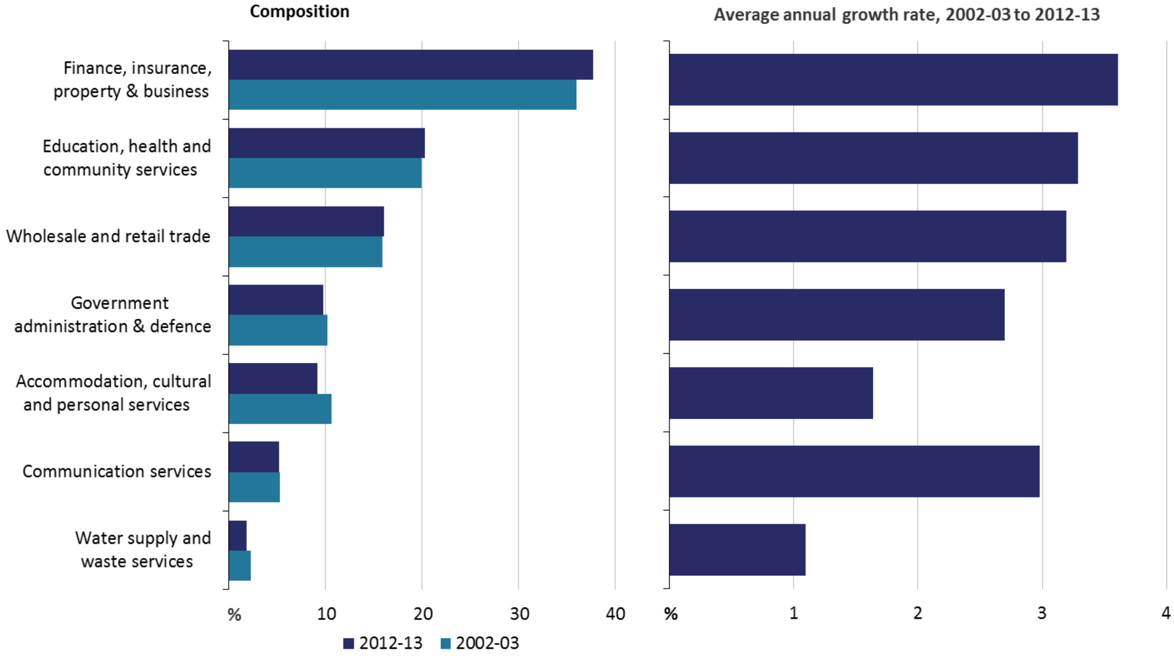
Notes: Chain volume measures. Reference year is 2011–12.

Source: Department of Industry and Science 2015; ABS 2015b.

5.42 Changes in structure

Structural changes in the services sector partly offset the increase in energy consumption due to increasing activity in the sector over the past decade. The strongest growth has been seen in the finance, insurance, property and business subsector, with its share of total services increasing from 36 per cent in 2002–03 to 38 per cent in 2012–13 (Figure 5.51). As these types of services are often more labour- and capital-intensive than energy-intensive, increasing shares in activity of these subsectors contributed to a reduction in energy use in the services sector.

Figure 5.51: Activity in the services sector



Source: Department of Industry and Science 2015; ABS 2015b.

5.43 Changes in energy intensity

Energy intensity in the services sector is influenced by the composition of energy use within its subsectors. Between 2002–03 and 2012–13, energy consumption in the services sector increased by 1.6 per cent a year on average (Table 5.17).

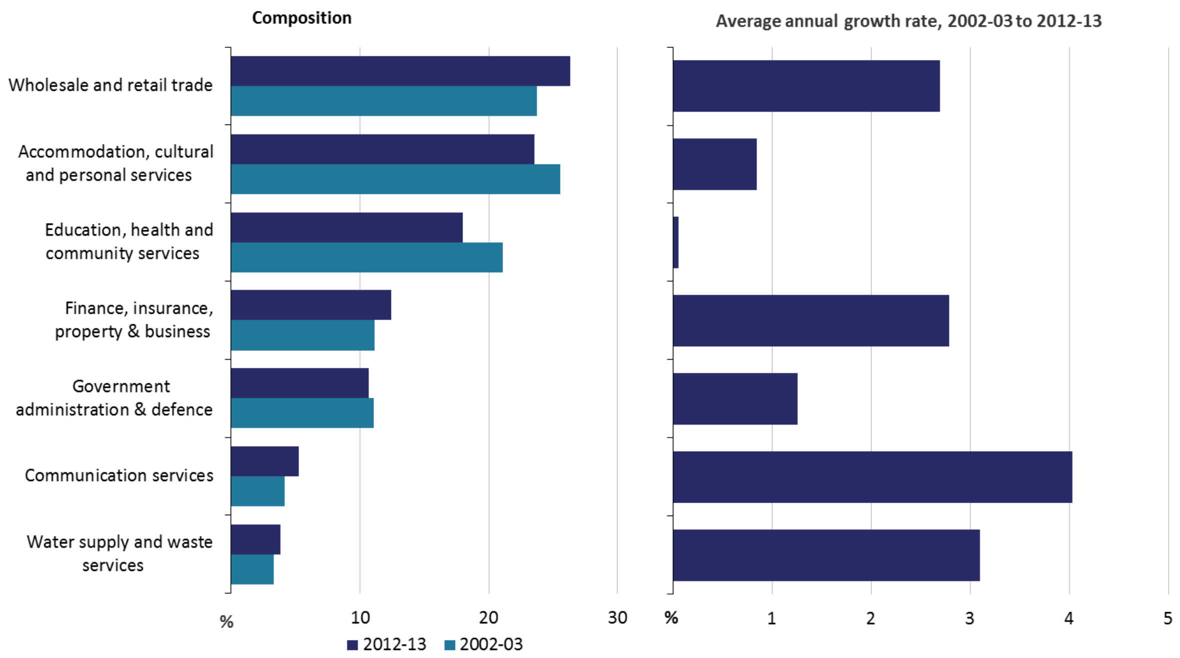
The largest increase in energy consumption over the period was observed in the communication services subsector. Strong growth in energy consumption was also recorded in the water supply, sewerage and drainage services; the finance, insurance, property and business and; the wholesale and retail trade subsectors (Figure 5.52). The shares of those subsectors in total energy consumption also increased over the period. The fastest growth in energy consumption over the past decade occurred in the least energy intensive subsectors: finance, insurance, property and business, and communication services (Figure 5.52 and Figure 5.53).

Table 5.17: Energy consumption in the services sector

Energy consumption	*2002–03*	*2012–13*	*2002–03 to 2012–13*	
	PJ	PJ	% change	Annual growth(%)
Wholesale and retail trade	62.0	80.9	30.4	2.7
Accommodation, cultural and personal services	66.6	72.4	8.7	0.8
Education, health & community services	55.0	55.2	0.5	0.1
Finance, insurance, property & business	29.0	38.2	31.6	2.8
Government administration and defence	28.9	32.7	13.3	1.3
Communication services	10.8	16.1	48.5	4.0
Water supply, sewerage & drainage services	8.6	11.6	35.6	3.1
Total	260.9	307.1	17.7	1.6

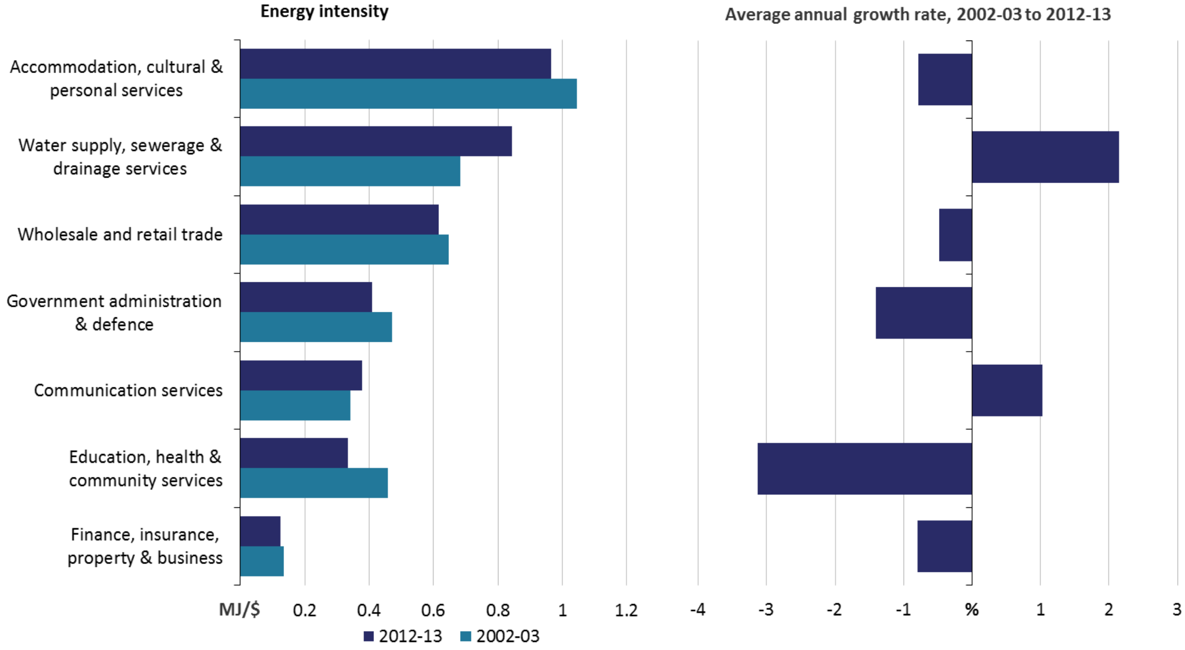
Source: Department of Industry and Science 2015; BREE 2014 (unpublished data).

Figure 5.52: Energy consumption in the services sector



Source: Department of Industry and Science 2015; BREE 2014 (unpublished data).

Figure 5.53: Energy intensity in the services sector, by subsector



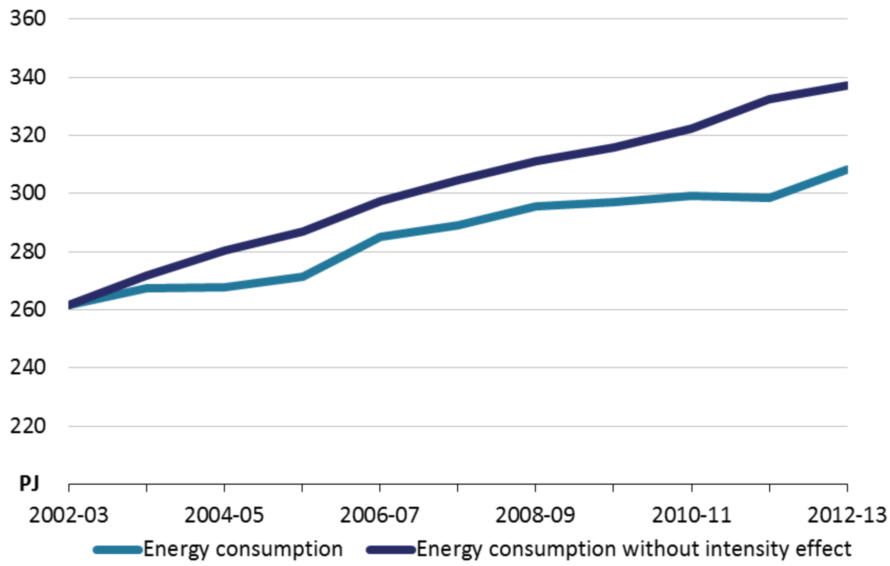
Source: Department of Industry and Science 2015.

5.44 Energy efficiency in the services sector

The services sector has become more efficient in its energy use, with energy savings achieved steadily during 2002–03 to 2012–13 (Figure 5.54). This could be attributable to the uptake of energy saving measures by businesses such as investment in technologies that bring both energy and maintenance cost savings. These include investment in energy efficient lighting such as LEDs and sensors, installing solar hot water heating for industrial and commercial buildings, and upgrading IT, communications and other electronic equipment. Other measures that could lead to more efficient use of energy are staff awareness training on energy savings. This is likely to have increased in importance, given the increases in electricity prices over the past decade.

Government policies and regulations also affect energy efficiency in the services sector. These include minimum energy performance requirements for new buildings and major refurbishments. For instance, the National Building Construction Code now includes energy efficiency measures for all building classifications. The National Australian Built Environment Rating System (NABERS) also includes energy ratings for commercial buildings, using a star approach from zero to six stars.

Figure 5.54: Energy consumption in the services sector, with and without intensity effect



Source: Department of Industry and Science 2015; BREE 2014.

6. Conclusions

Improving the way we use energy has increasingly become a focus for households, businesses and governments, in Australia and globally. Understanding how energy use has changed over time informs decision making by consumers, and can instruct policy to drive change to achieve better outcomes. The relative contribution of the different factors influencing changes in energy use has important implications when considering policy options to meet potential targets to improve energy productivity.

Energy intensity indicators provide a useful way to track trends in energy use over time, not only in terms of improvements in Australia's energy productivity but also in how energy consumption patterns have changed both across and within sectors of the economy.

Final energy consumption in the transport, manufacturing, construction, mining, residential and services sectors rose by 88 per cent over the period 1980–81 to 2012–13, compared with an increase in economic output of 196 per cent. This declining trend in the energy intensity of the Australian economy over the past three decades has been the result of a range of factors, including improvements in energy efficiency in buildings, appliances, vehicles and production processes, as well as structural changes in the economy towards less energy intensive sectors such as services.

This study found that over the past three decades, economic activity has made the largest contribution to changes in energy consumption. The activity effect indicates that the change in energy consumed over the last three decades would have almost been double compared to the realised energy consumption, without taking into account the contribution of other explanatory factors for energy consumption.

The actual increase in energy consumption may also be explained by changes in the structure of the economy, from relatively more energy-intensive activity to less energy-intensive activity, as well as improvements in energy productivity. The analysis shows that the structural effect contributed to a reduction of 17 per cent to changes in the energy used over the period 1980–81 to 2012–13, with the intensity effect contributing a further reduction of 56 per cent.

After taking account of structural changes in the economy, Australia's energy intensity declined by 1.0 per cent a year (28 per cent) over the past three decades, compared with 1.4 per cent a year when energy intensity is measured using the energy/output ratio.

Most of the fall in energy intensity in the Australian economy over the past three decades is in the transport and manufacturing sectors. Businesses and consumers are shifting away from road transport to relatively less-energy intensive rail and air transport. Further, there has been a shift in the composition of the manufacturing sector away from heavy industry toward less energy-intensive manufacturing production processes.

In contrast, higher commodity prices have provided incentives for firms to extract from more marginal resource deposits which have largely driven increased energy use and energy intensity in the mining sector. The increasing share of iron ore and coal in the Australian mining sector, relative to the share of oil and gas extraction, has seen a shift toward lower value-add and more energy intensive activities.

This report also identifies other factors that may have affected energy intensity trends across sectors, including energy prices, technological advances, and government policies. A more detailed analysis supported by the availability of disaggregated data would be required to further assess the effect of these factors on energy intensity.

Appendix A Mathematical framework

This appendix reviews the method of decomposition and composite index method used in this report. To retain consistency with previous studies of energy intensity in Australia, in this report the approach follows the method, with some minor revisions, applied by Sandu and Syed (2008) and Sandu and Petchey (2009), Nhu and Pham (2012).

A.1 Decomposition method

Previous studies by Sun (1998) and Albrecht et al. (2002) contributed to the methodology applied to energy consumption decomposition analysis, in particular in relation to the issue of perfect decomposition. Ang et al. (2003) proved that, mathematically, the Shapley decomposition is the same as the method proposed by Sun (1998).

This report applies a similar approach used in the report by Sandu and Petchey (2009) for energy consumption decomposition analysis (see Ang 2001 and Ang et al 2003). Changes in energy use over the period 1980–81 to 2012–13 are decomposed into three components that affect energy consumption—the activity effect, the structural effect and the intensity effect. The decomposition technique, also known as factorisation, used in this report is the LMDI-I method, disaggregates changes in energy consumption into these three components. This method has a number of advantages over other decomposition methods and does not leave an unexplained or residual component.

The activity effect of an economic sector refers to the changes in energy consumption that arise solely from the changes in activity in the economy typically. In this report activity is measured in terms of passenger-kilometres and freight-kilometres for the transport sector, population for the residential sector, and gross value added for other sectors.

The change in energy consumption associated with changes in the composition of activity 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 overall activity.

The change in energy consumption associated with the change in energy intensity of each sector is referred to as the intensity effect. This measure provides a useful indicator of energy efficiency. However, it is not equal to energy efficiency in the strict engineering sense unless the analysis is undertaken at the most disaggregated level of the economy.

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

$$E = \sum_{i}^{n} A \cdot \frac{A_i}{A} \cdot \frac{E_i}{A_i} \qquad (1)$$

where A is the total activity for the sector, A_i is the activity of a sector's i^{th} subsector 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 sector activity and the third term gives the energy intensity of the i^{th} subsector. By defining $S_i = A_i / A$ and $I_i = E_i / A_i$, equation 1 can be rewritten as:

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

Equation 2 provides the basis for various energy decomposition methods (see Ang et al. (2003), Liu and Ang (2003) and Ang (2004) for comparisons of these methods). Ultimately, of interest is in how changes in energy consumption over time can be decomposed into the three factors on the right-hand side. This decomposition can be done either additively or multiplicatively. For the additive decomposition method, each of the three components of energy consumption is expressed in absolute terms; that is, in energy units. In this report, energy consumption is measured in terms of petajoules. For the multiplicative decomposition method, each component is expressed in terms of an index. For details of the multiplicative form see Ang and Liu (2001), Ang et.al (2003) and Ang (2004).

The additive type of the LMDI decomposition method allows us to express a given change in energy consumption of the i^{th} subsector as the sum of a change in activity (activity effect), a change because of shifts in structure (structural effect) and a change because of changes in energy intensity (intensity effect):

$$\Delta E_i = E_{i,T} - E_{i,O} = \omega_i \cdot \ln\left(\frac{A_{i,T}}{A_{i,O}}\right) + \omega_i \cdot \ln\left(\frac{S_{i,T}}{S_{i,O}}\right) + \omega_i \cdot \ln\left(\frac{I_{i,T}}{I_{i,O}}\right) \tag{3}$$

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 ω_i is the logarithmic mean of energy consumption across the start and end periods and is defined as:

$$\omega_i = \frac{E_{i,T} - E_{i,O}}{\ln E_{i,T} - \ln E_{i,O}} \tag{4}$$

Similarly, the multiplicative type of the LMDI decomposition method allows us to express a given change in energy consumption of the i^{th} subsector as the product of an activity effect, a structural effect and an intensity effect:

$$\Delta E_i = \frac{E_{i,T}}{E_{i,O}} = \exp\left[\psi_i \cdot \ln\left(\frac{A_{i,T}}{A_{i,O}}\right)\right] \times \exp\left[\psi_i \cdot \ln\left(\frac{S_{i,T}}{S_{i,O}}\right)\right] \times \exp\left[\psi_i \cdot \ln\left(\frac{I_{i,T}}{I_{i,O}}\right)\right] \tag{5}$$

Here, the variable ψ_i is the logarithmic mean of energy consumption across the start *0* and end *T* periods and is defined as:

$$\psi_i = \frac{(E_{i,T} - E_{i,O})/(\ln E_{i,T} - \ln E_{i,O})}{(E_T - E_O)/(\ln E_T - \ln E_O)} \tag{6}$$

The first term on the right-hand side of equations 3 and 5 is the activity effect, the second is the structural effect and the third is the intensity effect. It is this third term that can be used to develop the composite energy intensity indicator. The intensity effects derived at the subsector level can be aggregated into the sectoral composite energy intensity indicator. This sectoral indicator can be further aggregated into the economy-wide composite energy intensity indicator.

A.2 Composite index method

The composite index method is a straight forward method of calculating an aggregate energy intensity indicator as an alternative to the energy-GDP ratio. The composite energy intensity indicator is based on a bottom-up approach (Ang 2004), developed by aggregating energy intensities derived for individual sectors (or subsectors) within any level of the hierarchy. The advantage of this method is that it allows for a high degree of flexibility in the choice of activity variables used. That is, it can be used to aggregate both physical-thermodynamic and economic-thermodynamic indicators into a consistent aggregate composite indicator. This approach has been used in a number of country studies, including in Canada (NRC 2006) and the US (OEERE 2005).

The composite energy intensity indicator is developed by aggregating sectoral energy intensities derived from the decomposition method. Specifically, this method aggregates the influence of the intensity effect from the individual subsectors to approximate the energy efficiency of the whole economy.

In an additive decomposition, the composite energy intensity indicator *CEII* is simply the sum of the third term on the right-hand side of equation 3 for all subsectors:

$$CEII = \sum_{i}^{n} \omega_i \times \ln\left(\frac{I_{i,T}}{I_{i,O}}\right) \tag{7}$$

In a multiplicative decomposition, the composite energy intensity indicator *CEII* is defined as:

$$CEII = \exp\left[\sum_{i}^{n} \psi_i \times \ln\left(\frac{I_{i,T}}{I_{i,O}}\right)\right] \tag{8}$$

Further details about construction of CEIIs based on the LMDI method provided by Ang (2004).

Several factors can affect the composite energy intensity index, including the activity measure chosen (physical or monetary), the degree of sectoral or end use disaggregation (higher level of disaggregation leads to better estimates), data availability and quality. These factors must be taken into account when interpreting the results or when making international comparisons.

Appendix B Sector classifications used in the study

Sector/subsector	*ANZSIC code (2006 edition)*
Mining	Division B
Coal mining	Division B: subdivision 06
Oil and gas extraction	Division B: subdivision 07
Other mining	Division B: subdivision 08, 09 and 10
Manufacturing and construction	Division C and E
Food, beverage and tobacco	Division C: subdivision 11 and 12
Textile, clothing and leather	Division C: subdivision 13
Wood, paper and printing	Division C: subdivision 14, 15 and 16
Chemical	Division C: subdivision 18 and 19
Non-metallic mineral	Division C: subdivision 20
Iron and steel	Division C: subdivision 21 (groups 211 and 212)
Non-ferrous metal	Division C: subdivision 21 (groups 213 and 214)
Other metals	Division C: subdivision 22 (groups 221, 222, 223, 224 and 229)
Machinery and equipment	Division C: subdivision 23 and 24
Other manufacturing	Division C: subdivision 25
Construction	Division E
Services	Division F-H, J-S and D (subdivision 28)
Wholesale and retail trade	Division F and G
Communication services	Division J
Finance, insurance, property and business	Divisions K, L, M and N
Government administration and defence	Division O
Education, health and community services	Divisions P and Q
Accommodation, cultural and personal services	Divisions H, R and S
Water supply, sewerage & drainage services	Division D: subdivision 28
Transport	Division I: subdivision 46-49
Passenger transport	na
Buses	part of group 462
Cars	part of group 462
Light commercial vehicles	part of group 462
Motorcycles	part of group 462
Trucks	part of group 462
Hire and reward rail (excl. light rail)	part of group 472
Light rail	part of group 472
Coastal	part of group 482

Ferries	part of group 482
Air	part of group 490
Freight transport	na
Articulated trucks	part of group 461
Light commercial vehicles	part of group 461
Rigid trucks	part of group 461
Ancillary rail	part of group 471
Hire and reward rail	part of group 471
Shipping	part of group 481
Air	part of group 490
Residential	na
Electrical appliances	na
Refrigerators	na
Freezers	na
Clothes washers	na
Clothes dryers	na
Dishwashers	na
Televisions	na
Lighting	na
Air conditioners	na

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