vivideconomics

Analysis of electricity consumption, electricity generation emissions intensity and economy-wide emissions

Report prepared for the Climate Change Authority

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Executive Summary

This report explains changes in electricity consumption, emissions intensity of electricity supply and economy-wide emissions, since 2000 and since 2008, and identifies and quantifies their drivers

Trends in electricity consumption, emissions intensity of electricity supply and economy-wide emissions have changed significantly in recent years. Since 2008, electricity consumption in the National Electricity Market has slowed; electricity generation emissions intensity has declined after having been fairly stable; and economy-wide emissions have fallen rapidly (including land use and land-use change).

Electricity consumption

Growth in electricity consumption in Australia slowed after 2008[1] due to higher electricity prices and lower economic growth. Electricity consumption in Australia grew by a compound annual growth rate (CAGR) of just 0.2 per cent after 2008, in contrast to 1.9 per cent between 2000 and 2008.

- electricity prices rose by around 60 per cent between 2008 and 2011;
- real GDP growth slowed from 3.4 per cent per year between 2000 and 2008 to 2.1 per cent between 2008 and 2011. This was particularly pronounced in emissions-intensive sectors such as manufacturing, in which electricity consumption fell by a CAGR of 4 per cent between 2008 and 2011.

In comparison with the whole of Australia, the change of trend after the global financial crisis broke out was stronger in the National Electricity Market (NEM). NEM electricity consumption grew faster in the years leading up to the crisis, at nearly 2 per cent per year, and then declined afterwards, at -0.4 per cent per annum, trimming 1.7 per cent off total NEM consumption between 2008 and 2012. This contrasts with the growth in electricity consumption outside the NEM, specifically in Western Australia (WA) and Northern Territory (NT). Similar drivers of changes in electricity consumption are at work in WA and NT, but relatively higher growth, in particular in mining, has led to increases in electricity consumption since 2008. This compares with falling consumption since 2008 in the NEM.

The recent change in electricity consumption in the NEM was driven by falling activity in the manufacturing sector, offset by consumption increases in the residential and commercial and services sectors. The results for the sectors are as follows.

Manufacturing

Manufacturing electricity consumption in the NEM declined sharply (by 7.6 per cent from 2008 to 2011) due to slower growth and higher electricity prices:

[1] All dates refer to fiscal years such that the fiscal year 2007-08 is shown as 2008.

- reduced activity (measured by Gross Value Added) in the manufacturing sector was a contributory factor, falling by 6.5 per cent between 2008 and 2012;
- manufacturing has responded more strongly to rising electricity prices than residential or commercial and services, identified statistically by a higher electricity price elasticity, of -0.55 compared with -0.42 in commercial and services and a low elasticity of -0.14 for residential.

Trends in manufacturing electricity consumption continue to be influenced by the activity of electro-intensive industries and the degree of restructuring away from manufacturing towards services.

Residential
Residential electricity consumption grew by a CAGR of 1.5 per cent between 2008 and 2011.

Residential electricity consumption has been less responsive to electricity price increases since 2008 than before 2008. This implies that residential electricity consumption is higher than would be expected given current levels of spending.

Residential electricity consumption per capita was static between 2003 and 2012, suggesting that higher consumption is due to population growth rather than higher spending per capita.

Commercial and services
Electricity consumption in commercial and services grew by 4.3 per cent between 2008 and 2011, largely as a result of a growth in activity. Higher electricity prices mitigated approximately one third of the increased electricity consumption.

Emissions intensity of electricity supply

The emissions intensity of electricity in Australia is relatively high: approximately 6 per cent higher than in China and 60 per cent higher than in the US.[2]

The emissions intensity of electricity supply fell by 6.3 per cent (from 0.84 to 0.79 tCO_2e/MWh) from 2008 to 2011. Recent data for the NEM region indicates a further decline of the emissions intensity of electricity supply of 4.5 per cent between 2012 and 2013, the period in which carbon prices were introduced.

Gas-fired and renewable electricity generation were the major drivers of the reduction in emissions intensity between 2008 and 2011 and contributed 80 per cent of the decline. In this period:

- gas-fired generation increased from 14 per cent to 19 per cent of generation output; and
- renewables rose from 8 per cent to 10 per cent of generation output.

Improvements in the carbon intensity within fuel types contributed the remaining share of the reduction, whereas changes in fuel efficiency have had no statistically observed impact.

Electricity supply emissions intensity changes have been stimulated by policy. The Mandatory Renewable Energy Target (M-RET), which split into the Large and Small Scale Renewable Energy targets in 2011, is the major driver of increased renewables deployment. Other policies, such as the Queensland Gas Scheme and the New South Wales Greenhouse Gas Reduction Scheme, contributed to an increase in the share of gas-fired generation.

Solar PV has been supported by various state-wide solar feed-in-tariffs commencing in 2008, the Small Scale Renewable Energy Target and the accompanying solar feed-in-tariff, but made a minor contribution compared with wind. Solar PV constituted 0.6 per cent of generation output in 2012, up from 0.1 per cent in 2008. Wind contributed 2.4 per cent of generation output in 2011, up from 1.3 per cent in 2008. Solar PV generated less than a quarter as much output as wind in 2012.

Several sources suggest that gas prices will continue to rise in the future while coal prices are projected to be constant. This could mean that the costs of gas-fired generation, not including carbon prices, continue to be above the costs of coal-fired generation. Unless the carbon price mechanism tightens, to the disadvantage of coal and the advantage of gas, greater reliance may be placed on renewables as a contributor to improvements in the emissions intensity of electricity supply. Renewables themselves are currently supported by the LRET and SRET, and thus these policies, together with the carbon price mechanism, are the key determinants of future electricity emissions intensity.

[2] Compared with the average intensity of these countries between 2008 and 2010.

Economy-wide emissions

Economy-wide emissions including land use, land-use change and forestry (LULUCF) were virtually unchanged between 1990 and 2011 at around 560 $MtCO_2e$.

Changes in emissions from LULUCF, in particular forestry, offset emissions from economic growth in other parts of the economy between 2008 and 2011. LULUCF emissions fell while economy-wide emissions *excluding* LULUCF increased.

Emissions intensity continued to decline at a virtually unchanged rate of 1.9 per cent per year between 2000 and 2011, offsetting the effect of economic growth. The greatest driver of the decrease in emissions growth has been the improvement of emissions intensity within subsectors. This effect reduced emissions by approximately 80 $MtCO_2$ between 2000 and 2011. In addition, restructuring between sectors in the economy contributed a further 60 $MtCO_2$ reduction over this period.

However, since 2008, there has been a departure from these trends. Growth in emissions *excluding* LULUCF has slowed from 1.3 per cent per year between 2000 and 2008 to 0.1 per cent per year between 2008 and 2011. This was mainly due to electricity supply, which alone reduced economy-wide emissions excluding LULUCF by 1 per cent between 2008 and 2011. Lower economic growth after 2008 and higher emissions intensity in other economic sectors also contributed to the overall effect. A notable sector is mining, in which emissions grew between 2008 and 2011 due to increased activity and a higher emissions intensity.

Outlook

Electricity price and economic growth projections show that electricity consumption is likely to start increasing again but at a rate below the trend observed between 2000 and 2008.

Electricity generation emissions intensity changes are responsive to policy in the long run. The policy environment is important for long-term decisions such as power plant construction, which influences the share of gas generation and renewables, as well as the level of incentives for small scale generation such as solar PV, which makes a much smaller contribution.

Further decreases in economy-wide emissions intensity in the future, together with stable or declining levels of emissions, would be consistent with:

- continuing strong renewable incentives;
- further substitution of gas for coal, encouraged by a carbon price, despite projected gas price increases; and
- additional structural change in the economy away from emissions-intensive subsectors such as manufacturing and mining.

Economy-wide emissions depend to a large extent on emissions from electricity. With consumption growing at a slower rate and electricity emissions intensity falling, increased emissions from expanding activity in sectors such as mining can be partially offset. Land use, land-use change and forestry emissions have been the main driver of economy-wide emissions in recent years and their future role will be critical to the aggregate trend.

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1 Introduction

New work on electricity consumption, electricity generation emissions intensity and economy-wide emissions trends since 2008

Section contents:

Economic growth, electricity prices and policies in the electricity sectors changed markedly after 2008

The analysis decomposes changes in electricity consumption, electricity generation intensity and economy-wide emissions to identify the underlying drivers and quantifies their relative contribution. Further statistical analysis on electricity consumption identifies whether the trends between 2008 and 2012 are in line with the relationships before 2008. Electricity generation emissions intensity is decomposed into the contribution of gas fired electricity and renewables deployment, which is qualitatively attributed to market changes and policy. Economy-wide emissions are decomposed, identifying structural changes between sectors and subsectors, trends in emissions intensity and the offset underlying growth from the greater economic activity.

'Australia has experienced significant changes since 2008'

1.1 Background

Australia has experienced changes in electricity consumption, electricity generation emissions intensity and economy-wide emissions since 2008, which differ from the period between 2000 and 2008.

Electricity consumption in Australia and National Electricity Market (NEM) slowed since 2008 after a period of growth between 2000 and 2008, and while consumption in some subsectors continued to grow, in others it declined. At the same time, the emissions intensity of electricity generation declined rapidly after 2008, albeit from an internationally high level. Australia has internationally high electricity emissions intensity driven by its reliance on black and brown coal, which represented 83 per cent of the generation mix in 2000. However, its reliance on coal has been falling, reaching 69 per cent in 2012, being displaced by gas-fired generation and renewables. This share has fallen further since.

These figures are important because electricity contributes a large proportion of economy-wide emissions. Another important factor in the decline of economy-wide emissions is the change in land use, land-use change and forestry emissions.

1.2 Aims

The contribution of this work is to identify where these changes in electricity consumption, electricity generation emissions intensity and economy-wide emissions have occurred and what has driven the changes, in particular since 2008. While previous studies have focused on one or other aspect, the unique contribution of this work is that it considers the main drivers together.

Additional econometric analysis quantifies the contribution of electricity prices and economic growth to recent changes and evaluates what other factors might have driven trends in each sector.

Previous work by the Bureau of Resources and Energy Economics (BREE) has decomposed changes in energy use, which spans all energy use in the economy. This analysis looks more deeply at the electricity sector and places it alongside results for economy-wide emissions.

1.3 Approach

The statistical analysis requires a relatively long time series. This restricts the available datasets to the BREE for electricity consumption, for which the latest year available is 2012, and the National Greenhouse Gas Inventory for electricity generation and economy-wide emissions, for which data is available until 2011for emissions and 2012 for electricity consumption.

The work breaks new ground by analysing the official data provided by BREE, as this identifies contributions from individual sectors and subsectors. This offers insights which supplement the work presented in the Australia Electricity Market Operator (AEMO) National Electricity Forecast Report (NEFR). This is work at an aggregate level of electricity consumption from residential, commercial and services, and light industry, whereas this report separates out residential and shows how much it contributed.

1.3.1 Electricity consumption

Previous work left opportunities for further exploration of the drivers of electricity consumption trends. Reports by AEMO describe the evolution of sector consumption trends, which leads to questions about trends between and within sectors. Using BREE data, this analysis explores changes by sector and subsector and the drivers of these changes.

The analysis of electricity consumption first quantifies how economic growth, restructuring in the economy and electricity intensity of sectors have influenced electricity consumption in the NEM. It goes on to analyse residential, commercial and services, and manufacturing demand. In doing so, it reveals the effect of prices, economic growth and other potential drivers, and evaluates whether the trends since 2008 are in line with previous trends.

1.3.2 Electricity generation emissions intensity

The analysis of electricity generation highlights the contribution of changes in the fossil fuel mix and of increased renewables deployment. It also considers whether fossil fuel generation within each type has become less or more carbon-intensive over time.

Changes in two main areas, fossil fuel generation mix and renewables share, are then attributed to drivers. The contribution of the Queensland Gas Scheme and New South Wales Greenhouse Gas Reduction Scheme to changes in gas-fired electricity generation and capacity is explored. For renewables, the effect of the Mandatory Renewable Energy Target and its successors, the LRET and SRET, is found to be the principal driver of new renewable generation and capacity. The impact of the SRET and solar feed-in-tariffs on solar PV generation is also identified.

1.3.3 Economy-wide emissions

The next component of work establishes where changes in economy-wide emissions have occurred before and after 2008. The data allows the identification of sectors, such as manufacturing, and of subsectors within each main sector. This granularity allows contributions to be distinguished, for example, those of oil and gas exploration from those of iron ore mining and coal mining, whereas previous work grouped all these into a single category. This is important because subsectors differ in their contribution to the activity, structural and intensity effects which are driving changes.

The quantification of restructuring towards less emissions-intensive sectors, as well as changing emissions intensity within sectors, provides details on the trends in emissions excluding LULUCF, and explains where and why these emissions have risen more slowly since 2008.

1.4 The context for the results

This work covers some ground already explored by others, applies quite advanced statistics to open up answers to new questions, and tackles politically sensitive issues. In order to do this, it has to embrace the complexity of the electricity market and emissions trends, consider the merits of its results alongside the findings of previous work, and make the findings policy-relevant without going beyond the reach of the evidence.

The presentation of the work in this report is intended to be sufficiently transparent that expert readers can assess the reliability of the results and would be able to reproduce them. For those of a less technical background, the language chosen indicates the degree of reliance which can be placed on the results. In general, the statistical techniques have to work quite hard to produce answers from the data available, and so one can have confidence in the direction and general magnitude of effects which are reported without focusing in too much detail on precise numbers.

This work has drawn out evidence from BREE data using statistical tools to complement other sources of evidence, in particular from the NEM. The results corroborate the findings of the NEM work and allow new insights into some of the drivers of change, particularly changes in the structure of the economy. While the statistical methods may be able to identify the types and scale of changes that have happened, the causes or origins of these changes which lie in the market and policy environment cannot be determined statistically in most cases. Instead, descriptive evidence provides the narrative and here the nature of work is economic history rather than statistics.

The main effort in this work has been the statistical research. Thus, while those statistical results have been set in the context of an economic history, the reader who is interested in that history may be much more satisfied by reading the work of other authors referenced within this report. This is particularly important around the effects of market and policy changes, the changes in the structure of the Australian economy and the drivers of the rise of gas-fired and renewable generation. The analysis in this work stops in 2011 for electricity generation emissions intensity and economy-wide emissions, and in 2012 for electricity consumption, so those readers interested in the effect of the carbon price introduced in 2012 will also have to turn to other sources.

As in all statistical investigations, what comes out of the analysis depends on what goes into it. Here, the BREE data-set was selected because it makes possible the exploration of various questions which would not have been possible using NEM data. For this work, the more helpful structure of the BREE data was chosen above the potentially higher data quality of the NEM. This introduces some uncertainty around estimated values and challenges the analyst to make some decisions concerning the introduction of structural breaks and the adjustment of data values in the models. This introduces some subjectivity into the work about which experts may reasonably disagree.

1.5 Structure of the report

The report addresses electricity consumption in Section 2, electricity generation emissions intensity in Section 3 and economy-wide emissions in Section 4.

Section 5 concludes the analysis and summarises the main results.

Section 6 describes the methodology of decomposition and trend analysis.

Section 7 lists the data used in the analysis, which differs from data used in other studies such as the NEFR. The data has been collected solely from public sources, such as the Bureau of Resources and Energy Economics and the National Greenhouse Gas Inventory.

The Appendix contains further detailed results.

2 Electricity consumption in the National Electricity Market

Electricity consumption in the National Electricity Market has recently started to stabilise and fall after a period of growth

Section contents:

Lower economic growth and higher electricity prices reduced electricity consumption between 2008 and 2012

This section decomposes changes in electricity consumption in the NEM between 2000 and 2012. It investigates residential, commercial and services, and manufacturing consumption, which represent over 75 per cent of total consumption, and quantifies the contribution of prices, economic growth and weather. The data separates sectors in the decomposition and detailed analysis and includes off-grid generation and consumption. This leads to new estimates, such as that residential electricity consumption grew slightly between 2008 and 2012.

‘Residential electricity consumption did not respond as strongly to prices as expected.’

2.1 Regional and sectoral differences in consumption trends

This section describes how electricity consumption changed in Australia, on the grid of the NEM and within the three main electricity consuming sectors in the NEM: residential, commercial and services, and manufacturing.

2.1.1 The stabilisation of electricity consumption across Australia since 2009

Electricity consumption in Australia grew by 19 per cent in the dozen years from 2000 to 2012, which corresponds to a compound annualised growth rate (CAGR) of 1.5 per cent. Consumption rose steadily from 2000 to 2008 and then, coinciding with the global financial crisis, stabilised between 2009 and 2012. The data is shown in Table 1 and Figure 1.

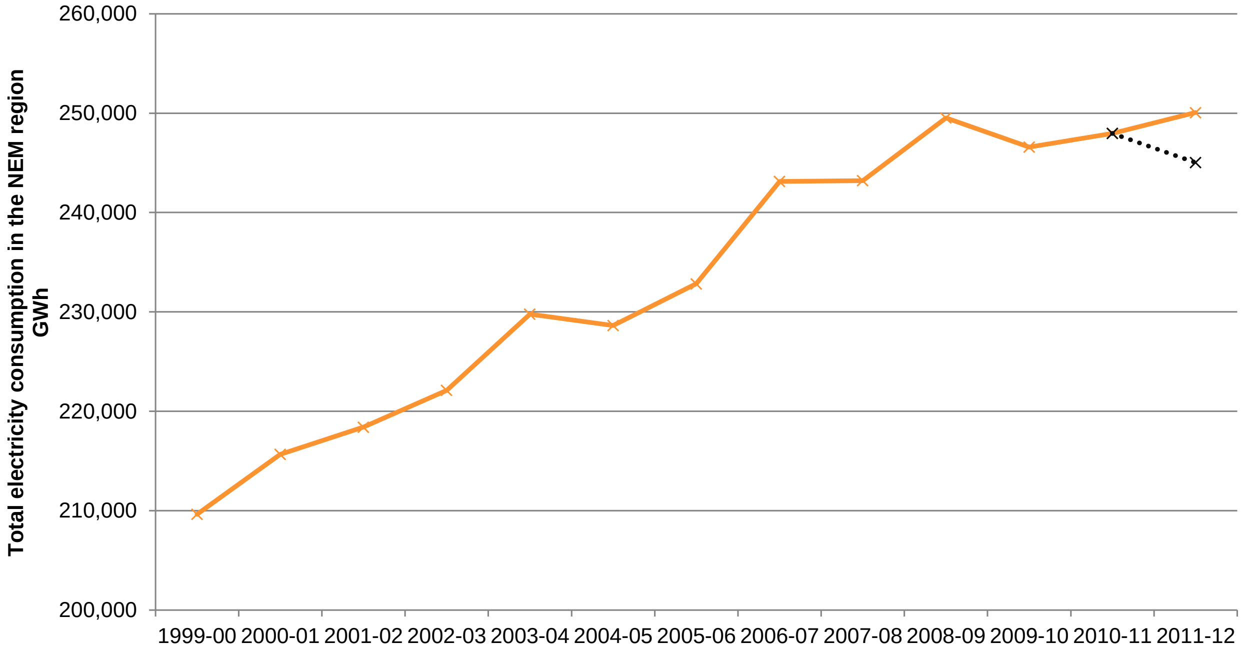
Table 1. **Growth in electricity consumption in Australia slowed to a stop after 2008**

Period	**Years**	**Compound annual growth rate (per cent)**	**Total growth over period (GWh / per cent)**
First period	2000 to 2008	1.9	33,600 / 16
Second period	2008 to 2012	0.2*	1,900* / 2.8*
Overall	**2000 to 2012**	**1.3***	**35,400* / 16.9***

Notes: *Compound annual growth rate (CAGR) is defined as the geometric mean that provides a constant rate of return over the time period and dampens the effect of volatility, which would bias an arithmetic mean. * If commercial and services sector electricity consumption in 2012 is not adjusted to reflect a consistent consumption pattern, the CAGR is 0.7 per cent in the second period and 1.5 overall*

Source: *Vivid Economics*

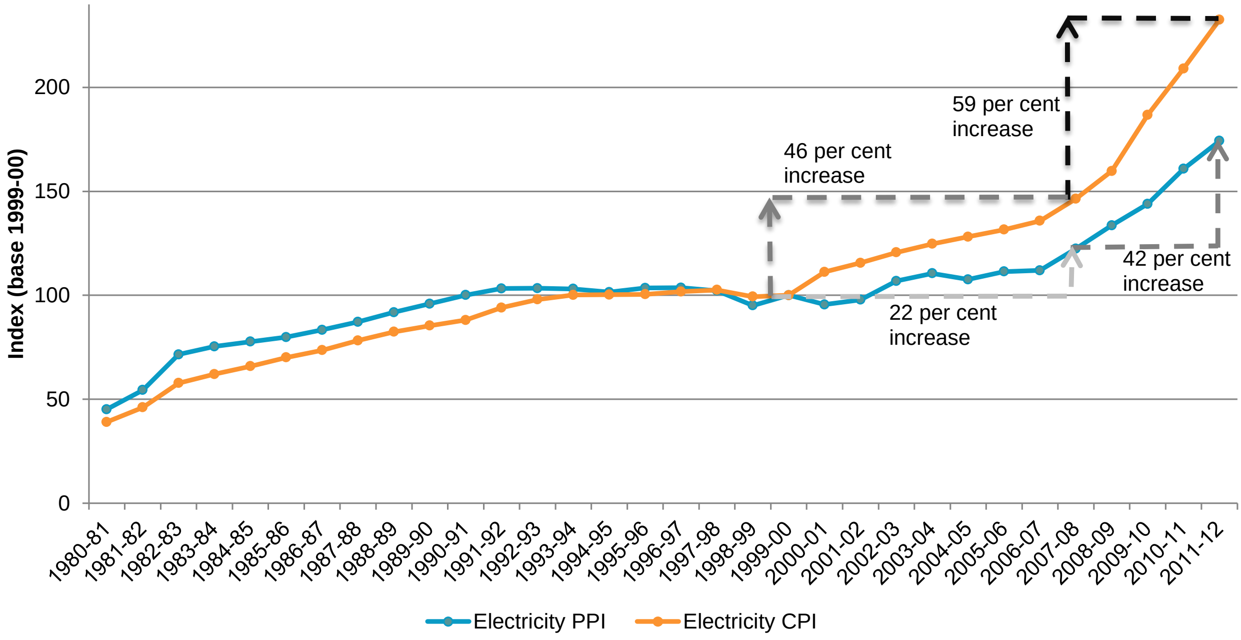
Figure 1. **Electricity consumption in Australia grew rapidly between 2000 and 2009 and slowed down between 2009 and 2012**



Notes: *The commercial and services sector electricity consumption in 2012 jumps up by 11.8 per cent compared with 2011, which is potentially an erroneous observation. The dotted line shows how Australian electricity consumption behaves if the final data point for commercial and services sector electricity consumption is adjusted using past trends.*

Source: *Vivid Economics based on Australian Government Bureau of Resource and Energy Economics (2013)*

Figure 2. **Between 2008 and 2012 producer electricity prices increased by 9.2 per cent per year while consumer electricity prices increased by 12.2 per cent per year**



Note: *Prices indexes are rebased to 2000 to highlight the recent increase.*

Source: *Vivid Economics based on Australian Bureau of Statistics (2013)*

2.1.2 The fall in electricity consumption in the NEM region since 2009

In contrast to the whole of Australia, the reversal of trend before and after the global financial crisis broke was stronger in the NEM region.[3] The NEM region's electricity consumption grew faster in the years leading up to the crisis, at nearly 2 per cent per annum. It fell back afterwards at -0.4 per cent per year, trimming 1.7 per cent off total consumption and leaving a cumulative rise in consumption of 15 per cent across the twelve year period between 2000 and 2012. All figures are based on adjusted data for commercial and services consumption in 2012.[4] The data is shown in Table 2 and Figure 3.

[3] The NEM consists of New South Wales, Queensland, Victoria, Tasmania and South Australia.

[4] Unadjusted figures result in a growth of 0.1 per cent per year, increasing total demand by 0.4 per cent and resulting in a cumulative rise of 17.5 per cent between 1999-00 and 2011-12.

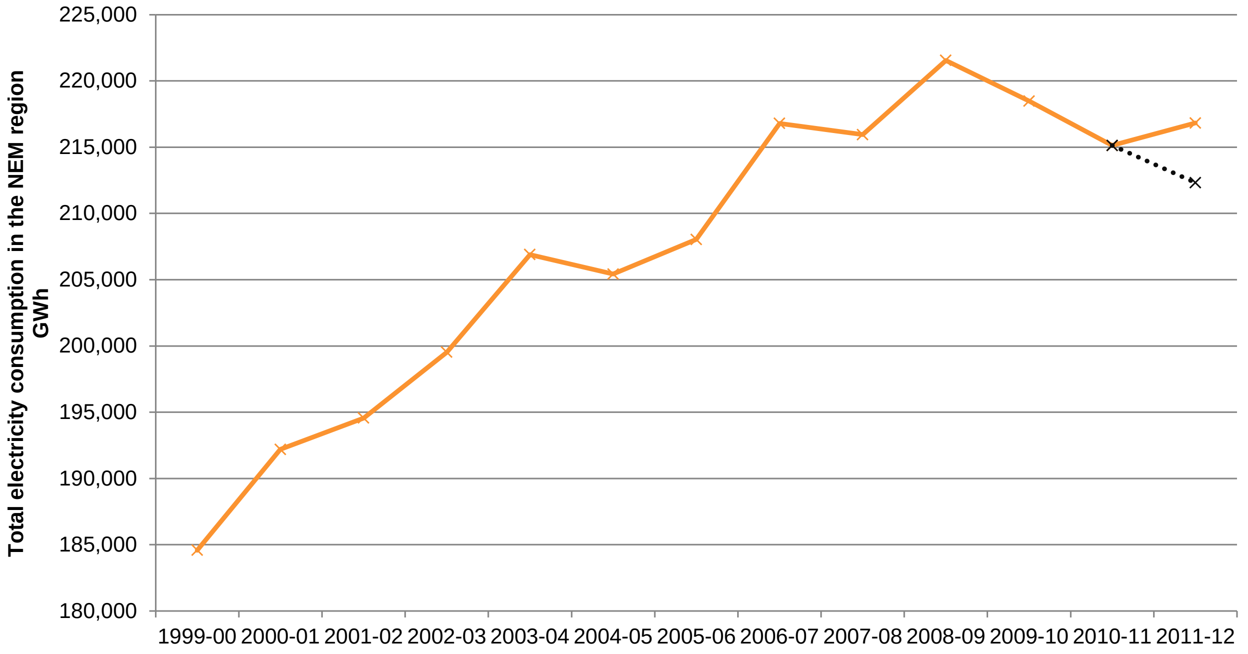
Table 2. **Growth in electricity consumption in the NEM region reversed after 2008**

Period	Years	Compound annual growth rate (per cent)
First period	2000 to 2008	2
Second period	2008 to 2012	-0.4*
Overall	**2000 to 2012**	**1.2***

Note: ** If commercial and services sector electricity consumption in 2012 is not adjusted to reflect a consistent consumption pattern, the CAGR in the second period is +0.1 per cent and the overall increase is 0.4 per cent.*

Source: *Vivid Economics*

Figure 3. **Total electricity consumption in the NEM fell after 2009**



Notes: *The commercial and services sector electricity consumption in 2012 jumps up by 11 per cent compared with 2011, which is potentially an erroneous observation. The dotted line shows how NEM electricity consumption behaves if commercial and services sector electricity consumption is adjusted to follow past patterns.*

Source: *Vivid Economics based on Australian Government Bureau of Resource and Energy Economics (2013)*

2.1.3 Consumption by sector

The focus of the discussion of sectoral electricity consumption is on three sectors:

– residential;

– commercial and services; and
– manufacturing.

These are the largest consumers of electricity in the NEM region, followed by utilities and mining, as shown in Table 3.

There was a redistribution of electricity consumption in the NEM region, between 2008 and 2012, from manufacturing to residential and commercial and services sectors. Over this period, the share of consumption attributable to manufacturing fell by 3.9 percentage points and was transferred to commercial and services and residential.

Table 3. **The share of electricity consumed by manufacturing declined between 2008 and 2012 whereas the share of commercial and services consumption grew in the same period**

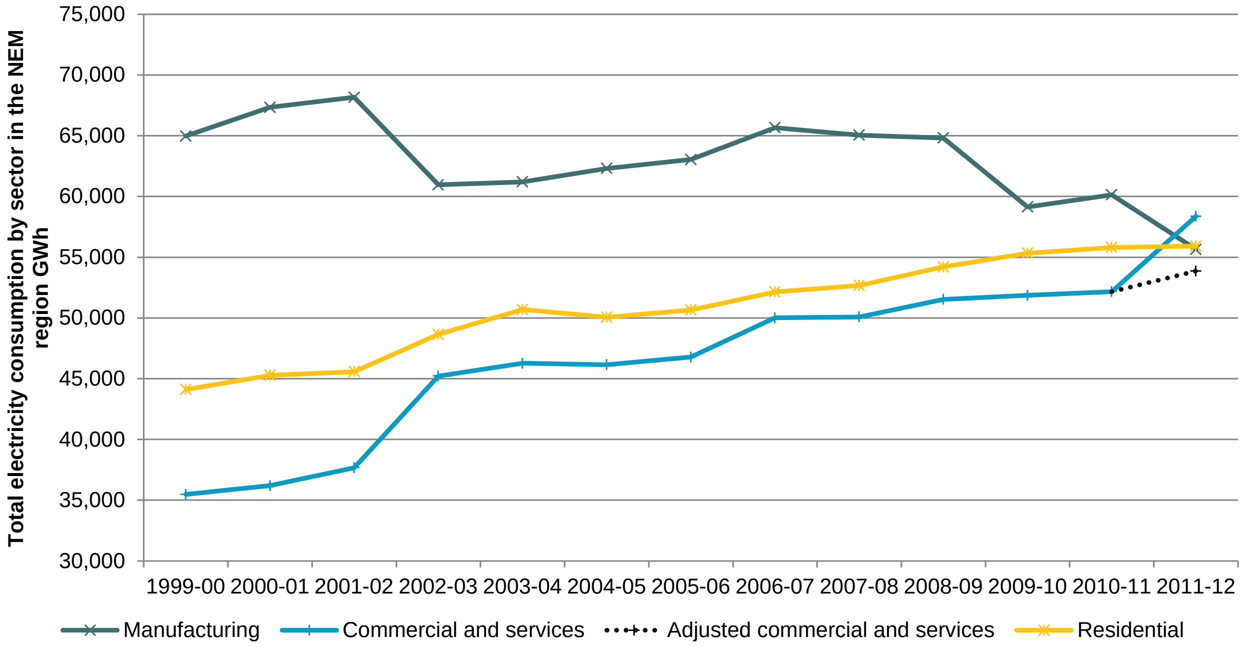
Sector	Share of electricity consumption (per cent)	
	2008	2012*
Div. A Agriculture, forestry and fishing	1	1
Div. B Mining	5	6
Div. C Manufacturing	30	26
Div. D Electricity, gas, water & waste services	14	14
Div. E Construction	0	0
Div. I Transport & storage	2	2
Commercial and services	23	25*
Residential	24	26
Total	**100**	**100**

Notes: *2012 data is adjusted by using an estimated figure for commercial and services sector consumption that reflects the same sector use intensity (consumption GWh/real GVA) as in the year 2011. * indicates adjusted figure for commercial and services consumption in 2012 was used.*

Source: *Vivid Economics based on Australian Government Bureau of Resource and Energy Economics (2013)*

Notwithstanding a change in data definitions in 2003, see Figure 4, manufacturing consumption rose in the years preceding 2007, then, after a brief levelling off, started falling sharply from 2010. It fell by a CAGR of 4 per cent over the period 2008–2012, while residential and adjusted commercial and services consumption grew steadily at rates of 1.5 and 1.8 per cent respectively over the same period, see Table 4.

Figure 4. **Electricity consumption has been falling in the manufacturing sector whereas it has been increasing in the residential and commercial and services sectors, NEM region**



Notes: *In 2003, a sectoral redefinition placed some subsectors of manufacturing into commerce and services. The dotted line for commercial and services electricity consumption shows adjusted data.*

Source: *Vivid Economics based on Australian Government Bureau of Resource and Energy Economics (2013)*

Table 4. **Electricity consumption fell after 2008 in agriculture, manufacturing, utilities and transport, NEM region**

Sector	**CAGR of electricity consumption (per cent)** First period 2003 to 2008	Second period 2008 to 2012	Whole period 2004 to 2012
Div. A Agriculture, forestry and fishing	-0.3	-3.3	-2.5
Div. B Mining	3.0	1.3	2.3
Div. C Manufacturing	1.3	-4.0	-1.1
Div. D Electricity, gas, water & waste services	0.9	-1.5	-0.2
Div. E Construction	0.1	8.9	4.0
Div. I Transport & storage	2.8	-2.1	0.6
Commercial and services	2.1	3.9 [1.8*]	2.9 [2.0*]
Residential	1.6	1.5	1.6
Total	**2.0**	**0.1 [-0.4*]**	**1.4 [1.2*]**

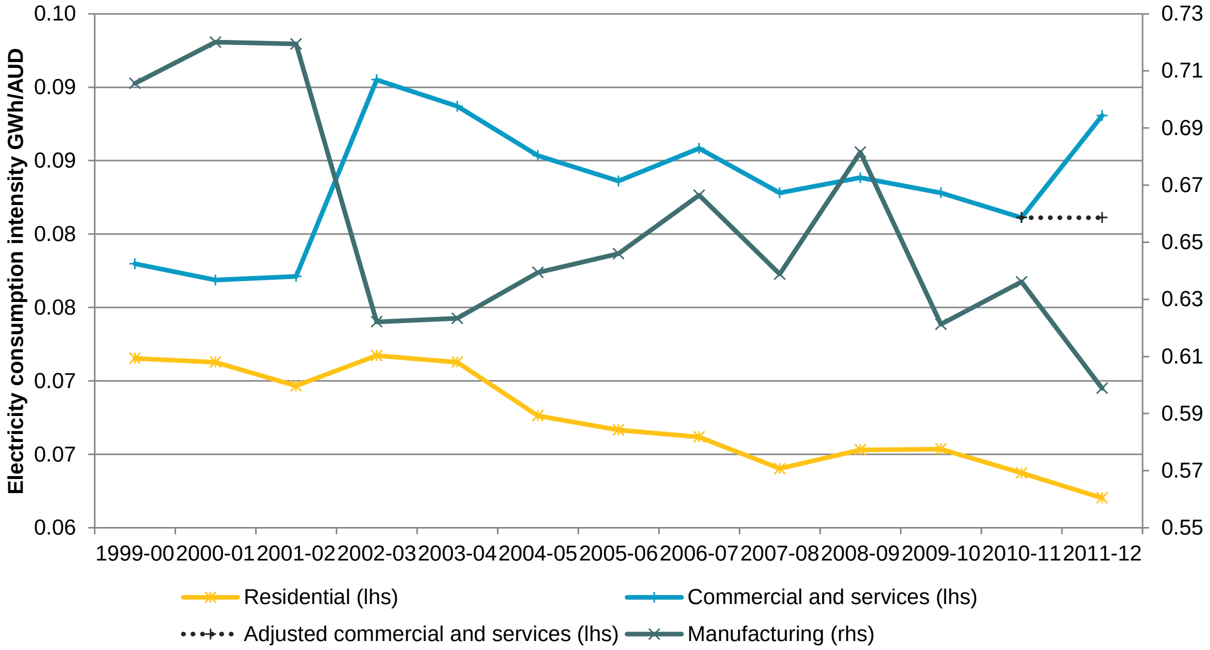
Notes: *CAGR is the compound annualised growth rate. * indicates that the adjusted figure for commercial and services consumption in 2012 was used.*

Source: *Vivid Economics based on Australian Government Bureau of Resource and Energy Economics (2013)*

The electricity intensity of sectors is defined as the ratio of electricity use per unit of output and varies according to structural change in the sector between more and less electro-intensive sectors and the electricity intensity of specific subsectors.

Electricity intensity decreased in the residential, commercial and services and manufacturing sectors from 2008 to 2012, as shown in Figure 5. Commercial and services consumption intensity appears to increase abruptly in 2012, hence the proposed data adjustment, whereas it declined by 10 per cent over the period 2003 to 2011. This is the largest improvement in intensity of the three sectors. Manufacturing intensity declined by 3.7 per cent over the period 2003 to 2012, but more recently has been improving faster than commercial and services, declining by 6.3 per cent against 2 per cent in commercial and services (excluding the last year). Residential intensity fell by 3.0 per cent over the same period, on a steady trend.

Figure 5. **Electricity intensity, use per unit of GVA fell fastest in manufacturing in recent years, while commercial and services and residential exhibit similar, lower rates of improvement**



Notes: *Manufacturing represented by the right-hand axis. Intensity is measured as electricity consumption in GWh divided by chain volume measured GVA for both manufacturing and commercial sectors and as electricity consumption divided by chain volume measured final consumption expenditure for residential. The change in 2003 is due to a redefinition of sectors between manufacturing and commercial and services.*

Source: *Vivid Economics based on Australian Government Bureau of Resource and Energy Economics (2013) and Australian Bureau of Statistics (2013)*

Table 5. **Electricity intensity in the NEM fell more in manufacturing than in commercial and services**

Sector	Electricity consumption per unit of GVA or income		
	First period	Second period	Whole period
	2003	2008	2012
Div. C Manufacturing	0.622	0.638	0.599
Commercial and services	0.093	0.085	0.090 [0.083*]
Residential	0.073	0.066	0.064

Note: * indicates that the adjusted figure for Commercial and services consumption in 2012 was used.

Source: Vivid Economics based on Australian Government Bureau of Resource and Energy Economics (2013) and Australian Bureau of Statistics (2013)

2.2 Description of decomposition analysis

The first part of this section explains the trends in electricity consumption in terms of the factors driving them, which are economic activity, changes in shares of activity across sectors and changes in the electricity intensity of each sector.

2.2.1 The components which drive trends in electricity consumption

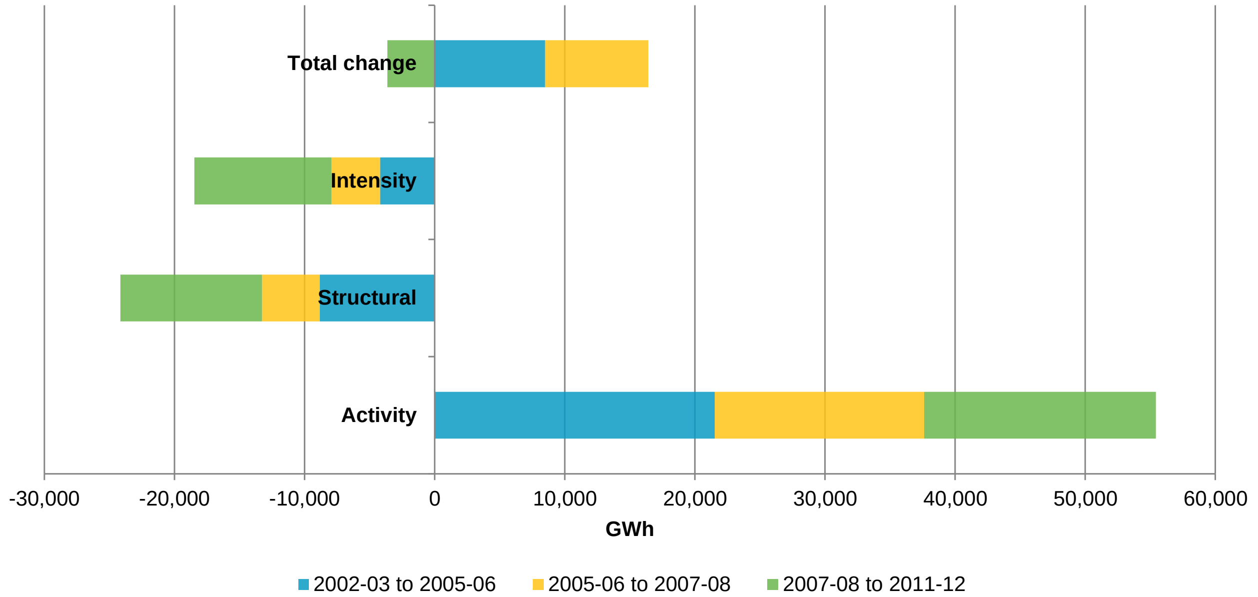
The statistical technique used for decomposition, Log Mean Divisia Index (LMDI), decomposes trends in electricity consumption into the three effects:

- **activity effect** (ΔE_{act}): the change in total electricity consumption due to changes in aggregate economic activity;
- **structural effect** (ΔE_{str}): the change in total electricity consumption due to changing shares of total economic activity between sectors;
- **intensity effect** (ΔE_{int}): the change in total electricity consumption due to changing energy intensity within sectors.

2.2.2 Headline results

The activity effect is the main driver of electricity consumption in the NEM between 2003 and 2012. The activity effect drives up electricity consumption. Both, the structural effect and the intensity effect offset parts of the activity effect in the first two periods (2003 to 2006 and 2006 to 2008), though they are weakest in the second period. The intensity and structural effects are greatest in the third period (2008 and 2012), and more than offset the activity effect in that period, see Figure 6 and Figure 7.

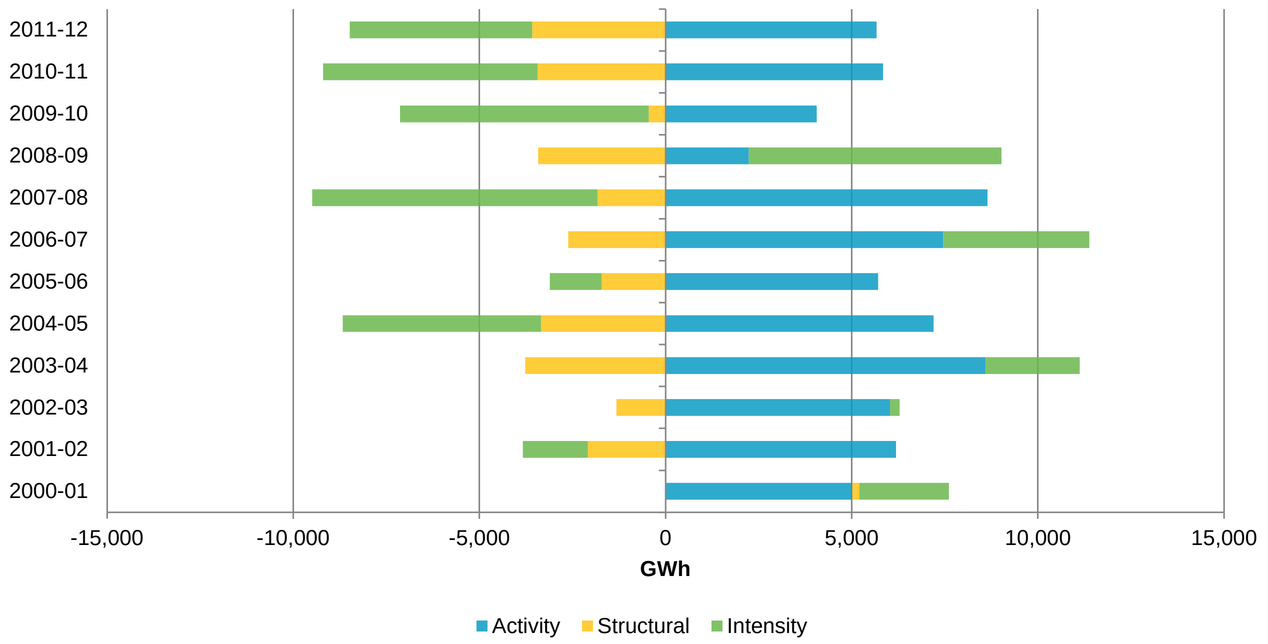
Figure 6. **The NEM region restructured towards less electro-intensive sectors and the sectors themselves became less electro-intensive, while the economy grew**



Notes: *LMDI decomposition of growth of electricity consumption in the NEM region between 2003 and 2011-2012. Chain volume measure of sectoral GVA and income were used. Adjusted data is used for Commercial and services sector in 2012.*

Source: *Vivid Economics based on Australian Government Bureau of Resource and Energy Economics (2013) and Australian Bureau of Statistics (2013)*

Figure 7. **Between 2010 and 2012, sectors became unanimously less electro-intensive**



Note: *LMDI decomposition of growth of electricity consumption in the NEM region between 2003 and 2011-2012. Chain volume measure of sectoral GVA and income were used. Adjusted data is used for Commercial and services sector in 2012.*

Source: *Vivid Economics based on Australian Government Bureau of Resource and Energy Economics (2013) and Australian Bureau of Statistics (2013)*

The total increase in electricity consumption between 2003 and 2012 was 6.4 per cent. Activity increased by 28 per cent, but the intensity effect offset one third of this figure and the structural effect a further 44 per cent. In total, three quarters of the increase in economic activity was offset by changes in the way electricity is used within the economy.

The structural effect has made a large contribution towards attenuating electricity consumption. It reduced consumption by -11,000 GWh in the period 2008 to 2012 and by -24,000 GWh in the period 2003 to 2012. In the period 2008 to 2012, a 5 per cent decrease in electricity consumption is the result of economic activity moving away from relatively high electricity intensive sectors. The contribution was 12 per cent over the whole period.

Almost equally important in abating consumption is improvement in intensity of use. It reduced consumption by 10,500 GWh in the period 2008 to 2012 and by -18,500 GWh in the period 2003 to 2012. In the last period a further 4.9 per cent of consumption was avoided through a more efficient use of electricity within broad sectors. The intensity improvement resulted in a reduction of 9.3 per cent over the whole period from 2003.

Although the restructuring of the economy between broad sectors is important in determining changes in electricity consumption over time, there is further restructuring *within* these broad sectors which is captured within the intensity effect. The intensity effect is itself a composite of subsectoral restructuring and improvements in electricity efficiency. Thus it is likely that restructuring as a whole, both at broad sector and subsector level, has played the most important role in mitigating electricity consumption as the economy has grown. All effects are summarised in Table 6.

Table 6. **Structural shifts between sectors have been more important in offsetting the effects of growth than within-sector changes in intensity**

		First period	Second period	Third period	Whole period
Effect	**Units**	**2003 to 2006**	**2006 to 2008**	**2008 to 2012**	**2003 to 2012**
Activity	GWh/yr	22,000	16,000	18,000 (18,000*)	55,000 (55,000*)
	change over period, %	10.8	7.7	8.3 (8.2*)	27.8 (27.8*)
Structural	GWh/yr	-8,800	-4,400	-11,000 (-11,000*)	-24,000 (-24,000*)
	change over period, %	-4.4	-2.1	-5.0 (-5.0*)	-12.1 (-12.1*)
Intensity	GWh/yr	-4,200	-3,700	-6,000 (-11,000*)	-14,000 (-18,000*)
	change over period, %	-2.1	-1.8	-2.8 (-4.9*)	-7.1 (-9.3*)
Total	GWh/yr	8,500	7,900	870 (-3,600*)	17,000 (13,000*)
	change over period, %	4.3	3.8	0.4 (-1.7*)	8.7 (6.4*)

Notes: *Effects derived from LMDI decomposition of electricity consumption using chain volume GVA/income. The chain volume measure was chosen because it recovers true electricity use intensity as a quantity measure. Nominal GVA would be biased by general inflation and deflated nominal GVA is susceptible to changes in relative prices. Deflated GVA and income will lead to a greater estimated reduction in intensity over this period, due to falling prices in manufacturing, where most of the intensity gain was achieved. (*) indicates adjusted figure for commercial and services consumption in 2012 was used.*

Source: *Vivid Economics based on Australian Government Bureau of Resource and Energy Economics (2012) and Australian Bureau of Statistics (2013)*

The intensity change is most prominent in the period 2008 to 2012. Adjusted figures show a 4.9 per cent fall in electricity consumption, equivalent to 11,000 GWh, in the period 2008 to 2012.

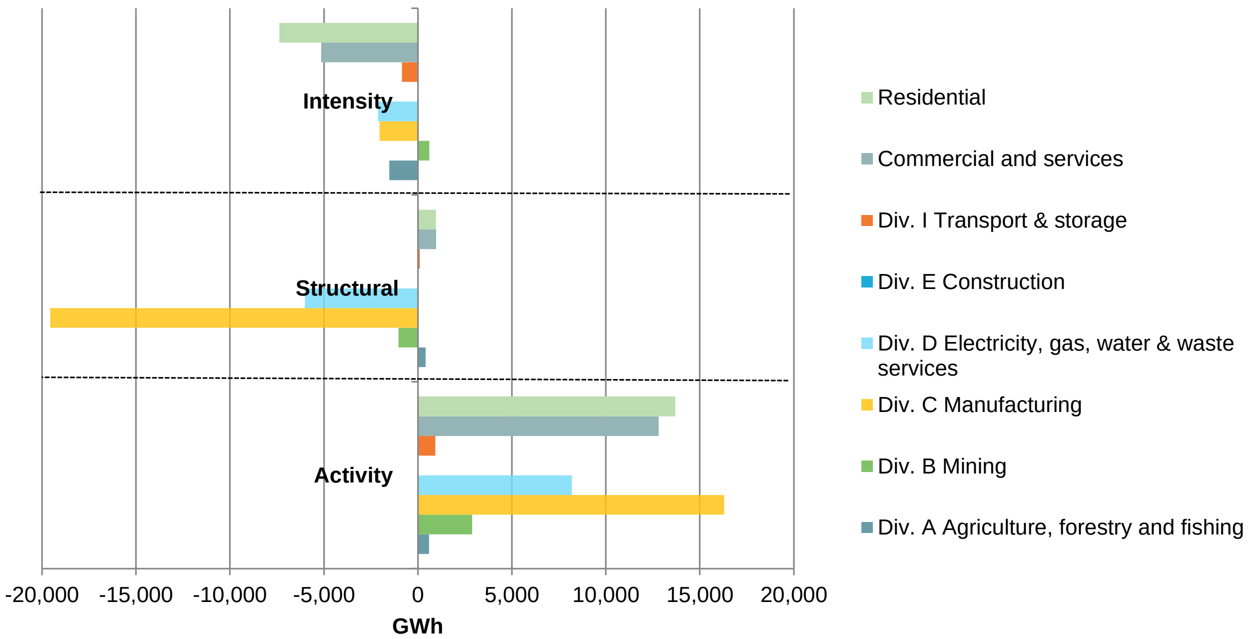
2.2.3 Detailed decomposition analysis by sector

In the whole period 2003 to 2012, the structural effect was mainly caused by shrinking manufacturing and utilities sectors. Their relative structural contributions are -20,000 GWh (10 per cent) and -6,000 GWh (3 per cent). They are visible in the left-pointing yellow and light blue bars in the middle section of the chart, Figure 8. The bars which point to the left show a reduction in electricity consumption. Residential and commercial sectors grew, making small additions to consumption, pointing to the right in the chart. This is a complex chart, so it will also be shown in three expanded parts, following below.

The intensity effect, in the top section of Figure 8, was negative for most sectors because of substantial gains in energy productivity. Over the entire period, residential and commercial had the largest effects of 7,400 GWh (3.7 per cent) and 5,100 GWh (2.6 per cent) respectively. These effects are partially related to energy efficiency measures, which are not quantified in this work, and increased electricity prices.

The activity effect, the bottom part of Figure 8, reflects growth in the economy with sectoral contributions directly proportional to their consumption intensity. Over the period there was strong growth in manufacturing, residential, commercial and services and utilities.

Figure 8. **The greatest contributions to changes between 2003 and 2012 come from the manufacturing and residential sectors in the NEM**

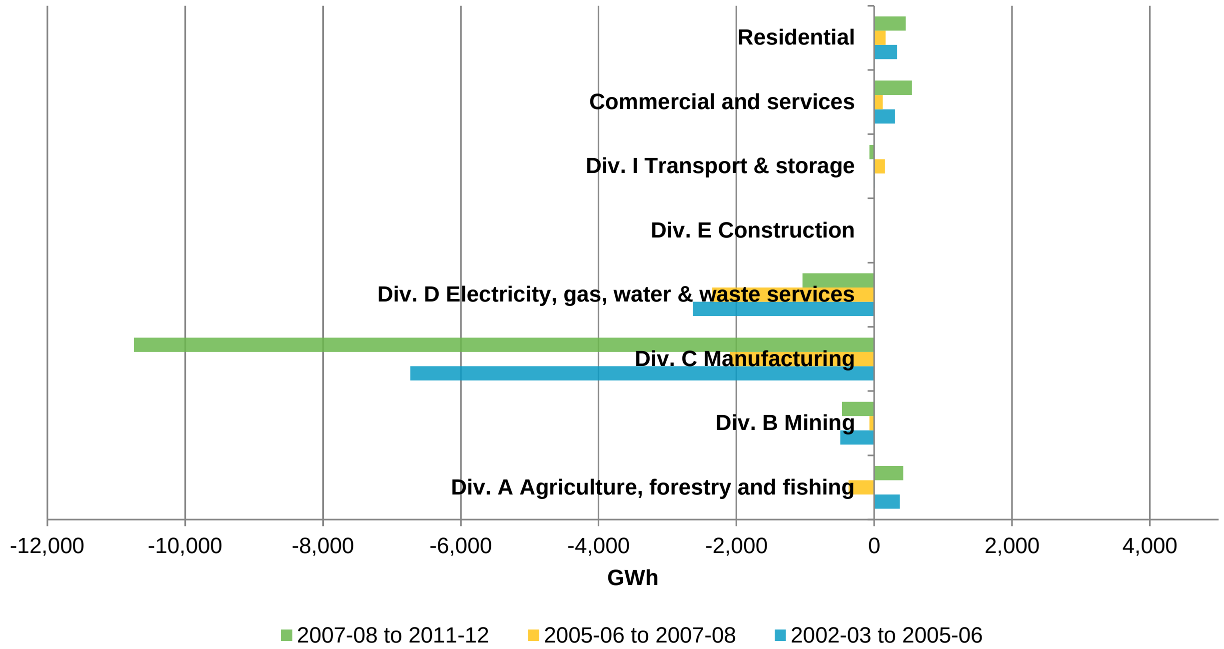


Notes: *LMDI decomposition of the change in electricity consumption in the NEM region between 2003 and 2012 into activity, structural and intensity effects. Activity is measured by GVA (income for residential); intensity is defined as electricity consumption per 1 AUD of activity (GWh/AUD). Sectors are as defined per 2006 ANZSIC.*

Source: *Vivid Economics based on Australian Government Bureau of Resource and Energy Economics (2013) and Australian Bureau of Statistics (2013)*

Manufacturing declined for the entire period 2003 to 2012 and utilities have followed manufacturing's lead. Manufacturing's shrinking share in the NEM region economy in the period 2008 to 2012 led to a reduction of 11,000 GWh in electricity consumption, see Figure 9 and Figure 10.

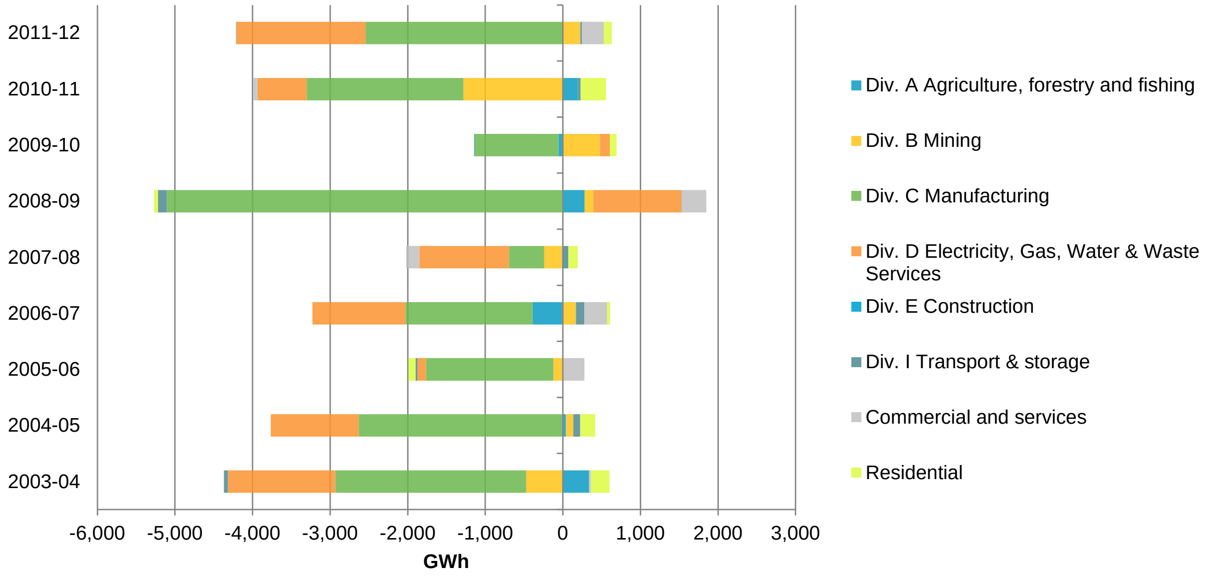
Figure 9. **Structural effect is driven by shrinking share of manufacturing output in overall economic activity**



Notes: *Structural effect contribution to electricity consumption growth in the NEM region. Sectors are as defined by 2006 ANZSIC.*

Source: *Vivid Economics based on Australian Government Bureau of Resource and Energy Economics (2013) and Australian Bureau of Statistics (2013)*

Figure 10. **Restructuring away from manufacturing to less electro-intensive sectors has been a continuous process since 2004**



Note: *Structural effect yearly contribution to electricity consumption growth in the NEM region. Sectors are as defined by 2006 ANZSIC.*

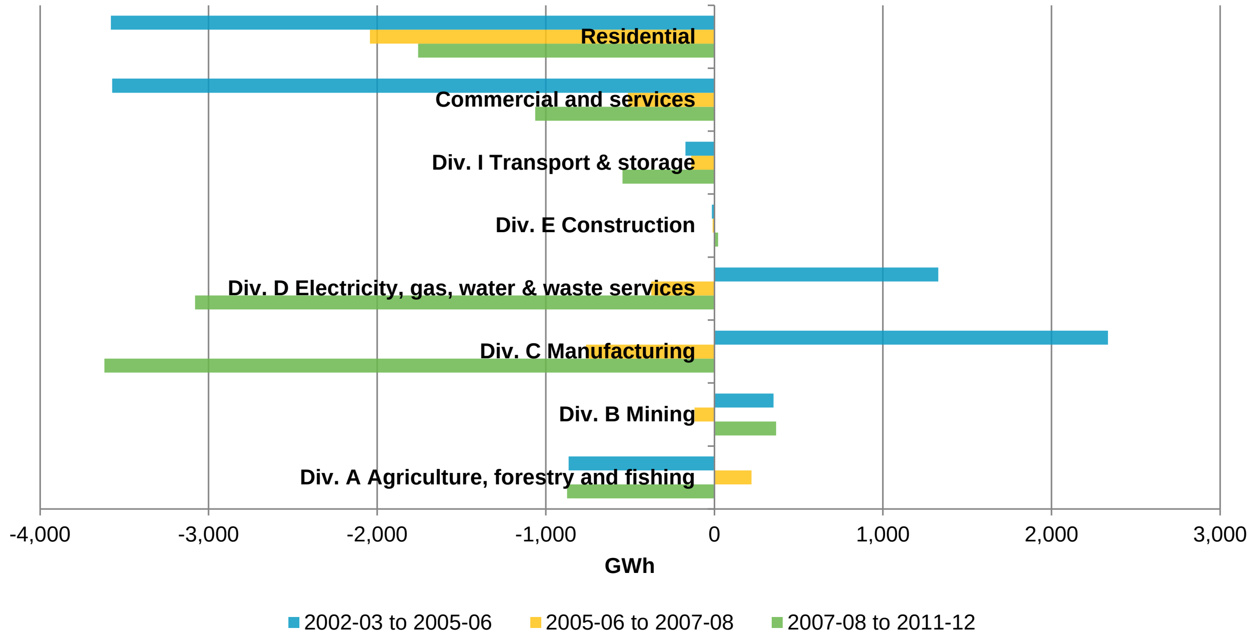
Source: *Vivid Economics based on Australian Government Bureau of Resource and Energy Economics (2013) and Australian Bureau of Statistics (2013)*

Most of the intensity gains in manufacturing happened in the period 2008 to 2012 as shown in Figure 11 and Figure 12. Electricity saving from less intensive use in manufacturing in this period was 4,000 GWh, which is a decrease of 1.7 per cent on 2008 aggregate electricity consumption. Shortly before, in 2003 to 2006, intensity had been increasing, raising aggregate consumption by 1,600 GWh. As before, utilities followed suit, with 3,000 GWh, 1.4 per cent, reduction in consumption in the period 2008 to 2012 and an increase of 1,000 GWh in the previous period.

Residential and commercial and services exhibit a more even reduction in intensity over the entire period, while agriculture still makes a significant contribution despite its low electricity intensity. In the period 2008 to 2012, agriculture improvements in intensity led to a 0.4 per cent saving in aggregate electricity consumption.

Finally, in the period 2008 to 2012, a net reduction in electricity consumption of 1.7 per cent is made up of reductions of 4.4 per cent in manufacturing and 0.7 per cent in utilities, and increases of 1.5 per cent and 1.7 per cent in the commercial and services and residential sectors respectively. The manufacturing figure is made up of positive activity effect amounting to 2.3 per cent, a negative structural effect of 5 per cent (it did not grow as fast as other sectors) and a negative intensity effect of 1.7 per cent. The residential figure is made up of 2 per cent in activity effect (household incomes rose), 0.2 per cent in structural effect (residential economic share remained unchanged) and -0.8 per cent in intensity effect. The commercial figure is made up of 2 per cent in activity effect (output grow modestly), 0.3 per cent in structural effect (it retained its economic share) and -0.5 in intensity effect.

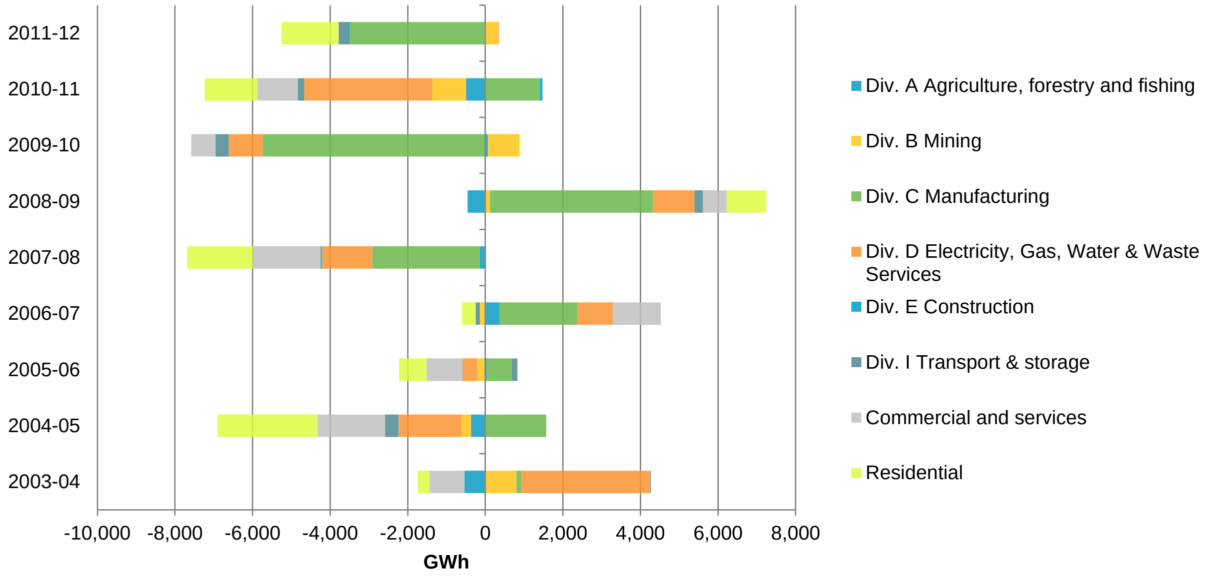
Figure 11. **Manufacturing and utilities had the largest intensity reduction in the period 2008 to 2012**



Notes: *Intensity effect contribution to electricity consumption growth in the NEM region. Sectors are as defined by 2006 ANZSIC.*

Source: *Vivid Economics based on Australian Government Bureau of Resource and Energy Economics (2013) and Australian Bureau of Statistics (2013)*

Figure 12. **The global financial crisis affected electro-intensity in 2009**

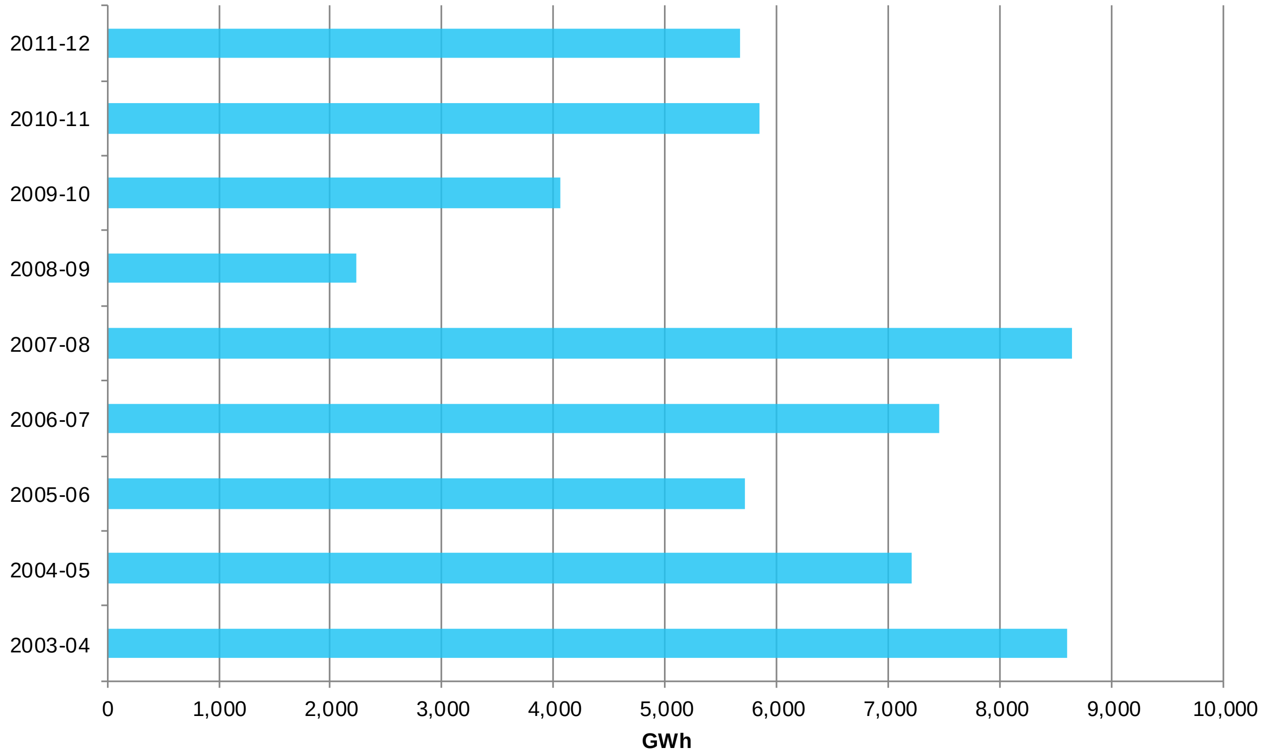


Note: *Intensity effect yearly contribution to electricity consumption growth in the NEM region. Sectors are as defined by 2006 ANZSIC.*

Source: *Vivid Economics based on Australian Government Bureau of Resource and Energy Economics (2013) and Australian Bureau of Statistics (2013)*

Part of the intensity effect in 2009 is explained by a decline in value added in that year. Correspondingly, the activity effect, which measures how changes in aggregate economic activity influence electricity consumption, was lower between 2009 and 2012 than in the years before, as shown in Figure 13. The small increase in economic activity was more than compensated for by restructuring away from electro-intensive sectors and by general decreased electricity intensity.

Figure 13. **Lower economic activity between 2009 and 2012 contributed to a decrease in NEM-wide electricity consumption**



Note: *The activity effect is computed for the aggregate of all economic sectors.*

Source: *Vivid Economics based on Australian Government Bureau of Resource and Energy Economics (2013) and Australian Bureau of Statistics (2013)*

Table 7 and Table 8 summarise the intensity and structural effects for the four main sectors: manufacturing, utilities, commercial and services, and residential.

Table 7. **The structural effect in four main sectors**

Structural effect		First period	Second period	Third period	Whole period
Sector	**Units**	**2003 to 2006**	**2006 to 2008**	**2008 to 2012**	**2003 to 2012**
Manufacturing	GWh/yr	-6,732	-2,095	-10,744	-19,571
	change over period, %	-3.37	-1.01	-4.98	-9.81
Utilities	GWh/yr	-2,629	-2,351	-1,041	-6,021
	change over period, %	-1.32	-1.13	-0.48	-3.02
Commercial and services	GWh/yr	304	123	547*	974*
	change over period, %	0.15	0.06	0.25*	0.49*
Residential	GWh/yr	335	164	457	956
	change over period, %	0.17	0.08	0.21	0.48

Notes: *Structural shares are measured by GVA (Income for Residential). Sectors are as defined by 2006 ANZSIC. * indicates that the adjusted figure for Commercial and services consumption in 2012 was used.*

Source: *Vivid Economics based on Australian Government Bureau of Resource and Energy Economics (2012) and Australian Bureau of Statistics (2013)*

Table 8. **Intensity effect in four main sectors**

Intensity effect		First period	Second period	Third period	Whole period
Sector	**Units**	**2003 to 2006**	**2006 to 2008**	**2008 to 2012**	**2003 to 2012**
Manufacturing	GWh/yr	2,335	-762	-3,619	-2,046
	change over period, %	1.17	-0.37	-1.6	-1.03
Utilities	GWh/yr	1,328	-374	-3,081	-2,127
	change over period, %	0.67	-0.18%	-1.43	-1.07
Commercial and services	GWh/yr	-3,573	-513	-1,063*	-5,149*
	change over period, %	-1.79	-0.25	-0.49*	-2.58*
Residential	GWh/yr	-3,580	-2,043	-1,757	-7,380
	change over period, %	-1.79	-0.98	-0.81	-3.7

Notes: *Structural shares are measured by GVA (Income for Residential). Sectors are as defined by 2006 ANZSIC. * indicates that the adjusted figure for Commercial and services consumption in 2012 was used.*

Source: *Vivid Economics based on Australian Government Bureau of Resource and Energy Economics (2012) and Australian Bureau of Statistics (2013)*

2.3 Trends in electricity consumption

Further analysis of residential, commercial and manufacturing electricity consumption aims to:

- shed light on the underlying drivers;
- investigate whether the relationship between the drivers and electricity consumption has changed; and
- distinguish whether the observed trends are short or long term.

2.3.1 Method

For each sector, an Autoregressive Distributed Lag (ADL) model is estimated to identify the main drivers. ADL models have been used in other studies for the same purpose (Madlener, Bernstein, & Gonzalez, 2011).

The methodology differs from the National Electricity Forecasting Report (NEFR) published by the Australian Electricity Market Operator (AEMO). The 2013 NEFR report uses dynamic Ordinary Least Squares (OLS) to identify the contribution of income and electricity prices on electricity consumption. The difference between the methodologies is that the ADL model estimates short and long run coefficient in a single step. More detail on the methodology comparison is provided in Section 6.

The drivers of interest are electricity prices, income, weather and value added. The effect of technology cannot be estimated beyond a general time trend, which might contain other non-technology effects. A detailed analysis of various policies cannot be undertaken since data is not available and, at the aggregate level, the effect of individual policies would be comingled.

The estimation is undertaken for both the NEM region as well as all of Australia since data going back further into the past is available for Australia, offering more accurate estimates. The estimates are combined to arrive at a realistic range of the relationship between drivers and electricity consumption.

For each model, specification tests are carried out to check their robustness. The details of the tests are explained in Section 6 and the model results are shown in the appendix.

The observed trends since 2008 are compared with forecasts to evaluate whether the relationship between the variable of interest and the identified drivers has changed. The forecasts are obtained by estimating the drivers and their coefficients from the beginning of the sample, 1972 for Australia and 1990 for NEM, until 2007, producing forecasts using observed values of the drivers between 2008 and 2012. Details of the methodology are explained in Section 6.

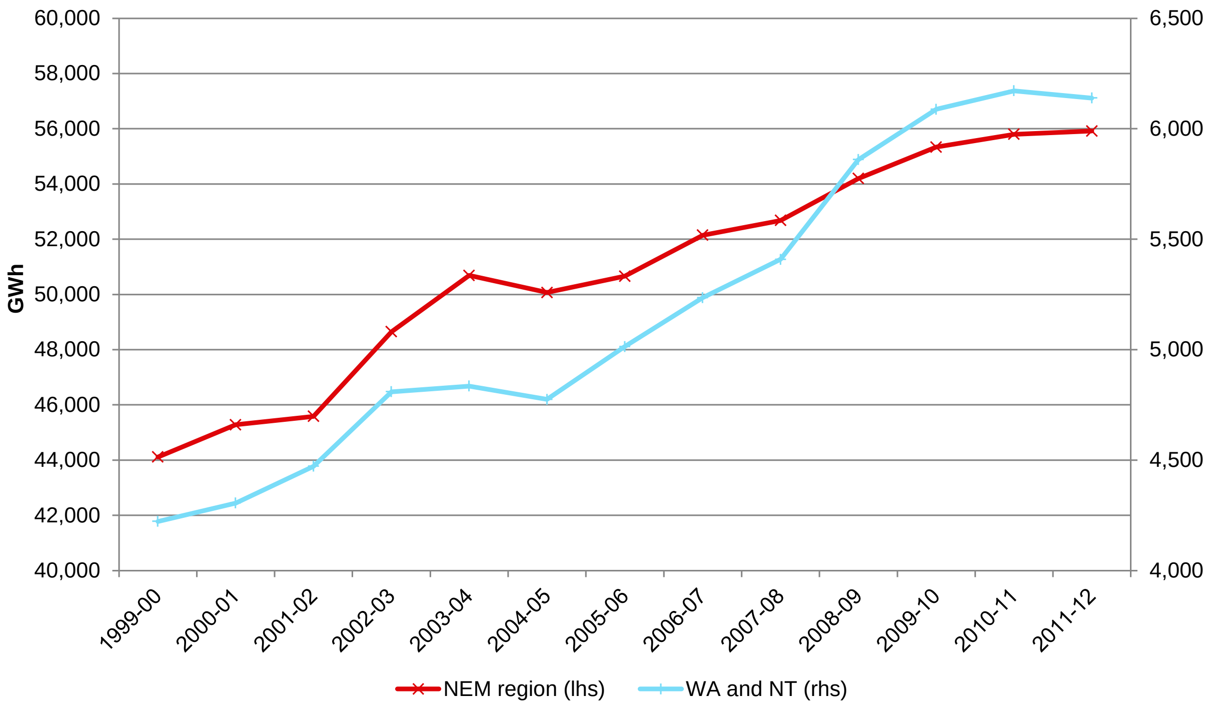
To investigate whether the effect of the drivers changed between 2008 and 2012, several forecasts are produced. For each, residential, commercial and services, and manufacturing consumption there is a central forecast. Central forecasts include all drivers and their observed values since 2008. In addition, forecasts are produced after turning off the effect of individual drivers. These forecasts show whether a driver has influenced the variable of interest more or less than expected recently based on its previous relationship. The methodology is explained in Section 6.

2.3.2 Residential

Residential electricity consumption grew more slowly between 2008 and 2012 in the NEM than from 2000 to 2008. The growth rate slowed slightly from a CAGR of 1.6 per cent between 2003 and 2008 to 1.5 per cent between 2008 and 2012.

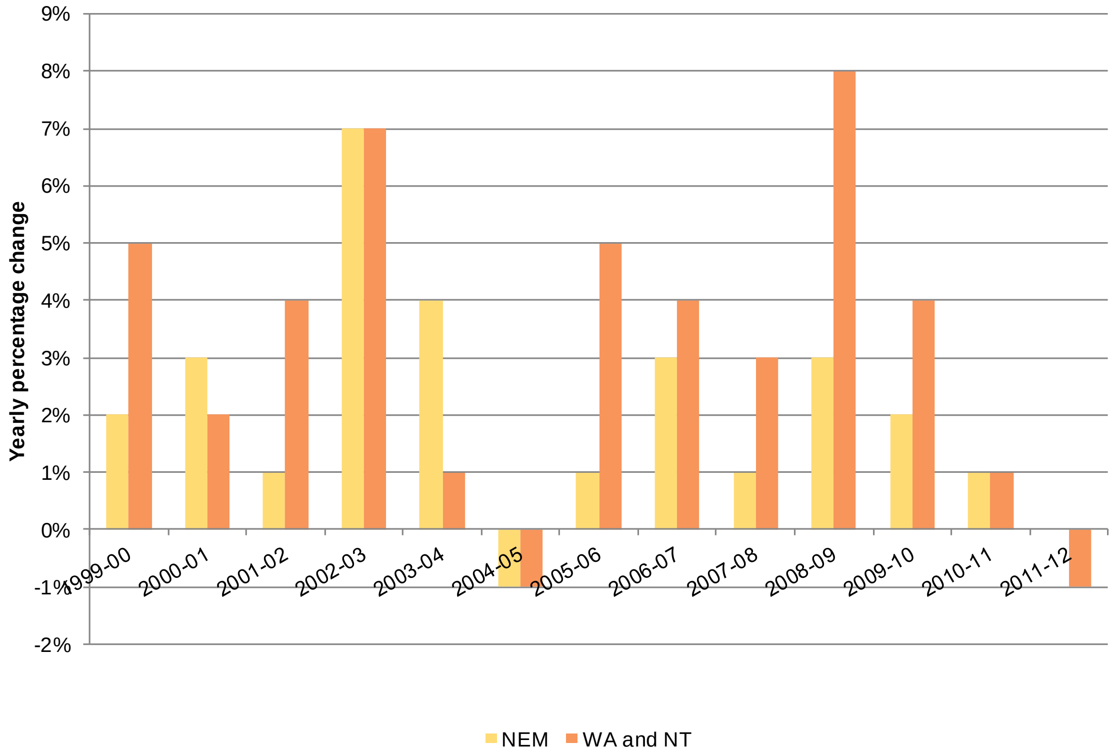
The trends in residential electricity consumption between NEM and the remaining two regions, Northern Territory and Western Australia, are similar as shown in Figure 14 and Figure 15. This comparison is important as the data for electricity consumption per sector for all of Australia extends back to 1972, whereas sectoral electricity consumption per state, which is necessary to single out the NEM, starts in 1990. The longer time series for Australia allows for a more accurate test for the drivers of residential electricity consumption as well as of their relative magnitude. To check for the robustness of the results, the estimates for all of Australia are compared with the NEM region estimates and the coefficients are not statistically significantly different, as shown in the appendix.

Figure 14. **The trends in residential consumption between NEM and Western Australia and Northern Territory are similar**



Source: *Vivid Economics based on Australian Government Bureau of Resource and Energy Economics (2013)*

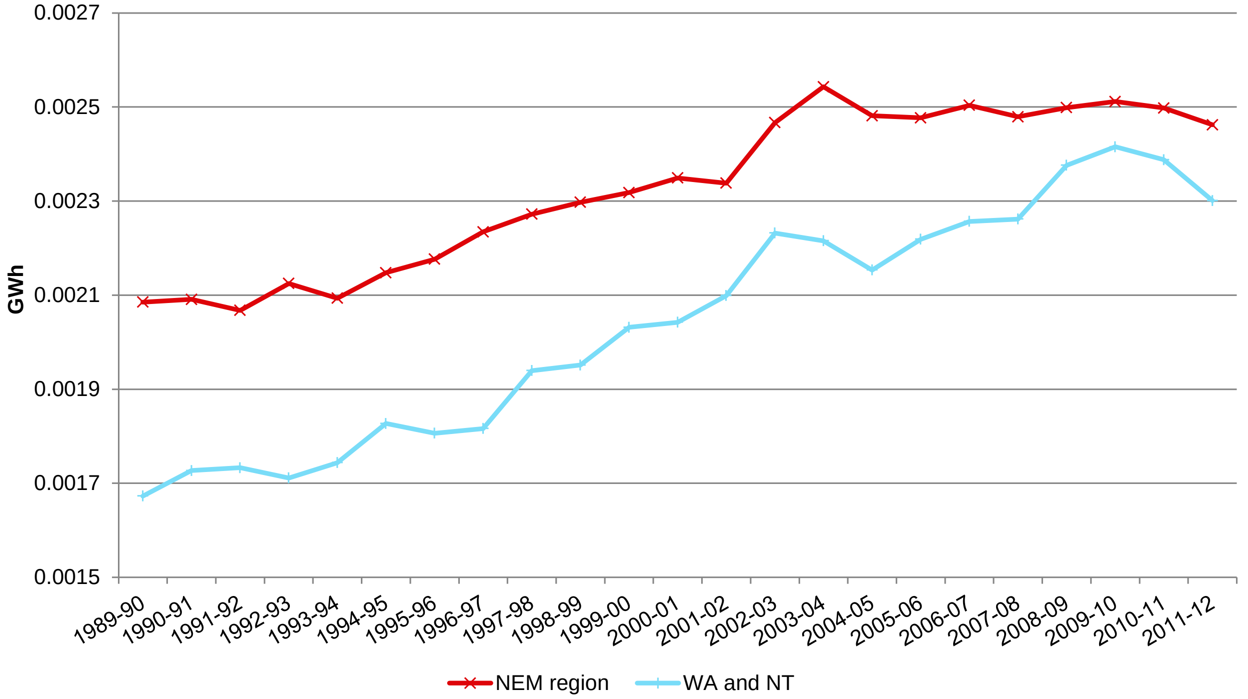
Figure 15. **The trends in residential consumption growth between NEM and WA and NT are similar**



Source: *Vivid Economics based on Australian Government Bureau of Resource and Energy Economics (2013)*

Electricity consumption was 6.36 MWh per household in 1990-00, and 6.41 MWh per household in 2012, the latest available year for household size. Household size is measured every five years, whereas electricity consumption per capita is available each year. Electricity consumption per capita was fairly constant between 2005 and 2007/08 and started to decline in 2011/12, as shown in Figure 16.

Figure 16. **Residential per capita electricity consumption in the NEM flattened between 2005 and 2012**



Source: *Vivid Economics based on Australian Government Bureau of Resource and Energy Economics (2013)*

The drivers of residential electricity consumption are prices and final consumption expenditure. Weather has been found to be statistically insignificant, which is in contrast to previous work by AEMO. Equation 1 below shows the estimation for changes in residential electricity consumption together with the coefficient and significance of each driver.

$$\Delta rese_t = \underbrace{1.06}_{0.01} - \underbrace{0.70}_{0.01} rese_{t-1} + \underbrace{0.48}_{0.01} c_{t-1} - \underbrace{0.10}_{0.35} p_{t-1} - \underbrace{0.18}_{0.17} \Delta p_t + \underbrace{0.04}_{0.00} ID_{0304} + \epsilon_t \quad (1)$$

Note: p values for the significance of the explanatory variables are provided under the coefficient estimates. The nature of the model requires conducting an F test, which has different bounds since it considers non-stationary, cointegrated time series data, and the F test rejects that the coefficients are insignificant.

where:

- *rese* is the logarithm of residential electricity consumption;
- *c* is final consumption expenditure (FCE);
- *p* is real electricity CPI; and
- ID_{0304} is an impulse dummy variable to isolate a possible outlier in 2003 and 2004.

Based on the estimation, the long run price elasticity[5] for electricity consumption in the NEM is approximately -0.14. The long run elasticity shows the permanent effect of a change in retail electricity prices on residential electricity consumption. The speed of adjustment is 0.7, meaning 70 per cent of any disequilibrium in long run relationship is adjusted within a year and 91 per cent in two years.

Final consumption expenditure (FCE) tracks consumer spending and, based on the estimation, has a long run elasticity in the NEM of 0.68. The long run elasticity of FCE shows the permanent effect of a change in retail electricity prices on residential consumption. The speed of adjustment is 0.7 meaning 70 per cent of any disequilibrium in long run relationship is adjusted within a year, 91 per cent in two years.

Figure 17 shows that residential electricity consumption in the NEM since 2008 is higher than expected given the changes in FCE and retail electricity prices. The central forecast predicted approximately flat residential electricity consumption between 2008 and 2012, whereas actual consumption increased further.

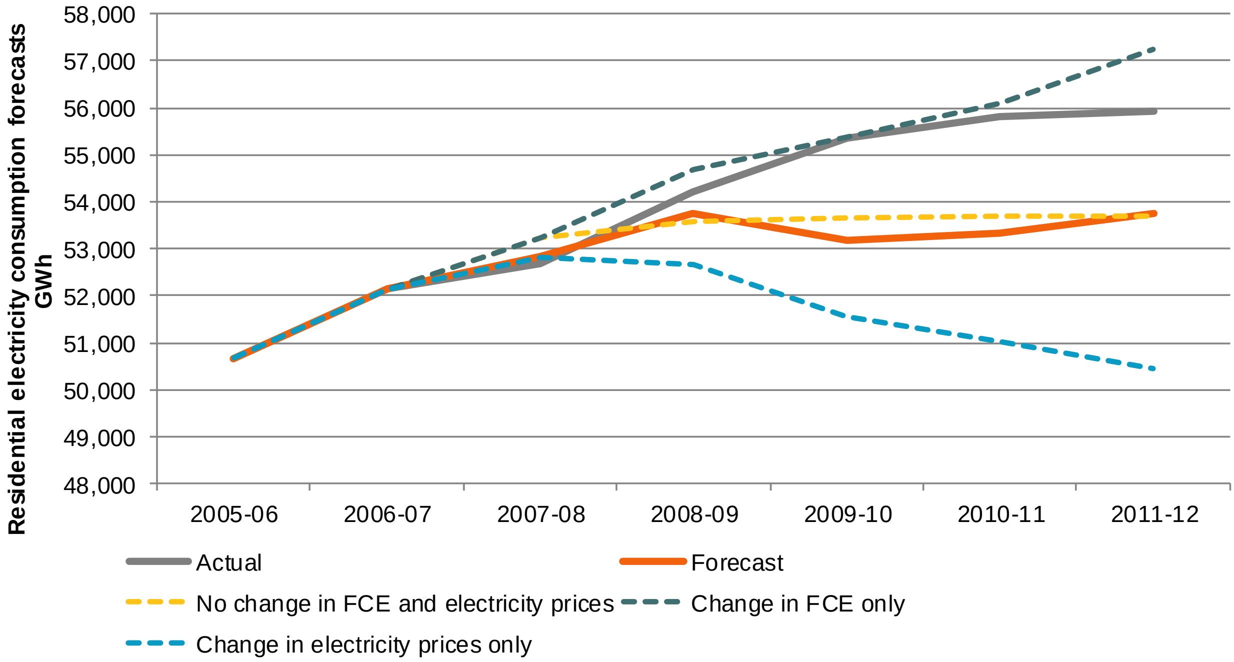
To further investigate the point, three forecast scenarios are created in addition to the central forecast:

– a scenario without changes in retail electricity prices;
– a scenario without changes in FCE; and
– a scenario without changes in either retail electricity prices and FCE, which solely relies on the autoregressive dynamics of residential electricity consumption.

Based on the relationship between drivers and residential electricity consumption, the statistical analysis shows that retail electricity prices, which have increased rapidly since 2008, did not have the same effect between 2008 and 2012 as they had before 2008. In fact, the forecast which keeps prices constant fits the data best, meaning that the actual residential electricity consumption is in line with past trends and changes in FCE when electricity prices changes since 2008 are excluded.

[5] The long run elasticity of a driver is obtained by dividing the coefficient of the driver, in this case electricity price (-0.1), by the coefficient of the lagged residential electricity consumption (-0.7).

Figure 17. **Residential electricity consumption did not react to prices since 2008 as it did before 2008**



Source: *Vivid Economics based on Australian Government Bureau of Resource and Energy Economics (2013) and Australian Bureau of Statistics (2013)*

The residential long run price elasticity is in line with previous work as shown in Table 9. The long run price elasticity of -0.14 implies that a 1 per cent in electricity prices in this period leads to a consumption reduction of 0.14 per cent. The elasticity with respect to expenditure is not directly comparable to AEMO estimates, which use either Gross State Product or State Final Demand. These are measures of income and not expenditure and differ by net savings. Nevertheless, the elasticities are comparable and the elasticity found in this work is within the range identified in the AEMO work.

Table 9. **The estimated residential electricity consumption price elasticity is at the low end of the estimates in the previous AEMO work**

Long run elasticity	Vivid Economics	AEMO*
Electricity price	-0.14	-0.13 to -0.44
Final consumption expenditure	0.48	0.23 to 0.71

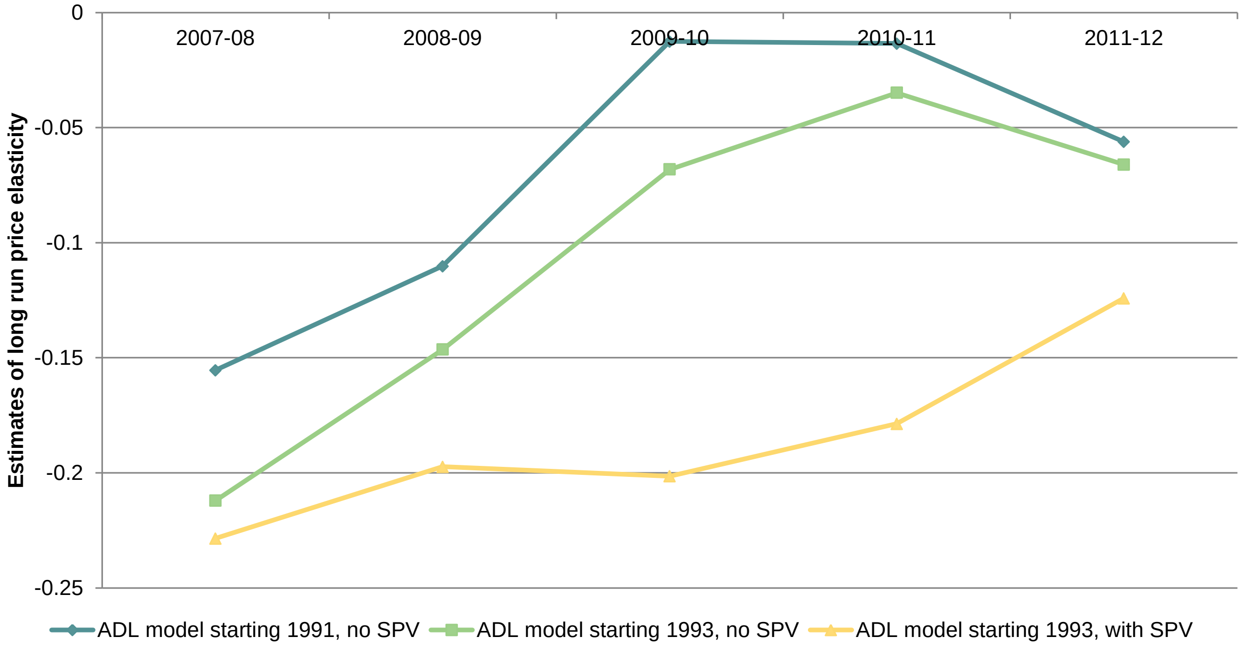
Note: ** AEMO elasticities are obtained per state and vary accordingly.*

Source: *Vivid Economics*

Residential consumption between 2008 and 2012 shows little response to electricity prices compared with the period before 2008. As a result, the estimated long run price elasticity falls rapidly when the estimation period is extended beyond 2008. The long run price elasticity more than halves from -0.15 in the period until 2008 to a mere -0.06 if the estimation period extends to 2012 as shown in Figure 18.

The declining price elasticity may be explained by slow changes in electricity consumption behaviour, longer periods necessary to switch to more efficient appliances or to undertake measures such as better insulation, and the influence of off-grid electricity generation, particularly solar PV. The replacement period of appliances and other measures might reduce residential electricity consumption further as electricity prices have risen rapidly only since 2008. In addition, electricity is a small fraction of residential household expenditure. To test the effect of solar PV, its contribution is included in the estimation. This is done by including the amount of overall solar on- and off-grid electricity generation. The result is that residential electricity consumption still responds almost as much to electricity prices since 2008 as before when solar PV[6] electricity generation is included in the estimation. This implies that on-grid residential electricity consumption continued to respond to prices and that high electricity prices and solar feed-in-tariffs resulted in increased off-grid solar generation.

Figure 18. **The estimated long run price elasticity for residential model collapses in 2010 but, when solar PV electricity generation is included as an explanatory variable in model, the elasticity is more stable**



Note: *The price elasticities shown here are for the estimation period from 1990-91 or 1992-93 until the year shown on the x-axis. The model without solar PV starts in 1990-91, the earliest data point for the NEM, while the model with solar PV starts in 1992-93 due to a lack of data for solar PV before. The obtained coefficients for the short estimation period in the NEM data shown here are not statistically different from estimates obtained for all of Australia using significantly more years, that is, starting in 1972.*

Source: *Vivid Economics*

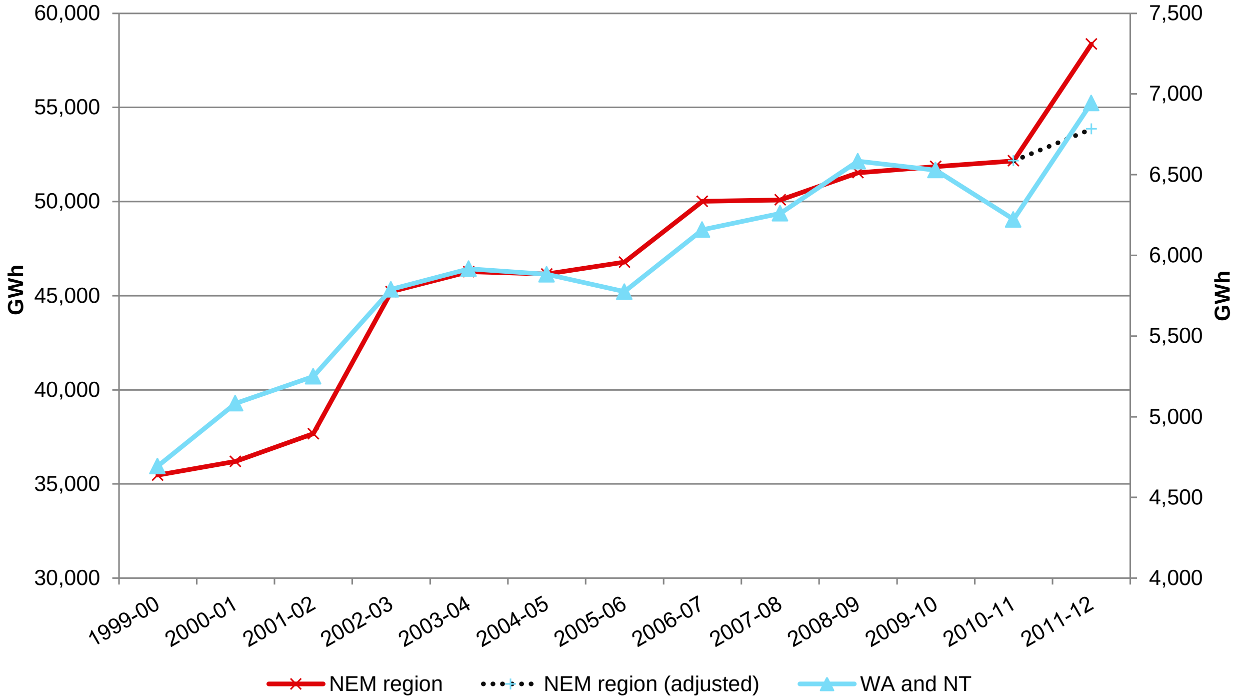
[6] Solar PV includes both large and small scale on- and off-grid solar due to data availability, which might lead to a slight overstatement of the effect if most of the increased solar PV generation is from large scale on-grid projects.

2.3.3 Commercial and services

Commercial and services electricity consumption grew more slowly between 2008 and 2011 in the NEM than from 2000 to 2008. The growth rate slowed from a CAGR of 2.1 per cent between 2003 and 2008 to 1.36 per cent between 2008 and 2011.[7]

The trends in commercial and services electricity consumption between NEM and the remaining two regions, Northern Territory and Western Australia, are similar as shown in Figure 19 and Figure 19. This comparison is important to ensure consistency of estimates, as explained in Section 2.3.2.

Figure 19. **The trends in commercial and services electricity consumption between NEM and WA and NT are similar, including the 2012 outlier**

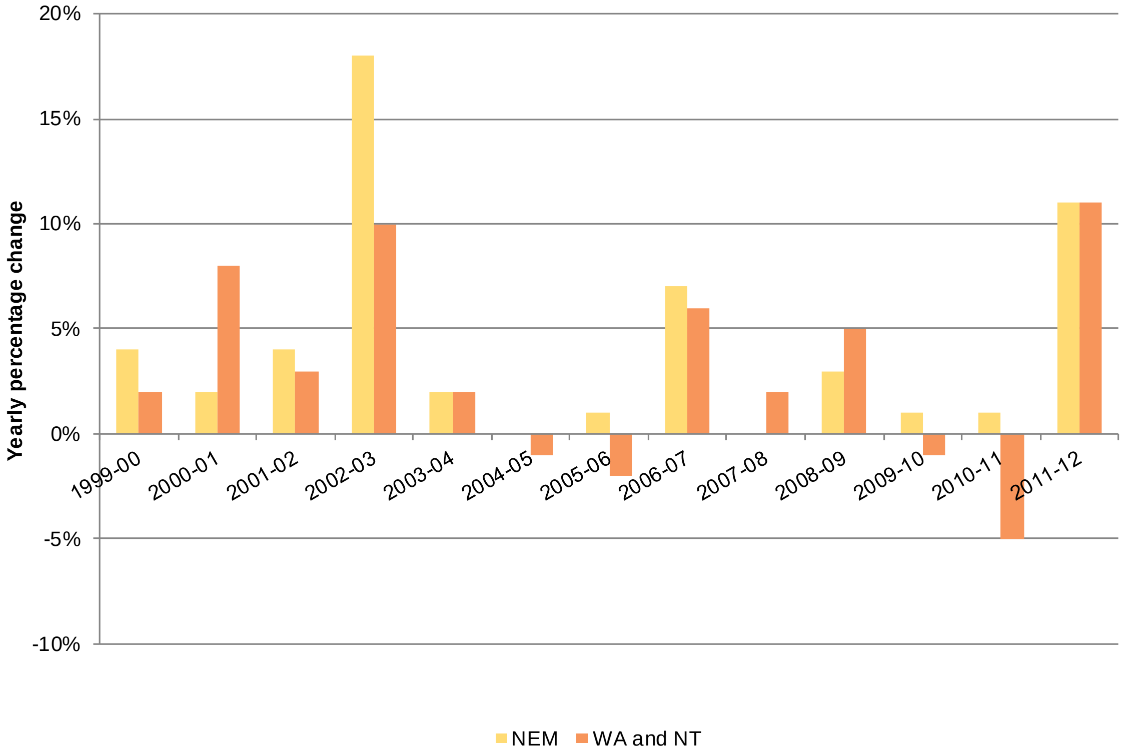


Note: *2012 is most likely an outlier as explained previously and is not used in the trend analysis. Consumption in WA and NT is also likely to be an outlier, but is not adjusted since it does not enter the decomposition or trend analysis.*

Source: *Vivid Economics based on Australian Government Bureau of Resource and Energy Economics (2013)*

[7] The CAGR is calculated until 2011 only because commercial and services electricity consumption in 2012 appears to be an outlier.

Figure 20. **The trends in commercial and services electricity consumption growth between NEM and WA and NT are similar, including the 2012 outlier**



Note: *2012 is most likely an outlier as explained previously and is not used in the trend analysis.*

Source: *Vivid Economics based on Australian Government Bureau of Resource and Energy Economics (2013)*

The drivers of commercial electricity consumption are electricity prices, Gross Value Added in the sector and the number of very hot days in a year. Equation 2 below shows the estimation for changes in commercial and services electricity consumption together with the coefficient and significance of each driver.

$$\Delta come_t = -\underbrace{1.48}_{0.01} - \underbrace{0.53}_{0.00}(come_{t-1} - comgva_{t-1}) - \underbrace{0.22}_{0.00}p_{t-1} + \underbrace{0.04}_{0.00}nvhd_{t-1} + \underbrace{0.26}_{0.00}\Delta come_{t-1} -$$

$$\underbrace{0.15}_{0.03}\Delta p_{t-1} + \underbrace{1.04}_{0.00}\Delta comgva_{t-1} - \underbrace{0.032}_{0.00}D_{00} - \underbrace{0.024}_{0.00}ID_{99} + \underbrace{0.106}_{0.04}1ID_{03} + \epsilon_t \qquad (2)$$

Note: p values for the significance of the explanatory variables are provided under the coefficient estimates. The nature of the model requires conducting an F test, which has different bounds since it considers non-stationary, cointegrated time series data, and the F test rejects that the coefficients are insignificant.

where:

- *come* is the logarithm of commercial and services sector electricity consumption;
- *comgva* is the GVA of commercial and services sector;
- *p* is the real electricity price PPI;

- *nvhd* is the number of very hot days in a year;
- D_{00} is a level dummy variable taking value 1 after 2000 and 0 before; and
- ID_{99} *and* ID_{03} are impulse dummy variables to isolate a possible outlier in 1999 and 2003.

Based on the estimation, the long run price elasticity for commercial electricity consumption in the NEM is approximately -0.42. This estimate is in line with previous estimates obtained by AEMO, yet it is towards the top range, as shown in Table 10. The speed of adjustment is 0.53 leading to an equilibrium correction of 50 per cent in the first year and 75 per cent within two years.

Table 10. **The estimated price elasticity is towards the top end of the range identified in previous AEMO work**

Long run elasticity	Vivid Economics	AEMO*
Price	-0.42	-0.13 to -0.44
GVA**	1.00**	0.23 to 0.71
Weather	0.08	NA

*Note: * AEMO elasticities are obtained per state and vary accordingly. ** The GVA long run elasticity is imposed to be 1 and statistical tests cannot reject that it could be 0.7. The long run elasticity of GVA is imposed to be proportionate. This restriction greatly improves model stability. If the GVA elasticity is estimated, it is lower than 1 but statistical tests cannot reject that it is in fact 1. The estimated long run price elasticity is similar to previous work.*

Source: Vivid Economics

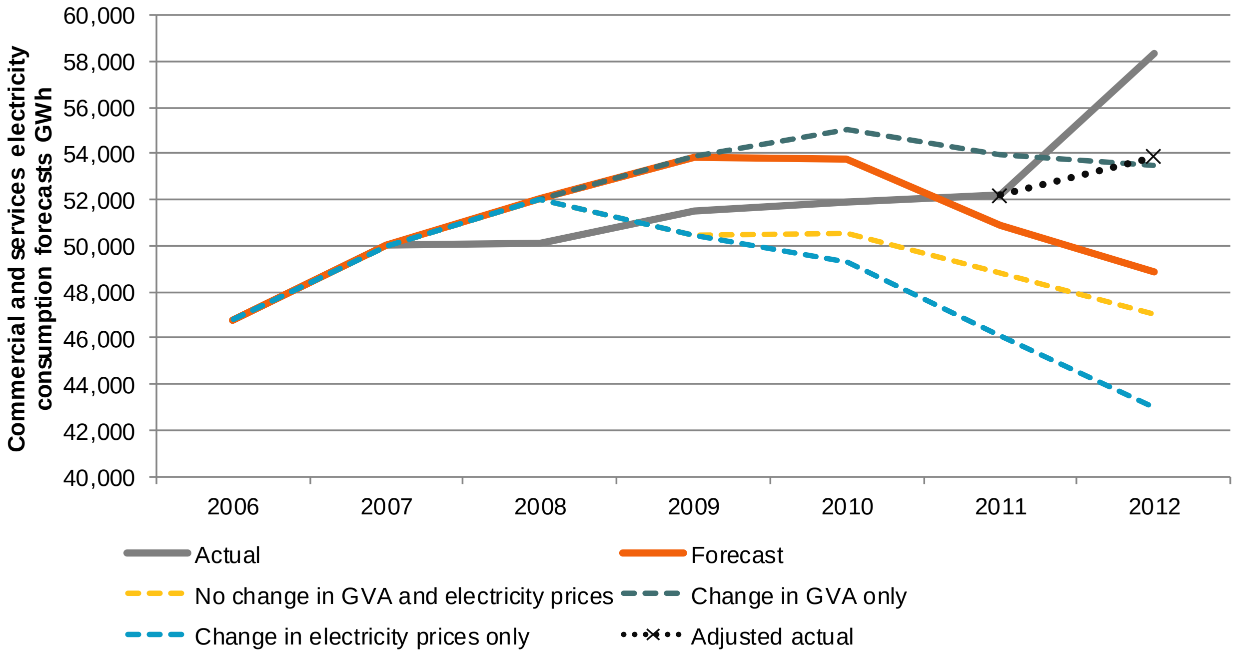
To investigate whether there are any significant differences between the period before 2008 and between 2008 and 2011, three different forecast scenarios are created in addition to the central forecast:

- a scenario without changes in electricity prices;
- a scenario without changes in commercial and services GVA; and
- a scenario without changes in either electricity prices or GVA, which solely relies on the autoregressive dynamics of commercial and services electricity consumption.

The observed commercial and electricity consumption between 2008 and 2011 is in line with the estimated past relationship between consumption and its drivers, electricity prices, GVA and weather as shown in Figure 21. Consumption in 2012 is significantly higher than in preceding years and could be an outlier, based on further evidence of a constant electricity intensity of the sector over time. If this outlier is adjusted, the forecast scenarios all projected a decline in commercial and services electricity consumption between 2008 and 2011 whereas actual consumption has levelled off in the same period.

AEMO data indicates that per capita energy consumption for residential, commercial and services users has been declining since 2009 (AEMO, 2013a). In Queensland, the National Electricity Forecasting Report (NEFR) predicted a 10-year average energy consumption growth of 3.1 per cent owing to population and economic growth, and an ‘easing of electricity prices after 2014-15’. However, a number of large new industrial projects were not operational at the expected time, leading to lower short-term energy consumption growth than previously forecast. In New South Wales, rising population and small industrial energy consumption was accompanied by a reduction in large industrial consumption, leading to a flatter 0.6 per cent energy per year consumption growth. In Victoria, the 10-year average energy consumption growth forecast is 0.9 per cent per year, down from 1.4 per cent per year forecast in 2012, owing to energy efficiency savings in the interim. In South Australia, a combination of lower-than-expected population and economic growth, energy efficiency savings owing to solar PV technologies, and the deferral of large industrial projects such as the Olympic Dam mining expansion, contributed to an average consumption growth of 0.1 per cent per cent for the next ten years, down from 0.7 per cent per year in the previous year's forecast. In Tasmania, consumption is forecast to be flat over the next ten years, owing to energy efficiency savings and lower-than-expected industrial consumption.

Figure 21. **Commercial and services electricity consumption in 2011 and 2012 is slightly higher than forecasted**



Note: *Adjusting commercial and services electricity consumption results in a more credible pattern.*

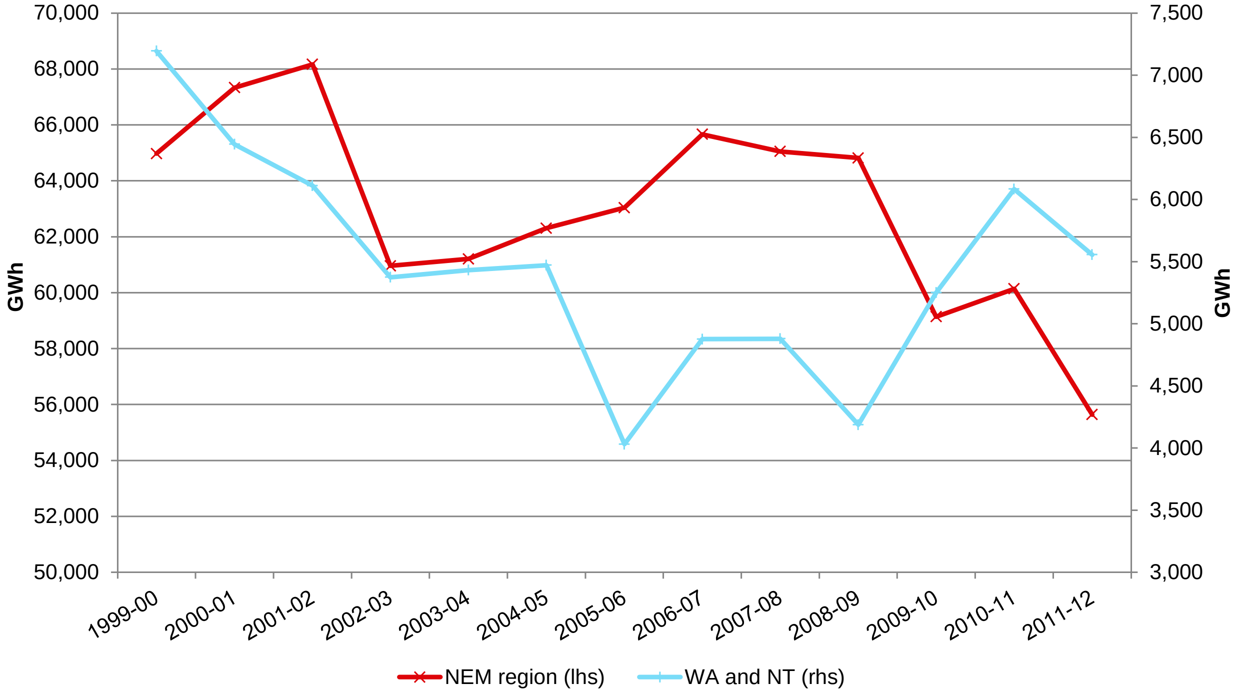
Source: *Vivid Economics based on Australian Government Bureau of Resource and Energy Economics (2013) and Australian Bureau of Statistics (2013)*

2.3.4 Manufacturing

Manufacturing electricity consumption declined between 2008 and 2011 in the NEM whereas it stayed relatively constant between 2000 and 2008. Manufacturing electricity consumption declined by a CAGR of 4 per cent between 2008 and 2012.

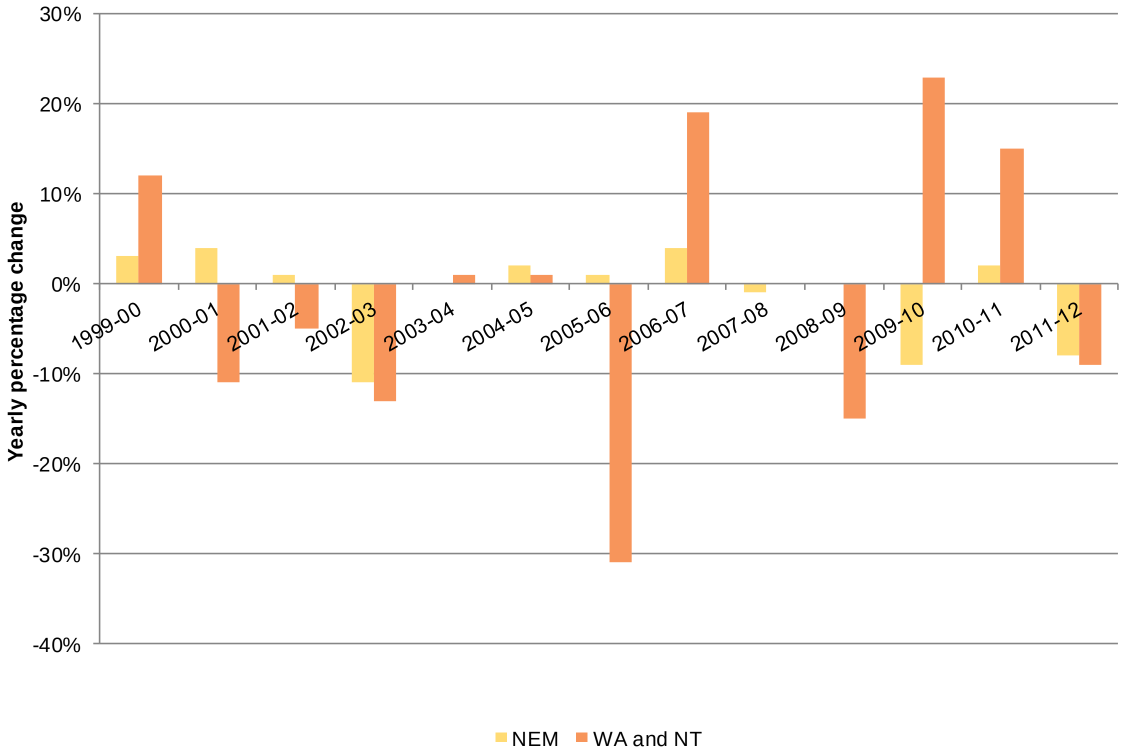
The trends in manufacturing electricity consumption differ slightly between NEM and the remaining two regions, Northern Territory and Western Australia, as shown in Figure 22 and Figure 23. This comparison is important to ensure consistency of estimates, as explained in Section 2.3.2. Even though the series differ slightly, WA and NT manufacturing electricity consumption is less than 10 per cent of the NEM region and the coefficients are not statistically significantly different as shown in the appendix. The difference in growth rates between the NEM, WA and NT is mainly due to increased mining activity in the latter two areas.

Figure 22. **There are differences between NEM and WA and NT manufacturing electricity consumption patterns, especially since 2006**



Source: *Vivid Economics based on Australian Government Bureau of Resource and Energy Economics (2013)*

Figure 23. **WA and NT manufacturing electricity consumption growth is more volatile than NEM, especially since 2006**



Source: *Vivid Economics based on Australian Government Bureau of Resource and Energy Economics (2013)*

The drivers of manufacturing electricity consumption are electricity prices and Gross Value Added in the sector. Equation 3 below shows the estimation for changes in manufacturing electricity consumption together with the coefficient and significance of each driver.

$$\Delta mane_t = -\underbrace{0.21}_{0.04} - \underbrace{0.52}_{0.03}(mane_{t-1} - mangva_{t-1}) - \underbrace{0.29}_{0.01}p_{t-1} + \underbrace{0.99}_{0.01}\Delta mangva_t + \underbrace{0.30}_{0.06}\Delta mane_{t-1} - \underbrace{0.59}_{0.05}\Delta mangva_{t-1} + \underbrace{0.37}_{0.03}\Delta p_{t-1} - \underbrace{0.069}_{0.03}D_{04} - \underbrace{0.18}_{0.00}ID_{03} + \epsilon_t \quad (3)$$

Note: p values for the significance of the explanatory variables are provided under the coefficient estimates. The nature of the model requires conducting an F test, which has different bounds since it considers non-stationary, cointegrated time series data, and the F test rejects that the coefficients are insignificant.

where:

– *mane* is the logarithm of industrial sector electricity consumption;
– *mangva* is GVA of industrial sector;
– *p* is real electricity PPI;
– D_{04} is a level dummy variable taking value 1 after 2004 and 0 before; and
– ID_{03} is an impulse dummy variable to isolate an outlier in 2003.

The long run price elasticity for manufacturing electricity consumption in the NEM is approximately -0.55, which is higher than in previous work by AEMO, as shown in Table 11.

The long run elasticity of GVA for manufacturing electricity consumption in the NEM is restricted to be unity for the same reasons it is restricted to be unity in the commercial and services consumption model. Statistical tests cannot rule out that the GVA long run elasticity is 0.7, as shown in the appendix.

Table 11. **The estimated long run price elasticity of manufacturing electricity consumption is higher than in the AEMO NEFR (2013)**

Long run elasticity	Vivid Economics	AEMO
Price	-0.55	-0.13 to -0.44

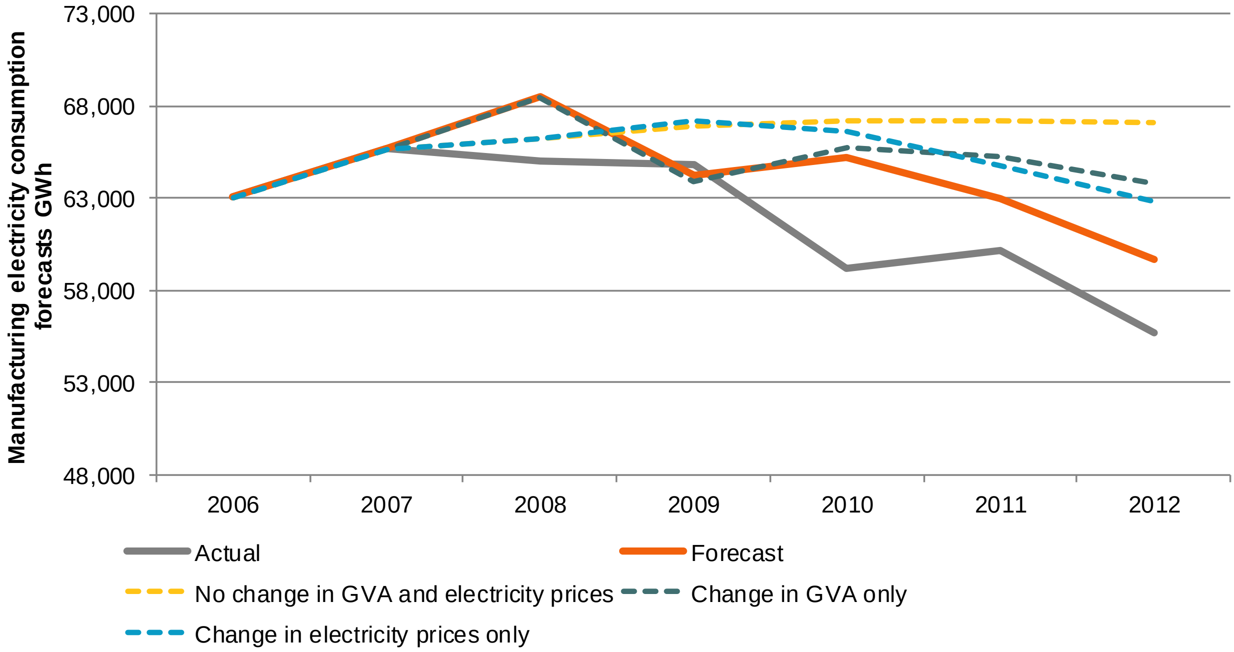
Source: *Vivid Economics*

To investigate whether there are any significant differences between the period before 2008 and between 2008 and 2011, three forecast scenarios are created in addition to the central forecast:

- a scenario without changes in electricity prices;
- a scenario without changes in manufacturing GVA; and
- a scenario without changes in either electricity prices or GVA, which solely relies on the autoregressive dynamics of manufacturing electricity consumption.

The observed manufacturing electricity consumption between 2008 and 2011 is in line with the estimated past relationship between consumption and its drivers, electricity prices and GVA, as shown in Figure 24. Electricity consumption declined slightly further than forecast, but is still within the statistically viable range given by the relationship between consumption and the drivers before 2008.

Figure 24. **The relationship between the drivers and manufacturing consumption since 2008 is unchanged**



Source: *Vivid Economics based on Australian Government Bureau of Resource and Energy Economics (2013) and Australian Bureau of Statistics (2013)*

Trends beyond this sample have been examined in other reports, such as the National Electricity Forecast Report by the Australian Electricity Market Operator. According to the report, electricity consumption in 2013-14 is will respond to consumption growth in residential and commercial and light industrial energy consumption, mitigated by the installation of rooftop solar PV systems and energy efficiency improvements necessitated by new building regulations (AEMO, 2013a). Changes in manufacturing consumption are to an extent driven by single events, such as the closure of the Kurri Kurri smelter in New South Wales; deferral of the Olympic Dam mine expansion in South Australia and changes to levels of operation of Victoria's Wonthaggi desalination plant.

2.3.5 Contribution of drivers to forecast electricity consumption in sectors

Shares of each factor of the total contribution are derived by comparing the no change in GVA/income and prices with the scenarios allowing for a change in only one driver. The forecast is made up of three main components being activity, price and short run dynamics plus trend. When keeping activity levels and price constant, the path of consumption represents short run dynamics and trends.

Allowing GVA to change shows what happens to consumption when only that driver changes. When comparing this path of consumption with the no change scenario above, the difference comes from changing activity level only. Likewise if only price is allowed to change the new path for consumption will represent the effect of price on consumption and when compared with the no change path it will isolate the price contribution to consumption growth over the forecast horizon.

Table 12 shows the estimated relative contribution of the main drivers to electricity consumption in each sector.

Residential electricity consumption increased due to higher final consumption expenditure in both periods. Electricity prices decreased residential electricity consumption but were outweighed by increased final consumption expenditures. The dynamics and residual contribute a significant part, which is expected since the forecast error is relatively large, as shown in the appendix and Table 12.

In the commercial and services sector, the response to higher electricity prices offsets approximately one third of the effect of increased GVA.

Manufacturing has responded more strongly to rising electricity prices than residential or commerce and services between 2008 and 2012. Declining GVA contributed further to a reduction in manufacturing electricity consumption between 2008 and 2012.

Table 12. **The percentage changes induced by drivers provide the relative magnitude of the effect of drivers on electricity consumption in the respective sectors**

	Contribution, in percentage points, to percentage changes induced by drivers, which explains how much of the total change is due to each driver					
Driver	**Residential**		**Commercial and services**		**Manufacturing**	
	2003 to 2008	**2008 to 2012**	**2003 to 2008**	**2008 to 2011***	**2003 to 2008**	**2008 to 2012**
Electricity price	-0.97	-2.06	1.59	-1.31	1.72	-5.35
GVA	NA	NA	20.65	4.65	2.66	-8.09
FCE	9.52	3.47	NA	NA	NA	NA
Weather	NA	NA	-0.9	-0.14	NA	NA
Dynamics and residual**	-0.27	4.73	-10.57	0.97	2.34	-1.04
Total	**8.28**	**6.14**	**10.77**	**4.17**	**6.72**	**-14.48**

Notes: *The respective ADL models are simulated under different scenario and relative contribution is obtained as the difference between relevant scenarios. *2011 is chosen as the latest point to exclude the likely outlier in 2012. ** Dynamics and residual include parts of the model beyond the driver, such as the constant, trend and autoregressive component and the difference between the forecast and observed electricity consumption.*

Source: *Vivid Economics based on* (Australian Government Bureau of Resources and Energy Economics, 2013) *and Australian Bureau of Statistics (2013)*

2.4 Summary of results

The main results are summarised in Box 1.

Box 1. **Electricity consumption in the NEM fell due to lower economic growth and higher electricity prices**

Electricity consumption in the NEM has fallen by 1.7 per cent (3,600 GWh) between 2008 and 2012, which is due to low economic growth, restructuring towards less electro-intensive sectors and improving electricity intensity.

Economic growth would have increased electricity consumption by 8.2 per cent (17,800 GWh) without restructuring of the economy or electricity intensity improvements within subsectors, however each offset 60 per cent of the growth (10,900 GWh and 10,600 GWh) respectively.

Manufacturing, commercial and services and residential were analysed and represent 78 per cent of total electricity consumption in the NEM. For these sectors, consumption fell by 1.4 per cent, or 2,400 GWh out of the total decline of 3,600 GWh in the NEM. Out of the 24,000 GWh reduction in these sectors, prices have reduced consumption by 6,200 GWh (3.7 per cent), and weather reduced consumption by 1,000 GWh (0.6 per cent) while changes in economic activity reduced consumption by a mere 550 GWh (0.33 per cent). The remaining increase of 4,300 GWh (1.4 per cent) stems from other unquantified factors.

2.5 Choice of dataset

For this study, data from the Australian Bureau of Resources and Energy Economics (BREE) are used. The BREE dataset was chosen because it offers a sectoral decomposition which is amenable to the decomposition techniques applied in this section. Previous studies, in contrast, such as the Australian Energy Market Operator (AEMO) National Electricity Forecast Report (AEMO, 2013b) , have used AEMO data. Box 2 summarises the differences between datasets.

Box 2. **Comparison of data for the NEM region from the Bureau of Resources and Energy Economics and from the Australian Electricity Market Operator**

The data for the NEM region from BREE and AEMO show similar trends but differ in two points. Firstly, BREE data uses the Australian and New Zealand Sector Industrial Classification (ANZSIC) whereas the NEM AEMO data uses an alternative grouping. Second, BREE data excludes all own electricity consumption in the electricity supply sectors, which consists of auxiliary consumption, grid losses and other usage, whereas the NEM AEMO data excludes all the above except other usage.

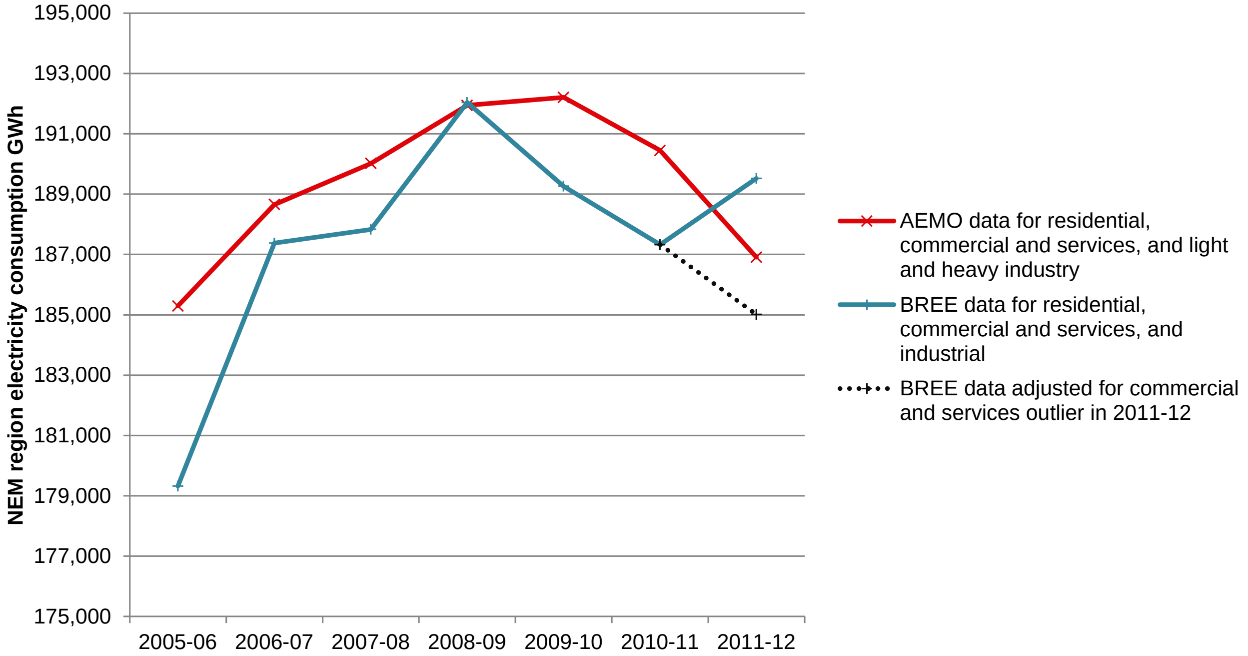
The BREE data allows for the investigation of electricity consumption within ANZSIC sectors, specifically residential, commercial and services, and manufacturing. The NEM AEMO data groups together residential, commercial and services and those parts of manufacturing consumption labelled ‘light industrial’. For the purpose of identifying trends in specific sectors and to decompose changes in electricity consumption by sector, the BREE data is preferable. In addition, BREE electricity consumption data extends back to 1972, which provides a greater number of data points and thus the opportunity to analyse trends more accurately, than the shorter AEMO dataset, which starts in 1990.

Vivid Economics constructed BREE data for the NEM region by subtracting the figures for Western Australia and Northern Territory from the national total.

The trends in the two datasets are similar, if the final year’s data point for NEM is adjusted. The commercial and services data was adjusted because it appeared to be an outlier because it exhibits an unlikely rise in electricity in the year 2012 for which an adjustment has been made. The adjusted data point is measured by taking the sector’s ratio of electricity consumption to GVA in the previous year, and applying it to the level of GVA in 2012. The BREE figure for commercial and services sector consumption in 2011 is 58,361 GWh with a corresponding intensity of 0.09 GWh/AUD, whereas the intensity figure in 2011 is 0.083 GWh/AUD implying an electricity consumption of 53,856 GWh in 2012.

If one accepts this adjustment, one would expect results obtained from the BREE data to correspond closely to those if the AEMO data had been used, as illustrated in Figure 25.

Figure 25. **AEMO data and BREE equivalent data for the NEM region trends track quite closely when adjusting for 2012 commercial and services consumption**



Notes: *BREE NEM equivalent data was obtained by subtracting the consumption data for WA and NT for each sector then summing all sectors while subtracting the consumption of division '26 Electricity supply', which mainly represents auxiliary consumption and grid loss. The 2012 adjustment is made by adjusting the commercial and service consumption figure for 2012 by assuming that the intensity (consumption/GVA) remains at the 2011 rate and applying the 2012 GVA activity level.*

Source: *Vivid Economics based on AEMO (2013) and Australian Government Bureau of Resources and Energy Economics (2013). Development of electricity consumption in Australia and the National Electricity Market*

3 Electricity generation emissions intensity

Changes since 2000 and their drivers, particularly since 2008

Section contents:

The emissions intensity of electricity generation has fallen due to increased gas-fired and renewable generation replacing black coal

Renewable generation beyond existing hydro is chiefly driven by the Mandatory Renewable Energy Target and its successors, the Large and Small Scale Renewable Energy Target. This resulted in an increase of renewable generation from 8.5 per cent in 2000 to 9.5 per cent in 2012.

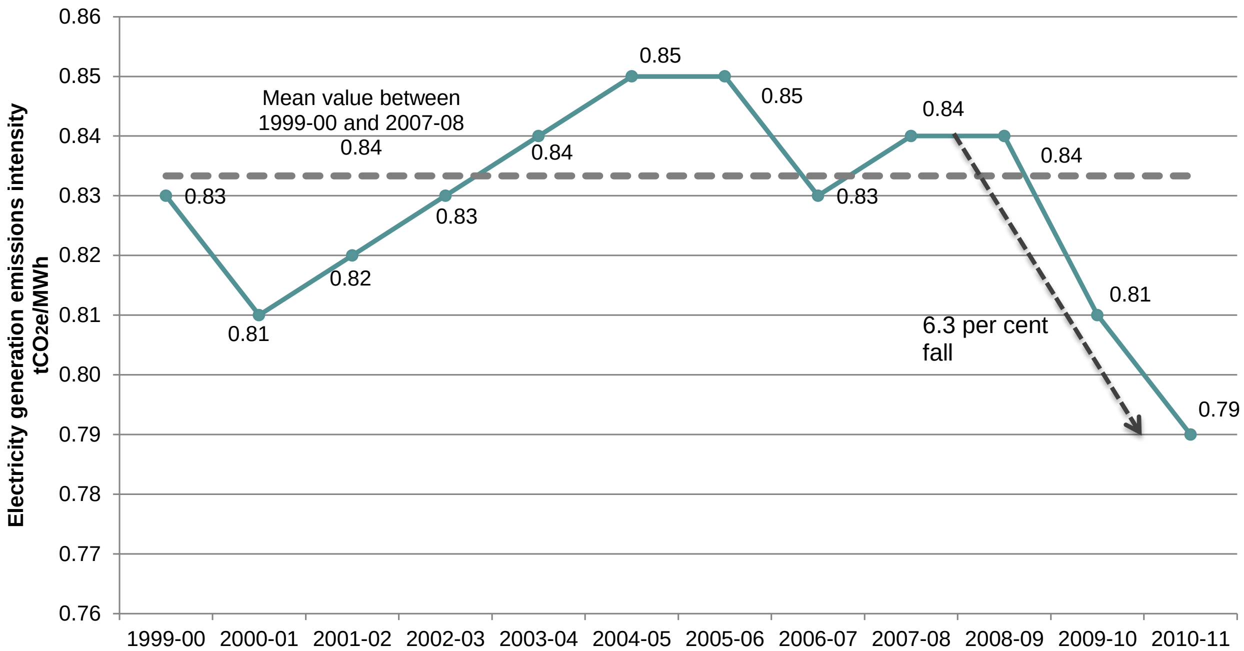
Gas generation increased more than doubled its share in the generation mix from 7.7 per cent in 2000 to 19.3 per cent in 2012. The increase is partially due to prices, the development of coal seam gas and policies such as the Queensland Gas Scheme and the New South Wales Greenhouse Gas Reduction Scheme.

‘Policy is a significant driver behind a decline in the emissions intensity of electricity generation.’

3.1 Development of electricity generation emissions intensity

The emissions intensity of electricity generation in the whole of Australia, both grid-connected and off-grid, remained relatively constant at around 0.84 tCO_2/MWh between 2000 and 2008, as shown in Figure 26. The emissions intensity fluctuated as the fuel mix varied.

Figure 26. **The emissions intensity of electricity started to decline since 2009 but was relatively constant before**

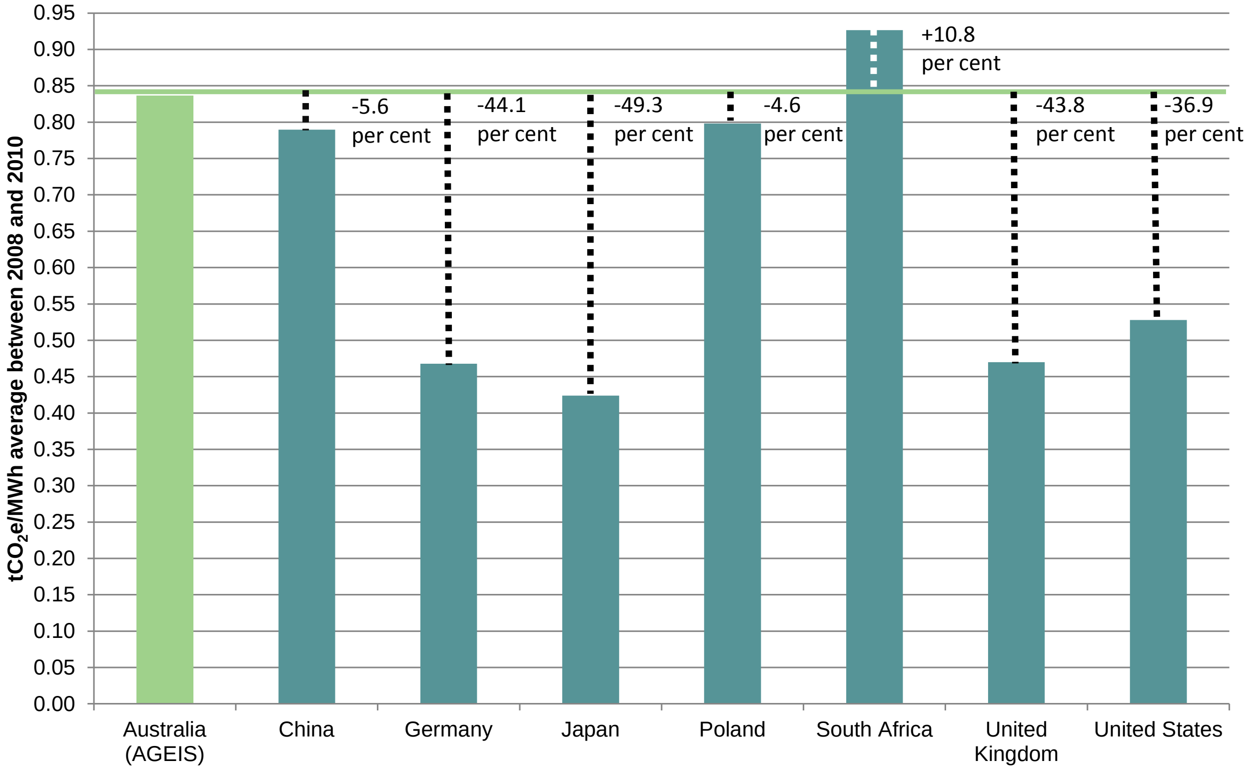


Note: *Intensity is defined as quantity of CO_2 equivalent gas emissions in metric tonnes per electricity generation in MWh.*

Source: *Vivid Economics based on* Australian Government Bureau of Resource and Energy Economics (2013) *and Australian Government National Greenhouse Gas Inventory (2013)*

The emissions intensity fell by 6.3 per cent between 2008 and 2011. This corresponds to a compounded annual decline of 2.2 per cent. Data for the NEM since 2012 show a further decrease, partially due the shutdown of the Yallourn brown coal plant and partially due to further gas and renewable expansion (Pitt and Sherry, 2013). This coincided with the introduction of national carbon pricing mechanism. Nevertheless, the emissions intensity of electricity generation in Australia is still higher than most countries as seen in Figure 27.

Figure 27. **Australia's emissions intensity of electricity generation is higher than in several countries**

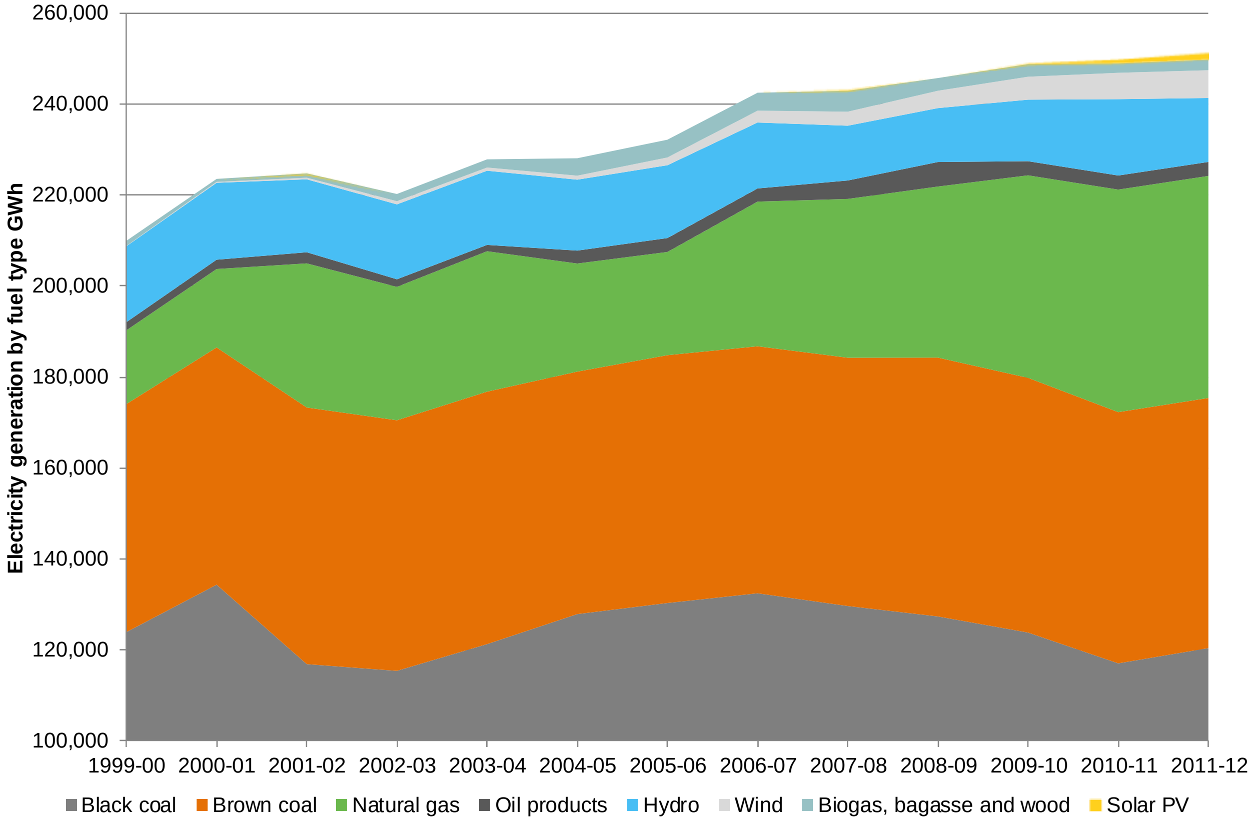


Note: *Emissions intensity is defined as tons of CO_2 equivalent greenhouse gases emissions per 1 MWh of generated electricity from all energy sources.*

Source: *Vivid Economics based on International Energy Agency (2013), World Bank, Australian Government National Greenhouse Gas Inventory (2013) and Australian Government Bureau of Resource and Energy Economics (2013)*

The reason for the decline in the emissions intensity has been a shift in the generation mix. Gas fired electricity generation and renewables have increased their shares from 7.7 and 8.6 per cent in 2000 to 19 and 9.5 per cent in 2011 respectively. Black coal's output share fell by 11 per cent between 2008 and 2012 and brown coal has fallen by 4.8 per cent since 2009 , representing a CAGR of -2.9 and -1.6 per cent respectively. The decline in black coal started in 2007, while brown coal started to decline in 2009. These trends are shown in Figure 28 and Table 13.

Figure 28. **Gas-fired generation and renewables increased from 2009 whereas black coal generation declined**



Note: *Electricity generation by fuel type. Black coal generation falls sharply in the year 2002 while total output is constant due to an increase in gas-fired electricity generation.*

Source: *Vivid Economics based on Australian Government Bureau of Resource and Energy Economics (2013)*

Table 13. **Generation shares in each year from 2007, changes and the CAGRs over the period**

Fuel	**Share in** 2007 %	**Share in** 2009 %	**Share in** 2012 %	**Change 2007 to 2012 %**	**CAGR 2007 to 2012 %**
Black coal	54.4	51.0	47.4	-9.1	-1.9
Brown coal	22.4	22.8	21.7	1.3	0.3
Natural gas	13.1	15.1	19.3	54	9
Oil	1.1	2.1	1.2	6.1	1.1
Renewable	8.71	7.47	9.47	13	2.6

Note: *Shares are calculated using total generated electricity in Australia.*

Source: *Vivid Economics based on Australian Government Bureau of Resource and Energy Economics (2013)*

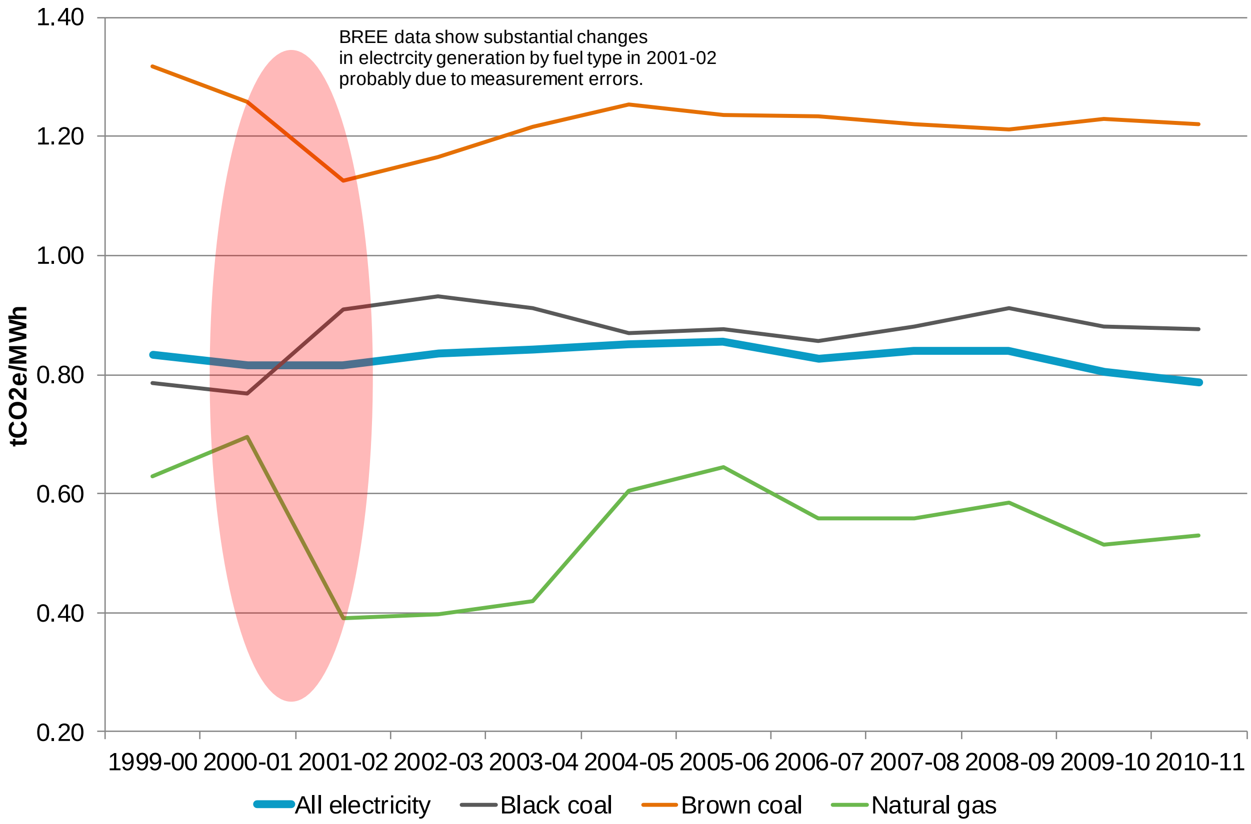
The emissions intensity within fuel types has changed significantly between 2008 and 2010-10. Gas, black and brown coal emissions intensity has changed significantly between 2008 and 2010-10 as shown Table 14. Black coal emissions intensity increased by 12 per cent between 2000 and 2011 and brown coal emissions intensity has fallen by 7.3 per cent in the same period. Changes in output, associated with changes in utilisation, may be behind these changes, see Figure 29.

Table 14. **Emissions intensity fell over time mainly due to decreased emissions intensity in brown coal and gas**

Electricity generation emissions intensity	**tCO_2/MWh**		
	2000	**2008**	**2011**
Total	0.83	0.84	0.79
Black coal	0.79	0.88	0.88
Brown coal	1.32	1.22	1.22
Gas	0.63	0.56	0.53
Oil	0.85	0.90	0.78

Source: *Vivid Economics based on Australian Government Bureau of Resource and Energy Economics (2013)*

Figure 29. **The emissions intensity of each fuel has changed significantly over time**



Note: *The changes in emissions intensity before 2005 are likely to be due to data revisions and not due to actual changes in the emissions intensity of different fuel types.*

Source: *Vivid Economics based on Australian Government Bureau of Resource and Energy Economics (2013)*

The contribution of renewables to electricity generation in the NEM continues to increase. Black coal showed a steady decline, while brown coal, which had remained relatively flat in both emissions intensity and contribution to electricity generation up to 2011, dipped sharply in 2012-13 Climate Works (2013), Pitt and Sherry (2013), Deutsche Bank (2013). The dip in brown coal generation is particularly striking, and several explanations have been proffered, key among these being: closures at Yallourn for a variety of operational reasons, amounting to more than 2,000 GWh of electricity (a third of the reduction in brown coal generation between 2011 and 2012); the introduction of the carbon price in July 2012, which is expected to hit brown coal generation, being almost two-fifths more emissions intensive than black coal generation, and more than two times more emissions-intensive than gas-fired generation. There has been a decline in the demand for grid-generated electricity, although total electricity consumption is not likely to have fallen by as much Deutsche Bank (2013).

3.2 Explaining the changes in electricity generation emissions intensity

3.2.1 Decomposition of effects

The changes in electricity generation emissions intensity can be decomposed into several effects, each capturing characteristics of the electricity market in Australia and the effects of the Mandatory Renewable Energy Target (M-RET) and solar feed-in tariffs. The analysis indicates whether the recent trends might continue for the next few years.

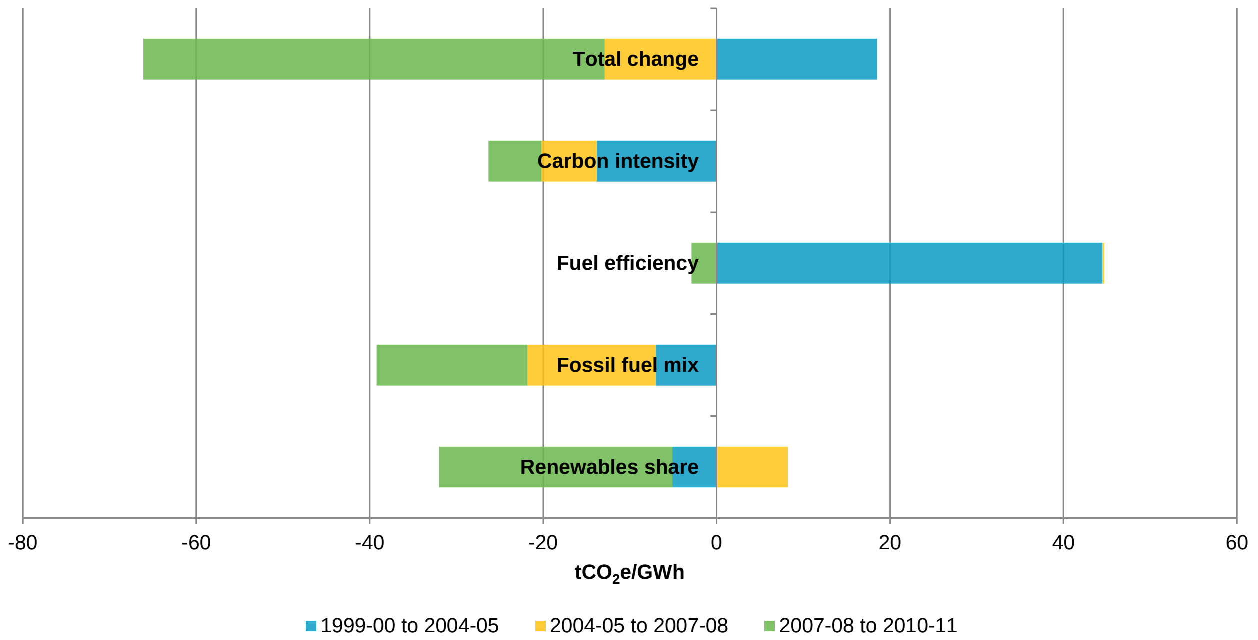
The four factors affecting electricity generation emissions intensity are:

- **fossil fuel mix**: how the shift between fossil fuels, black coal, brown coal and gas, has affected emissions, it measures for example if and by how much gas has replaced other fossil fuels such as black coal;
- **renewable share**: how increased renewable generation (share of total) has affected emissions, that is, how much increased renewable electricity generation in the overall generation mix changed the emissions intensity;
- **carbon intensity**: how changes in emissions intensity within each fuel type has changed, which is measured by emissions in metric tonnes of carbon dioxide for each fuel divided by fuel consumption in PJ of thermal input, and captures how changes in fuel quality and accounting for emissions has changed carbon emissions;
- **fuel efficiency**: how far fuel efficiency of transforming each fuel into power has changed, which is defined as electricity produced by each fuel divided by its input use, and captures factors like technology, power plant age and utilisation.

The contributions of each driver are quantified using the method described in Section 6. For brevity, only the LMDI decomposition results are included in the text. For a treatment of the difference between LMDI and Laspeyres, see Section 6.

Changes in the fuel mix and renewable deployment are the principal factors at work. The effects of changes in carbon intensity and increases in fuel efficiency are particularly weak between 2008 and 2011, see Figure 30, Figure 30 and Table 15. The large decline in fuel efficiency between 2000 and 2005 is due to a sudden change in the ration of electricity produced to fuel input in black coal in 2001 as shown in Figure 32. This is previously noted by the change in electricity generated from each fuel source in Figure 29. The following paragraphs describe how much each factor contributed to changes, what has been behind changes in the two main factors, and considers whether the trends might continue.

Figure 30. **The changes in the emissions intensity of electricity generation are mainly due to changes in the fossil fuel mix, increased renewable deployment and, to a lesser extent, a reduction in the carbon intensity of fuels**



Notes: ***carbon intensity:*** *changes in emissions intensity within each fuel type (emissions by fuel divided by fuel consumption);* ***fuel efficiency:*** *changes in electricity produced divided by fuel use;* ***fuel mix:*** *the shift between fossil fuels, that is, between black, brown coal and gas;* ***renewables share:*** *the effect of increased renewable generation.*

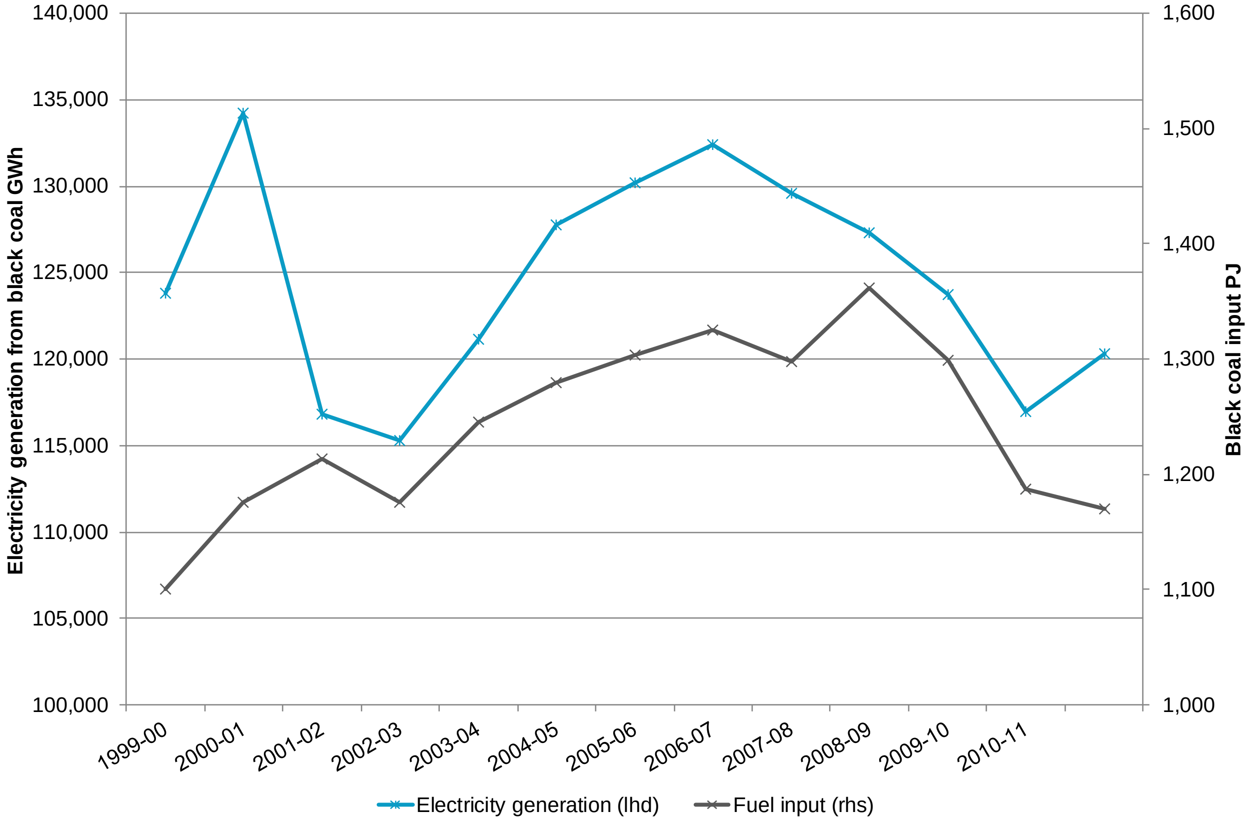
Source: *Vivid Economics based on Australian Government Bureau of Resource and Energy Economics (2013) and Australian Bureau of Statistics (2013)*

Figure 31. **Renewables have been consistently contributing to emissions intensity improvements since 2009**

Note: *LMDI decomposition of emissions intensity of electricity generation, two main effects yearly contribution.*

Source: *Vivid Economics based on BREE (2013) and AGEIS (2013)*

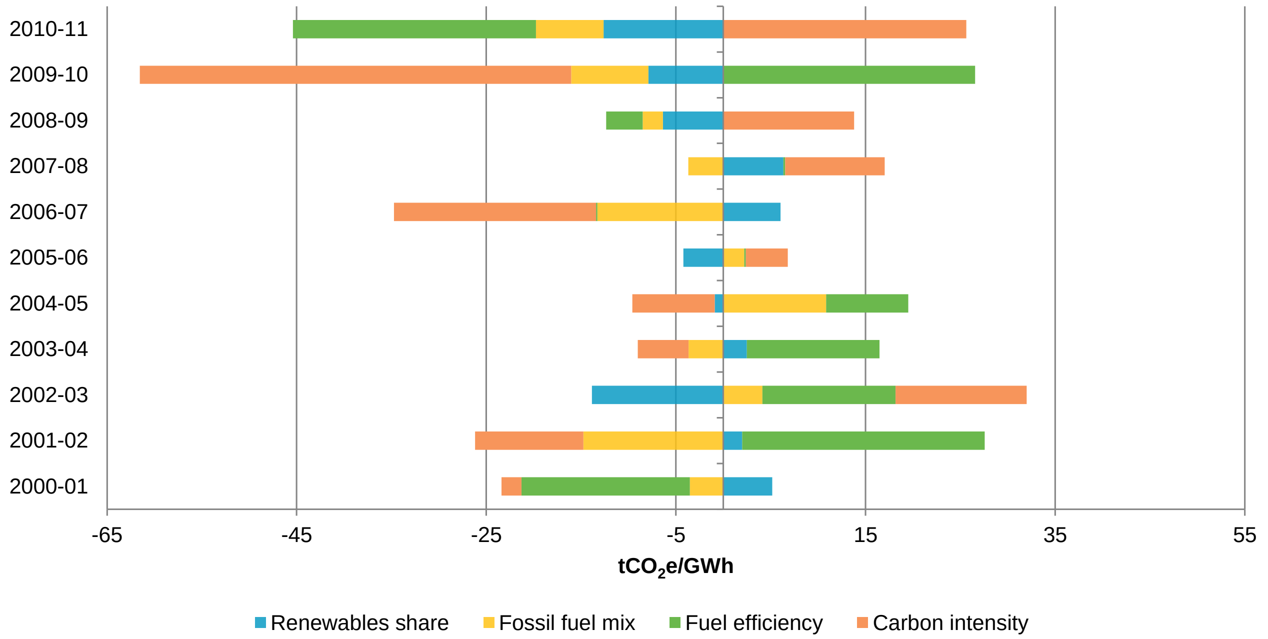
Figure 32. **Black coal electricity generation corresponds closely to black coal input in most periods, with 2000 and 2001 being outliers**



Source: *Vivid Economics based on BREE (2013) and AGEIS (2013)*

Figure 33 shows how volatile carbon intensity and fuel efficiency effects are compared with the fossil fuel mix and renewables share effects. These effects might be driven more by changes in fuel inventory or measurement than actual changes in technology, fleet age or other potential underlying drivers.

Figure 33. **The large changes in carbon intensity between years may be due to inventory movements**



Note: *LMDI decomposition of electricity generation emissions intensity.*

Source: *Vivid Economics based on BREE (2013) and AGEIS (2013)*

Table 15. **Renewables contributed most in recent years between 2008 and 2011**

Driver	**Contribution to total emissions intensity reduction in tCO_2e/GWh (percentage change)**		
	2000 to 2005	**2005 to 2008**	**2008 to 2011**
Renewables	-5.1 (-0.61)	8.2 (0.96)	-26.9 (-3.2)
Fossil fuel mix	-7 (-0.84)	-14.8 (-1.74)	-17.4 (-2.07)
Fuel efficiency	44.5 (5.34)*	0.2 (0.02)	-2.9 (-0.35)
Carbon intensity	-13.8 (-1.66)*	-6.4 (-0.75)	-6.1 (-0.73)
Total	**18.5 (2.22)**	**-12.9 (-1.51)**	**-53.2 (-6.34)**

Note: **Fuel efficiency between 2000 and 2005 worsens because of inconsistent data for black coal. Black coal generation falls rapidly while black coal fuel consumption stays approximately constant. The period between 2000 and 2005 likely contains statistical outliers and is therefore less useful.*

Source: *Vivid Economics based on Australian Government Bureau of Resource and Energy Economics (2013) and Australian Bureau of Statistics (2013)*

3.2.2 Explanation

A significant driver behind a decline in the emissions intensity of electricity generation is policy. Increased gas generation is partly, and renewable deployment is chiefly, driven by policies, specifically the Queensland Gas Scheme, state-wide greenhouse gas reduction efforts such as the New South Wales Greenhouse Gas Reduction Scheme and the Renewable Energy Target. Other drivers, such as movements in fuel prices, have not been as influential. The statistical analysis does not isolate the effect of changes in technology or environmental standards, but these too might contribute to changes.

The changes in the fossil fuel mix and increased renewable deployment appear to be the most important factors introduced above, accounting for -5.5 per cent out of total percentage change of -6.3 per cent and there are policies acting on both. The policy environment is set out in Table 16. A continuation of the main trends may depend on the policy environment and, to a lesser extent, on market factors such as prices: in particular, the strength of renewable energy incentives, the carbon price and the relative prices of coal and gas. Note that the Queensland Gas Scheme will cease at the end of 2013, relying instead on the national carbon pricing mechanism.

The Queensland Gas Scheme requires that 13 per cent of electricity consumed in Queensland stems from gas fired electricity generation between 2005 and 2011, and this target has risen to 15 per cent in 2011. The share of gas fired electricity generation increased by 62 per cent from 14.5 per cent to 21.9 per cent between 2009 and 2012.

In the NEM region gas-fired electricity generation rose by 36 per cent from 9.7 to 13.1 per cent of total generation in the NEM between 2009 and 2012. The Queensland Gas Scheme, introduced in 2005, mandated a 13 per cent contribution to state electricity generation from gas, which increased to 15 per cent over time. There were sharp spikes in commissioned gas-fired capacity in 2006 (of 1 GW) and 2009 (of 1.2 GW), which were associated with generation: gas-fired generation fell below target in Queensland in 2005 by 1,000 GWh, which narrowed to almost zero in subsequent years Queensland Department of Energy and Water Supply (2012).

The share of brown coal in Australian electricity generation, relatively steady up to 2011, dropped sharply in 2012-13 Climate Works (2013), Pitt and Sherry (2013), with the quantity of generation from brown coal declining from 55 TWh to 49 TWh, a 12 per cent reduction, between 2011 and 2012. This rapid and steep fall suggests that it was driven by factors other than the steady and monotonic decline in the demand for grid-generated electricity. Key candidate explanations are operational constraints such as the flooding of Yallourn power station necessitating closures amounting to 2 TWh of electricity and industrial action and fire incidents in Yallourn associated with further falls in generation as well as the introduction of the carbon price in 2012. The carbon price affects all carbon-emitting electricity generation, but is likely to have a stronger impact on brown coal, which has an emissions intensity of 1.2 tCO_2e/MWh, approximately 39 per cent higher than black coal and 167 per cent higher than gas in 2011 (Climate Works (2013).

Table 16. **Changes in electricity generation emissions intensity are driven by policy and prices affecting the fossil fuel mix and renewable incentives**

Factor changing emissions intensity	Relative importance	Main driver	Is the trend likely to continue?
Renewable deployment	1	Policy for wind, new hydro and solar; M-RET (now LRET and SRET together with solar feed-in-tariffs) Weather, specifically rainfall, for large scale hydro	An increase in renewables beyond past levels of full hydro utilisation depends on policy environment
Fossil fuel mix	2	Policy (Queensland Gas Scheme and New South Wales Greenhouse Gas Reduction Scheme) and coal seam gas development	Depending mainly on policy environment and, on fuel input prices
Carbon intensity per fuel type	3	Fuel quality, emissions counting between source and power plant	Uncertain
Fuel efficiency per fuel type	4	Utilisation, entry and exit, fleet ageing	Uncertain

Source: Vivid Economics

The following paragraphs provide more detail for each factor, describe the underlying driver and assess whether the observed trend between 2008 and 2012 might continue.

3.2.3 Fossil fuel mix

Changes in the fossil fuel mix and increased renewables deployment are the main drivers of the declining electricity generation emissions intensity between 2000 and 2011. Between 2008 and 2011 there was a significant increase in gas fired electricity generation. This contributes two fifths, approximately 2.1 per cent out of the total decline of 6.3 per cent, in electricity generation emissions intensity between 2008 and 2011, see Table 15. In addition, black coal fired generation declined between 2008 and 2011 and, in the latest available data,[8] the electricity generated from brown coal started to decline, partially due to the temporary shutdown of Yallourn brown coal power station in 2012.

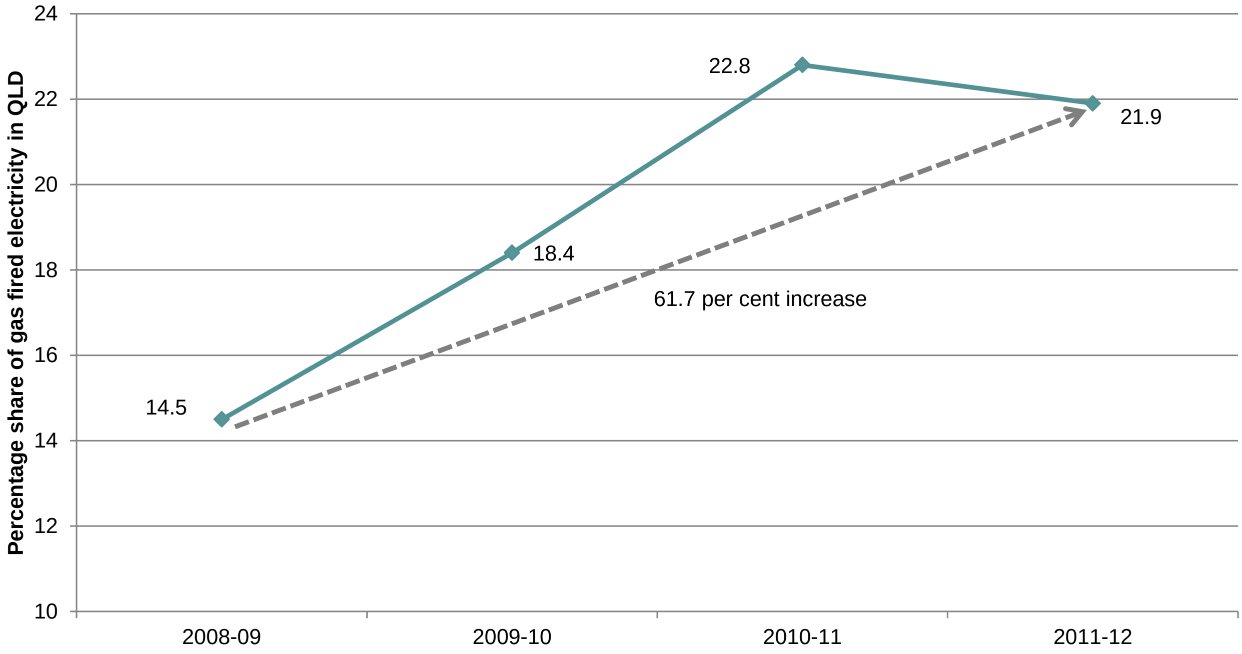
Policy decisions have been a major driver of changes in the fuel mix, especially the expansion of gas fired capacity. Gas generation was favoured in Queensland under the Queensland Gas Scheme and by efforts to reduce emissions from electricity in New South Wales via the Greenhouse Gas Reduction Scheme.

The Queensland Gas Scheme started in 2005 and is due to end in 2013 and during this period the share of gas fired electricity generation increased from 14.5 in 2009 to 21.9 per cent in 2012, as shown in Figure 6. The Queensland Gas Scheme required that 13 per cent of all electricity consumed is sourced from gas fired electricity generation. Queensland was particularly suited for this as it is the largest producer of gas from

[8] 2011/12 and 2012/13 electricity generation data is available for the NEM region from AEMO but not captured in the BREE or AGEIS datasets and therefore not included in the statistical analysis.

coal seams in Australia. The scheme is scheduled to close in 2013 as the carbon price mechanism provides additional incentives for emissions reductions and encourages gas.

Figure 34. **Gas generation share in Queensland between 2009 and 2012 has increased substantially**

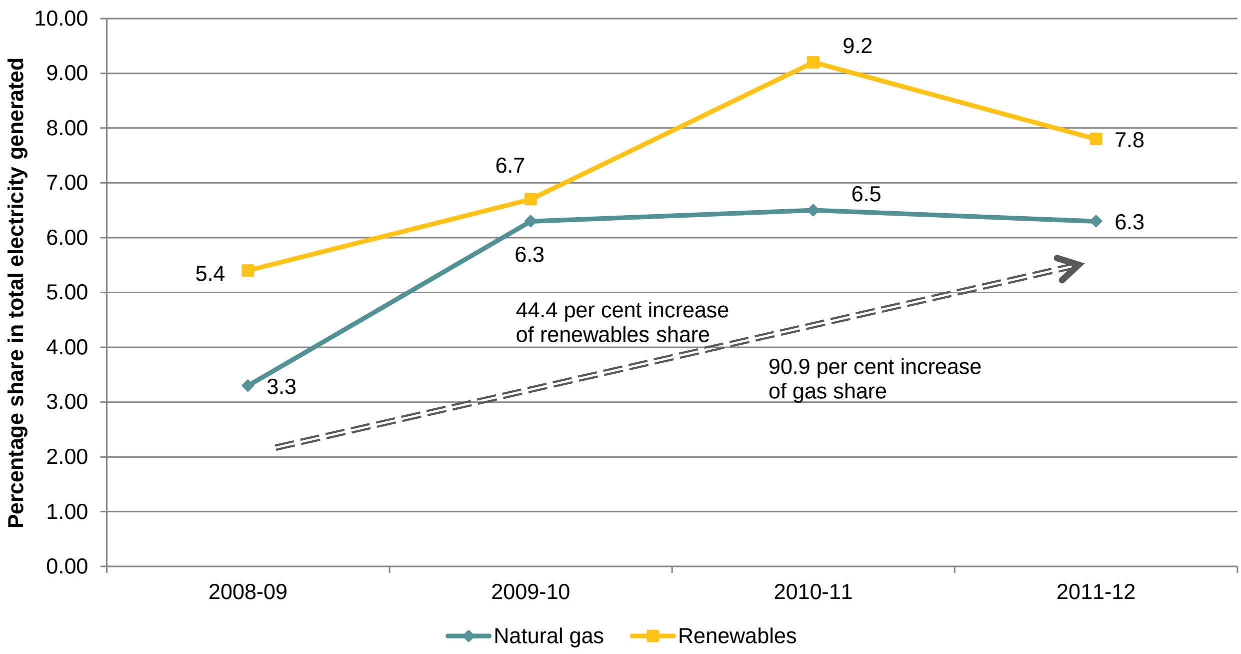


Note: *Share of gas-fired electricity generation in Queensland.*

Source: *Vivid Economics based on Australian Government Bureau of Resource and Energy Economics (2013)*

The New South Wales Greenhouse Gas Reduction Scheme started in 2003 and sets targets for the emissions intensity of electricity supply in New South Wales. These targets are a per-capita emissions benchmark of 8.5 tCO_2e between 2003 and 2007, decreasing to 7.3 tCO_2e after 2007. Gas and renewables contribute to the lower emissions intensity of electricity supply and this scheme encourages their deployment. The share of gas and renewable generation in New South Wales increased from 8.7 per cent in 2009 to 14.1 per cent in 2012 as shown in Figure 7.

Figure 35. **In New South Wales, both gas and renewables increased their share in the generation mix**



Note: *Share of gas fired electricity generation and renewable electricity in New South Wales.*

Source: *Vivid Economic based on Australian Government Bureau of Resource and Energy Economics (2013)*

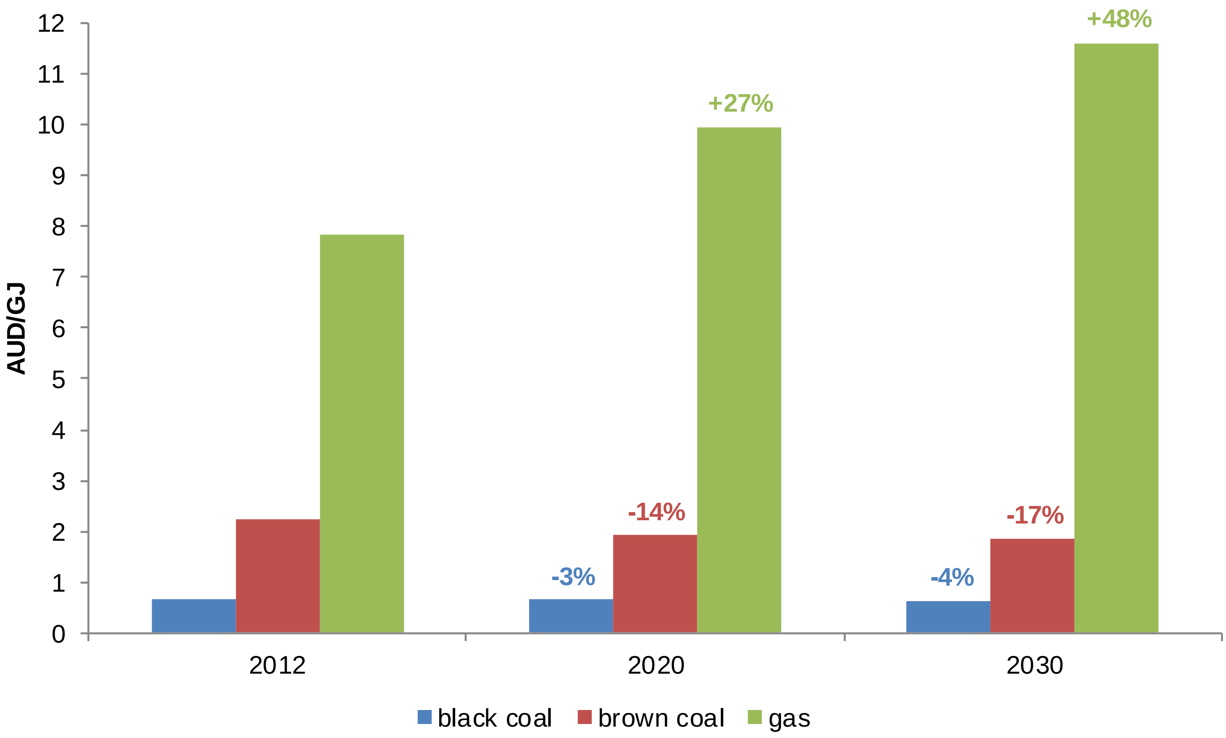
Changes in the prices of gas and coal in electricity generation were statistically insignificant; however, the actual coal and gas price paid by electricity generators might differ from market (export) prices and the analysis does not capture this.

The shape of the load duration curve, that is, the peakiness of demand, is unlikely to have had an effect on increased gas fired generation. The load shape has been relatively constant between 2000 and 2011.

The carbon price enacted in July 2012 post-dates the dataset. Nevertheless, policies raising the cost of emissions will favour lower emission electricity generation. This could partially offset higher fuel input prices of lower-carbon fuels compared with other fossil fuels as gas prices are projected to rise significantly compared with black and brown coal prices AEMO NEFR (2013). Gas prices are projected to increase by approximately 42 per cent until 2020 whereas coal prices are projected to stay constant, as shown in Figure 10. Unless the carbon price increases significantly, black and brown coal will continue to have a price advantage over gas fired electricity generation.

Thus the continuation of the trend of increased gas fired electricity generation appears to depend mainly on policies such as state and nationwide emissions reductions schemes and the carbon price. The expansion of gas fired electricity generation since 2008 is mainly driven by policy decisions and unless policies like the carbon price mechanism incentivise gas fired electricity sufficiently through a relatively high carbon price, increases in gas fired electricity generation may not continue. Nevertheless, gas represents approximately 30 per cent (8 GW) of all commissioned power plants between 2013 and 2016, whereas black and brown coal combined constitute less than 6 per cent (1.5 GW).

Figure 36. **Gas prices are projected to rise between today and 2030 whereas black and brown coal prices are constant and decreasing respectively**

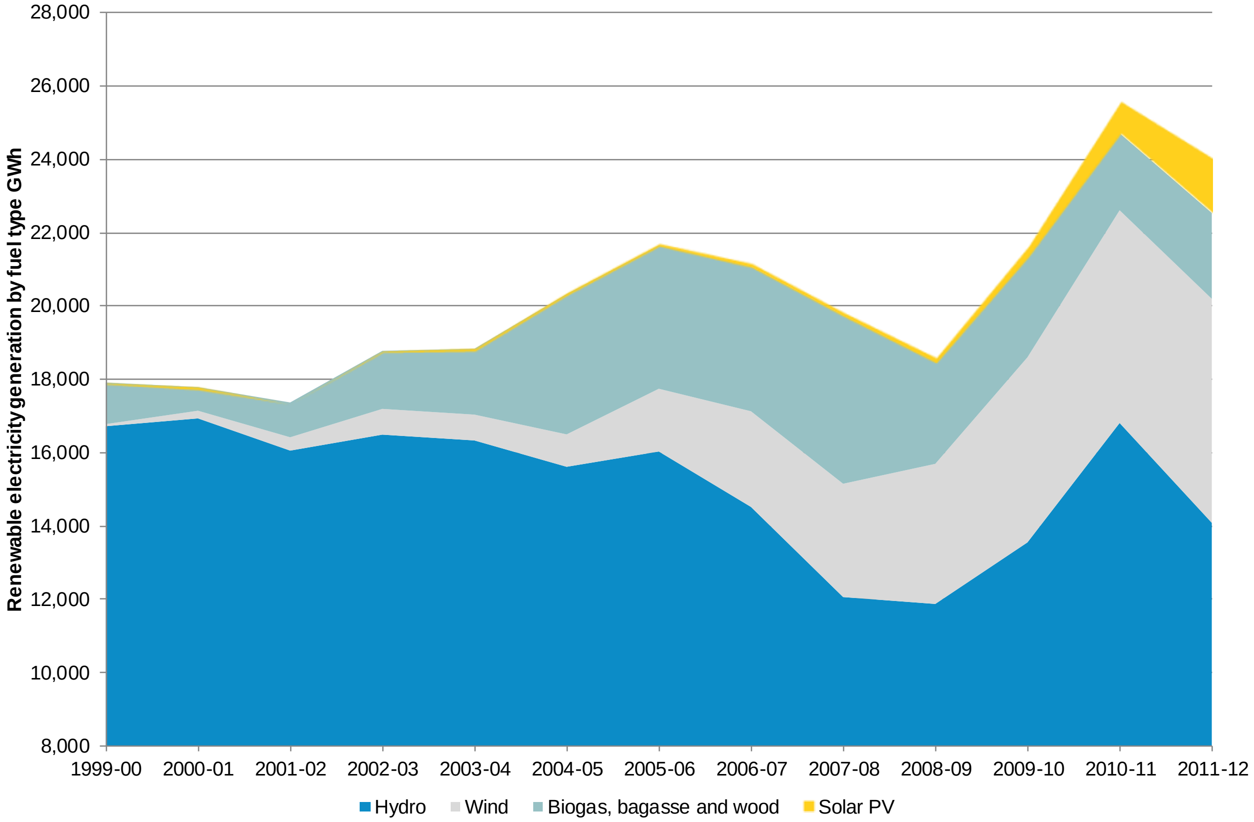


Source: *ACIL Tasman (2012) and BREE (2012a)*

3.2.4 Renewable generation

Renewable generation has increased by 34 per cent between 2000 and 2012. It is the main driver of decreasing electricity supply generation emissions intensity and in the third period, 2009 and 2012, it contributed approximately 3.2 per cent out of the total decline of electricity generation emissions intensity of 6.3 per cent. Hydro and wind are the most important sources between 2009 and 2012, as shown in Figure 37. Detailed shares for each renewable type are provided in Table 17.

Figure 37. **Renewable generation grew by 44 per cent between 2000 and 2012, supported by the LRET SRET policies**

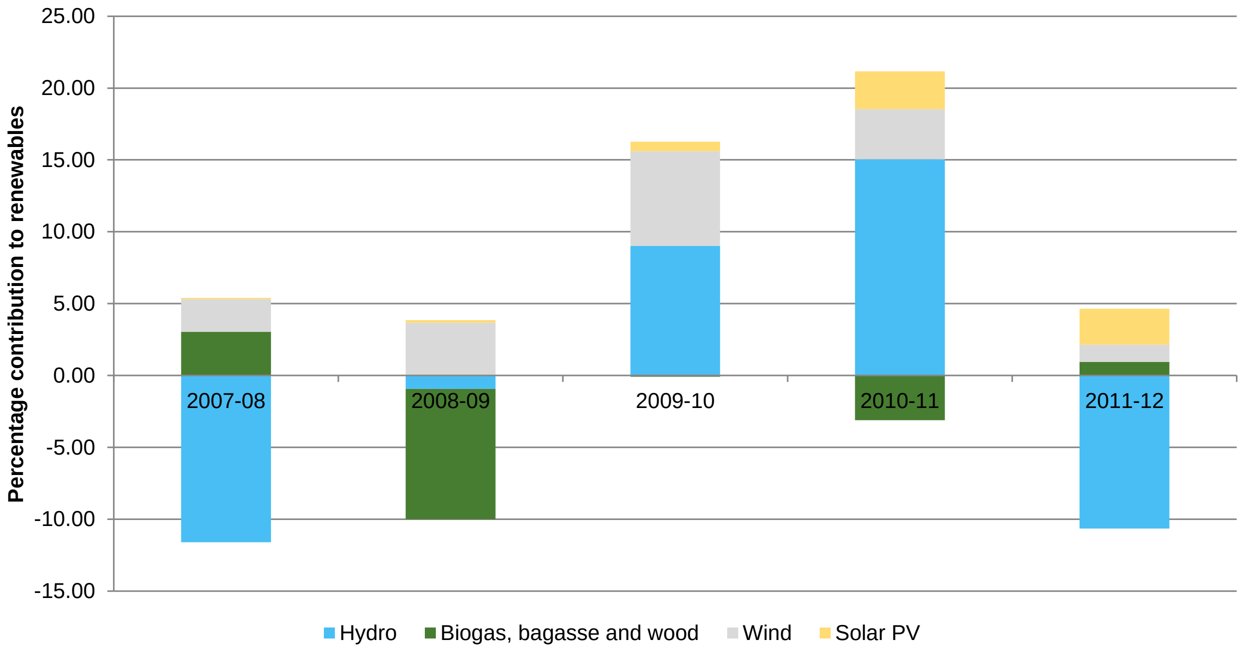


Note: *Lower hydro generation between 2007 and 2010 is due to drought conditions.*

Source: *Vivid Economics based on Australian Government Bureau of Resource and Energy Economics (2013)*

Renewable growth was steady over the 2008 to 2011 period. Hydro growth contributed 58 per cent, wind growth 33 per cent and solar PV added a further 9 per cent. Hydro exhibits inter-year variation in response to precipitation.

Figure 38. **The contribution of solar PV increased steadily from 2009**



Note: *Yearly percentage contribution to renewable electricity growth rate.*

Source: *Vivid Economics based on Australian Government Bureau of Resource and Energy Economics (2013).*

Table 17. **Wind generation has steadily gained a larger share of all renewable generation**

Renewable	Share of all renewables (per cent) 2000	2008	2012
Hydro	93.1	60.7	58.6
Wind	0.3	15.6	25.4
Biogas, bagasse and wood	6.3	23.1	9.75
Solar PV	0.2	0.6	6.20

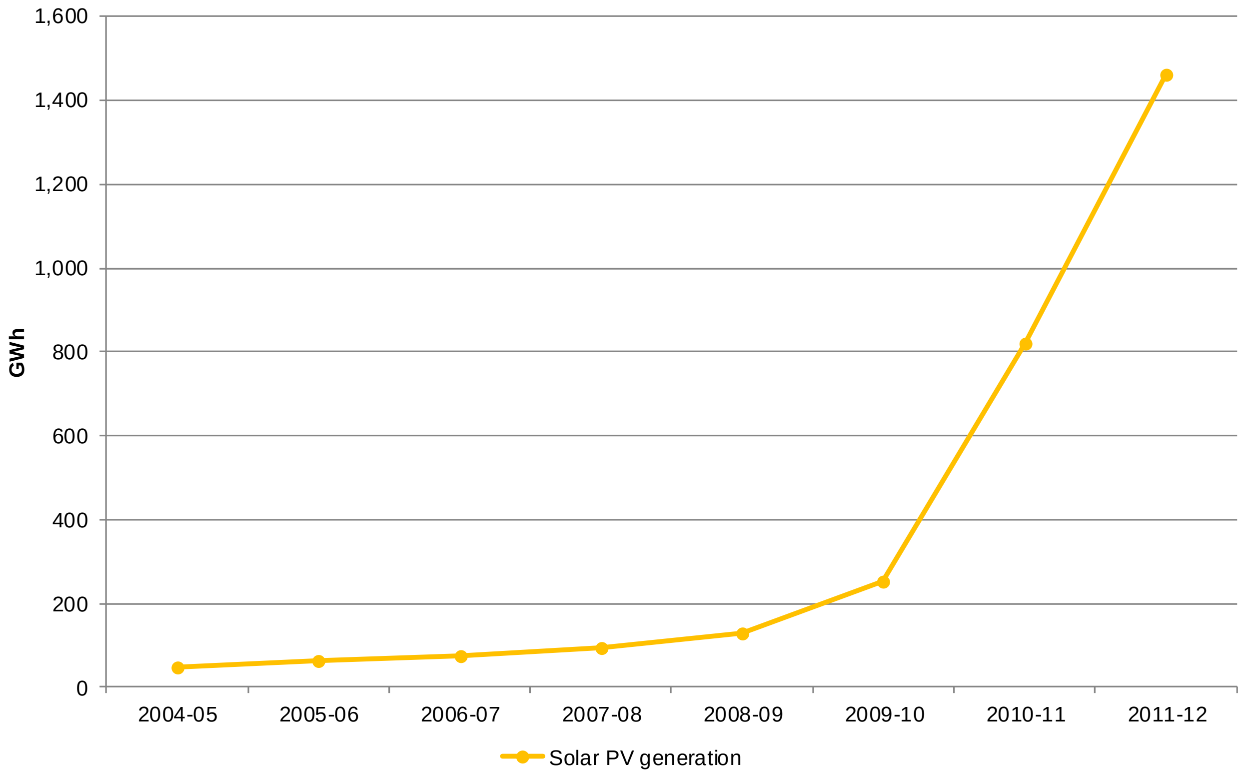
Source: *Vivid Economics based on Australian Government Bureau of Resource and Energy Economics (2013)*

Wind generation represented 25.4 per cent of renewable generation in 2012. Its share has been rising, from 15.6 per cent of all renewables in 2008, due to the mandatory renewable energy target.

Solar PV represents 6.2 per cent of renewable generation in 2012 and its share has risen from 0.5 per cent of all renewables in 2008, mainly due to policy support in the form of a feed-in tariff. The Small-scale

Renewable Target, and previously the Mandatory Renewable Energy Target, are the main drivers behind an increase in solar PV. Most of the capacity was installed after the introduction of the small scale renewable target and solar credit scheme in 2009, as shown in Figure 39.

Figure 39. **Solar PV took off after the introduction of the SRET in 2009**

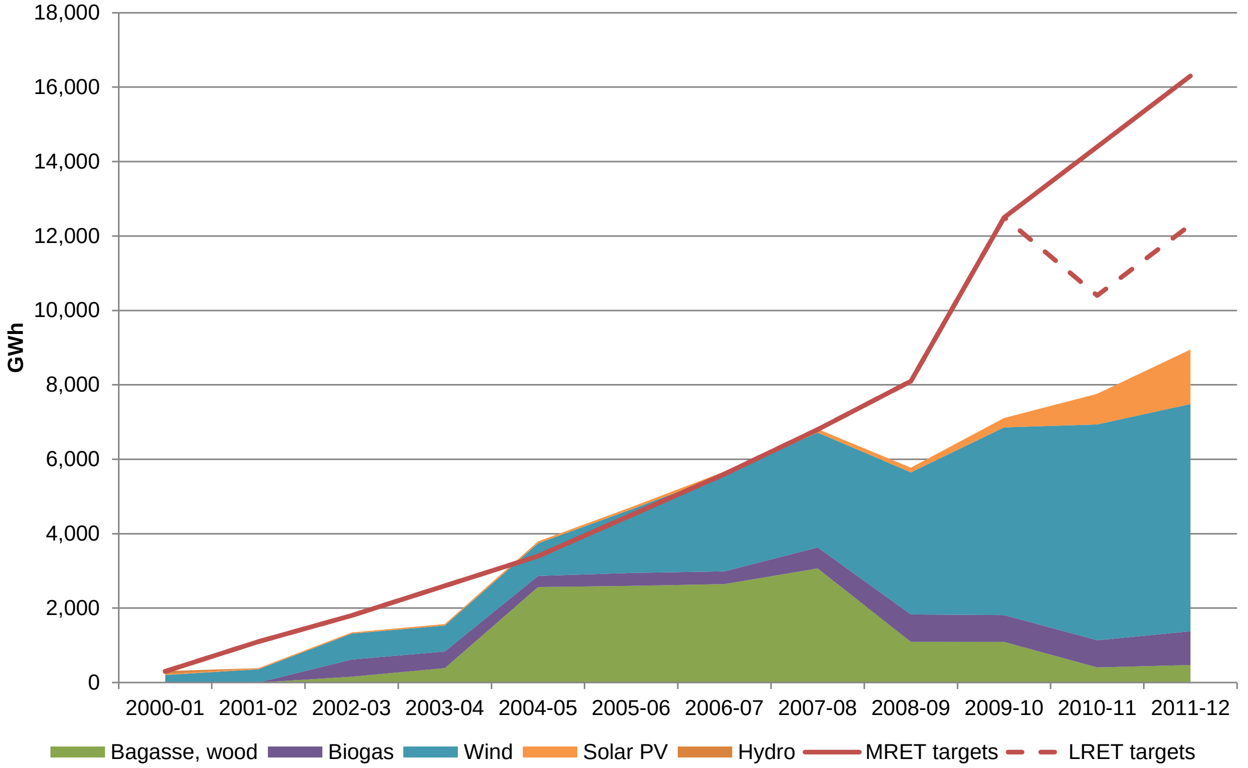


Note: *The solar credit scheme to incentivise solar PV reduces its incentive level over time.*

Source: *Vivid Economics based on Australian Government Bureau of Resource and Energy Economics (2013)*

Renewable deployment is mainly driven by the Mandatory Renewable Energy Target (M-RET). The M-RET demands that a specified share of overall electricity generation is met by renewable energy. Figure 40 shows total renewable generation since 2001 and the corresponding M-RET target.

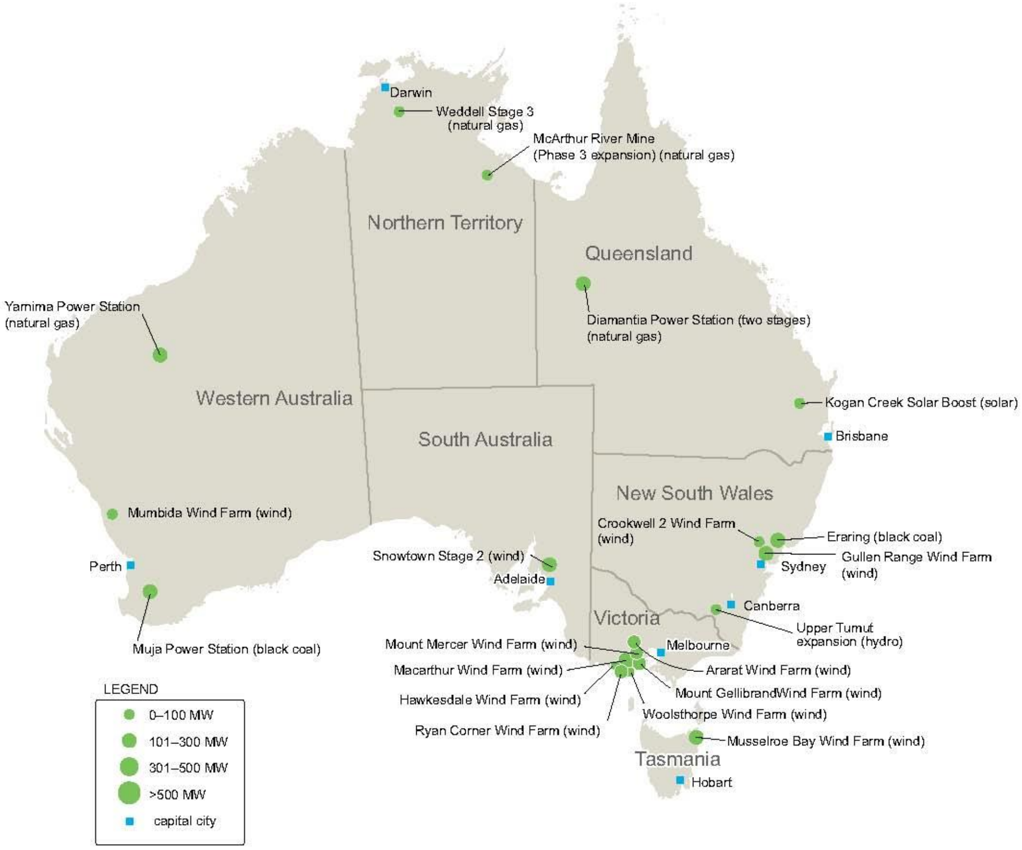
Figure 40. **Rapid growth in renewable generation is a consequence of the Mandatory Renewable Energy Target**



Note: *Renewable generation counts towards the M-RET if it exceeds its own average generation between 1994-95 and 1996-97. This means that all renewables constructed after 1996-97 are eligible for fulfilling the M-RET target whereas older renewable assets, which are primarily hydro and to a lesser extent bagasse and wood, have to exceed past generation levels to obtain support. In addition, waste coal mine gas is included in the M-RET, whereas wood from natural forests is excluded, which leads to a divergence of total M-RET-eligible generation from this chart and might explain the shortfall since 2009 as RET certificates have essentially been fully taken up since 2009.*

Source: *Vivid Economics*

Figure 41. **Wind represents majority of large electricity new generation projects by capacity in the NEM**



Note: *Renewable generation has significantly lower capacity factors compared with non-renewable, and therefore a large capacity increase compared with non-renewable generation does not translate into an equivalent generation increase.*

Source: *Australian Government Bureau of Resources and Energy Economics (2012)*

3.2.5 Carbon intensity

Carbon intensity is the amount of emissions released by burning one thermal energy unit (Joule) of fossil fuel; it captures changes in the emissions intensity within a fuel type. The energy units here are net of the heat of vaporisation of water, that is to say they state the thermal energy that is released during combustion and available to do useful work.

A reduction in carbon intensity contributed approximately 11.5 per cent to the total electricity generation emissions intensity reduction between 2008 and 2012. In terms of the percentage reduction of electricity generation emissions intensity of 6.3 per cent, reduction in carbon intensity contributed 0.73 per cent.

There is little evidence collected during this work to explain this effect. It is possible that changes in carbon intensity within fuel types are the result of changes in fuel quality arising from variation in fuel sources, but there could be other explanations.

3.2.6 Fuel efficiency

Fuel efficiency measures how much electricity is generated per unit of fossil fuel input within each fuel type; it captures changes in the efficiency of plants within a fuel type.

Fuel efficiency increase electricity generation emissions by approximately 5.5 per cent between 2008 and 2011, offsetting parts of the gains achieved by changes in the fuel mix and increased renewable deployment.

The large negative fuel efficiency between 2001 and 2006 is due to a sharp decline in the electricity produced from black coal without corresponding changes in the amount of black coal used as an input in electricity generation as shown in Figure 15.

Figure 42. **Black coal generation corresponds closely to black coal input, except for the previously identified outliers between 2000 and 2002**

Note: *Electricity generation from black coal fell sharply in 2002 while black coal fuel input increased.*

Source: *Vivid Economics based on Australian Government Bureau of Resource and Energy Economics (2013)*

The contribution of the fuel efficiency effect to overall emissions intensity has been minimal and is dwarfed by the effects of changing the fossil fuel mix and increased renewable deployment.

3.3 Summary of results

The main results from the analysis are summarised in Box 3.

Box 3. **The emissions intensity of electricity generation depends largely on policies**

Emissions from electricity generation between 2008 and 2011 have decreased by 5.5 Mt (2.7 per cent). There are two factors at work:

- decline in the emissions intensity of electricity generation, which fell by 6.3 per cent over the period; and
- growth in electricity generation, which increased emissions by 3.8 per cent.

The 6.3 per cent decline in emissions intensity of electricity generation in this period can be decomposed into:

- 3.1 per cent from increased renewable generation;
- 2.1 per cent from an increased share of gas in the generation mix; and
- 1.1 per cent from other effects.

Within renewables, hydro contributes 58 per cent to a reduction in emissions intensity, almost twice as much as wind with 33 per cent, and almost seven times as much as solar PV with 9 per cent. The reduction in emissions intensity achieved by increased wind generation is almost offset by a decrease in biogas, bagasse and wood generation. Wind and solar PV, representing 42 per cent of the total contribution of renewables to decreases in the electricity generation emissions intensity, are driven by policy whereas hydro, the remaining 58 per cent, is driven by changes in rainfall and only for new projects, particularly small scale hydro, by policy.

Within fossil fuels, the 2.1 per cent decrease in emissions intensity is likely to be due to an increased share of gas in the generation mix, which was in part driven by the Queensland Gas Scheme and the New South Wales Greenhouse Gas Reduction Scheme.

4 Economy-wide emissions

Explaining the decline in economy-wide emissions since 2008

Section contents:

Economy-wide emissions including LULUCF fell rapidly between 2008 and 2011

Although economy-wide emissions as measured by the Kyoto Protocol accounting framework did not fall between 1990 and 2011, emissions intensity declined between 2000 and 2011 as the economy restructured away from emissions-intensive subsectors in manufacturing and mining towards less emissions subsectors, particularly commercial and services.

‘Emissions in 2011 are virtually on the same level as in 1990.’

4.1 Emissions

Economy-wide emissions based on the Kyoto Protocol accounting framework are used in this analysis instead of using the United Nations Framework Convention on Climate Change (UNFCCC) framework as the Kyoto Protocol accounting framework missions allow for a sectoral split according to ANZSIC sector definitions, which emissions according to UNFCCC framework do not.

Overall emissions measured according to the Kyoto Protocol accounting framework including land use, land-use change and forestry (LULUCF) rose by 4.7 per cent, 0.3 per cent per year, between 1990 and 2008, then declined from a peak in 2008 by 3.7 per cent, 1.2 per cent per year, as shown in Figure 43.

Figure 43. **Emissions excluding LULUCF have risen since 1990 and stabilised after 2008**

Note: *Land use, land-use change and forestry (LULUCF) emissions are available only in 1990 and from 2008.*

Source: *Vivid Economics based on AGEIS (2013)*

Declining emissions from LULUCF is the main reason for the emissions reductions of 21,400 $MtCO_2e$ or 3.7 per cent between 2008 and 2011. Within LULUCF, a decline in deforestation and increases in afforestation and reforestation are the reasons for declining LULUCF emissions. Deforestation fell, particularly in Queensland and Tasmania.

Excluding LULUCF, emissions rose by 32 per cent, 1.3 per cent per year, between 1990 and 2011, far quicker than overall emissions, as shown in Table 18 and Figure 43. The growth rate in emissions excluding

LULUCF declined to 0.1 per cent per year between 2008 and 2011 and the absolute rise in emissions excluding LULUCF between 2008 and 2011 was only 0.35 per cent.

Table 18. **The growth rate of economy-wide emissions excluding LULUCF slowed from 2008**

Economy-wide emissions	Unit	First period 2000 to 2008	Second period 2008 to 2011	Whole period 2000 to 2011
Excluding LULUCF	change over period, $MtCO_2e$	57	2	59
	change over period, %	11.6	0.35	12
	CAGR, %	1.38	0.12	1.0
Including LULUCF	change over period,$MtCO_2e$		-21	
	change over period,%		-3.7	
	CAGR, %		-1.24	

Note: *Emissions including LULUCF figures are reported for comparison.*

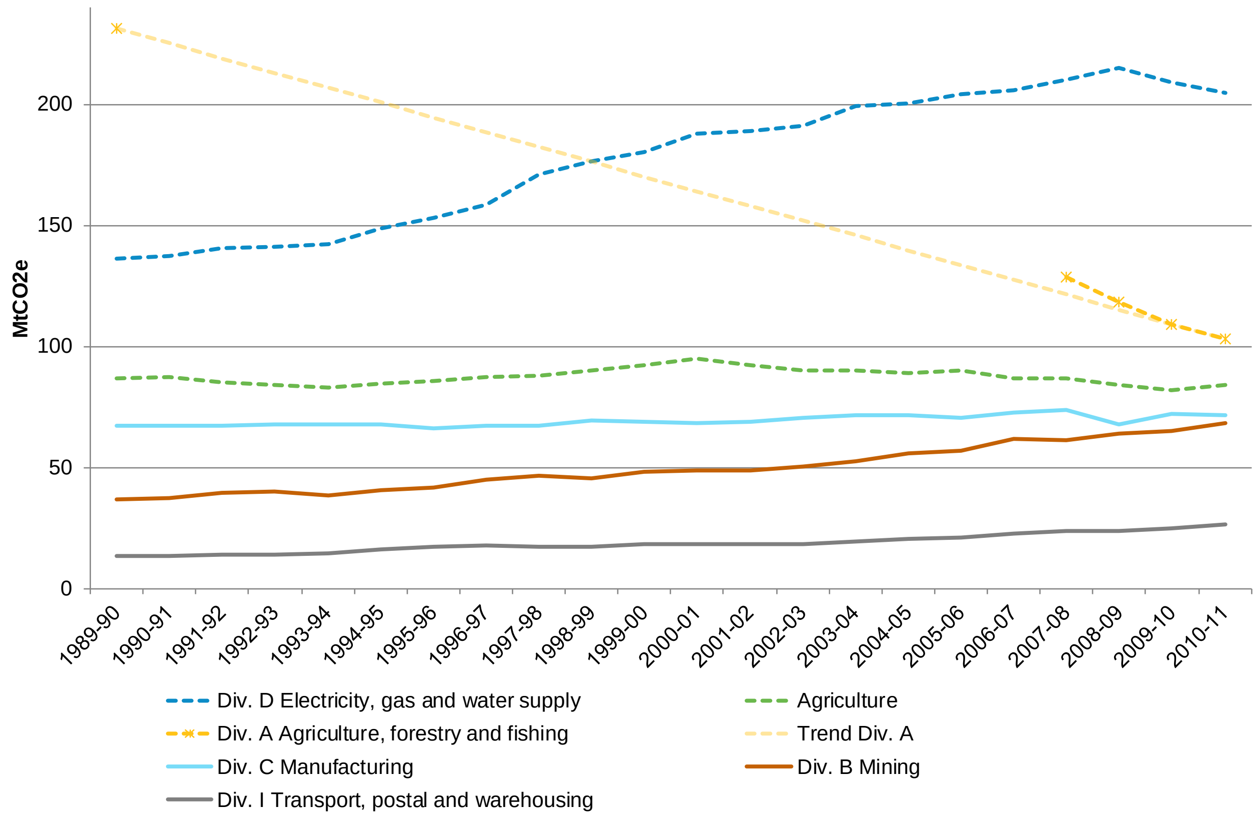
Source: *Vivid Economics based on AGEIS (2013)*

4.2 Emissions by sector

Within emissions excluding LULUCF, electricity (Div. D), manufacturing (Div. C) and mining (Div. D) are the main sources of emissions, as shown in Figure 44, each contributing 38, 13 and 13 per cent respectively of all emissions in 2011, excluding LULUCF.

Emissions from manufacturing and electricity emissions have increased over the whole period, except for the last few years, when they declined, whereas emissions from residential, mining and the remaining sectors increased throughout the whole period, see Figure 44 and Table 19.

Figure 44. **Emissions from mining and Div. I Transport are rising faster than from other sectors.**



Note: *Data for Div. A is available after 2008 only.*

Source: *Vivid Economics based on AGEIS (2013)*

Table 19. **Manufacturing and electricity emissions growth rates in the period 2008 to 2011 have turned negative**

Sector	Compound annual growth rate (CAGR) of emissions			
	2000 to 2005	2005 to 2008	2008 to 2011	2000 to 2011
Div. A Agriculture, forestry and fishing	not available	not available	-7.08	not available
Agriculture	-0.69	-0.91	-0.98	-0.83
Div. B Mining	3.03	3.13	3.72	3.25
Div. C Manufacturing	0.75	1.09	-0.95	0.38
Div. D Electricity, gas and water supply	2.01	1.60	-0.84	1.15
Div. E Construction	0.16	1.52	0.45	0.61
Div. I Transport, postal and warehousing	2.30	5.59	3.51	3.52
Commercial	-0.81	2.02	0.47	0.30
Residential	2.37	0.49	0.71	1.40
Total including LULUCF			-1.24	
Total excluding LULUCF	1.42	1.31	0.12	1.03

Notes: *Emissions from Div. A, Agriculture, are available only after 2008. The Agriculture sector is a sub-division of sector Div. A Agriculture, forestry and fishing.*

Source: *Vivid Economics based on AGEIS (2013)*

Table 20. **Agriculture subsector and Div. D Electricity, gas and water supply have helped reduce economy-wide emissions in the 2008 to 2011 period**

Sector	**Weighted growth rate of emissions**			
	2000 to 2005	2005 to 2008	2008 to 2011	2000 to 2011
Agriculture*	-0.64	-0.46	-0.47	-1.66
Div. B Mining	1.59	1.04	1.31	4.16
Div. C Manufacturing	0.54	0.45	-0.38	0.60
Div. D Electricity, gas and water supply	4.05	1.87	-0.97	4.98
Div. E Construction	0.01	0.07	0.02	0.11
Div. I Transport, postal and warehousing	0.45	0.69	0.48	1.71
Commercial and services	-0.22	0.30	0.07	0.18
Residential	1.16	0.14	0.21	1.55
Total	7.31	3.97	0.35	11.96

Notes: *Sector contribution to total emission percentage growth (excluding LULUCF). * This sector includes emissions from Enteric Fermentation, Manure Management, Rice Cultivation, Agricultural Soils, Prescribed Burning of Savannas and Field Burning of Agricultural Residues.*

Source: *Vivid Economics based on AGEIS (2013)*

Emissions from agriculture rose between 1990 and 2001, driven by a combination of operational inputs (increased fertiliser use) and expansion (savannah burning) (UNFCCC, 2010),(UNFCCC, 2013). Between 2002 and 2010, adverse weather conditions led to reduced activity and lower emissions (UNFCCC, 2013). With the cessation of the drought in more recent years, farmers are beginning to rebuild livestock populations and increase crop production and fertiliser use, and associated emissions are increasing.

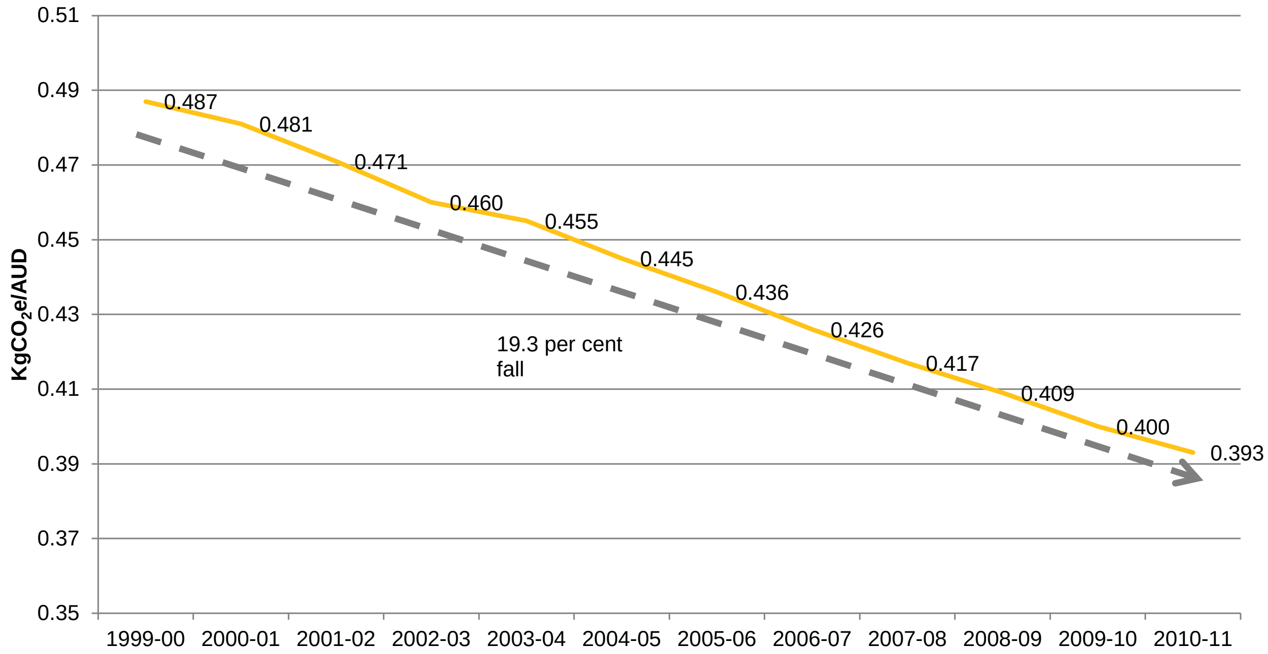
Between 1990 and 2011, LULUCF net emissions have declined from 106.3 $MtCO_2e$ to -40.3 $MtCO_2e$ (a reduction of 138 per cent), (UNFCCC, 2013). This reduction is largely driven by the conversion of forestry land to grassland and land for crops. Seasonal variability and weather incidents such as wildfire also contribute to changes in LULUCF emissions.

Emissions from electricity fell by -2.7 per cent (-0.9 per cent per year) between 2008 and 2011, which can be broken down to a 6.5 per cent (-2.2 per cent per year) decline due to decreases in the electricity generation emissions intensity and a subdued growth in electricity consumption in all of Australia down to 3.8 per cent (1.3 per cent per year) from 6.3 per cent (2.1 per cent per year) between 2005 and 2008. The lower growth in electricity consumption stems from decreased electricity consumption in the NEM while consumption increased elsewhere, particularly in Western Australia.

4.3 Emissions intensity

The emissions intensity of Australia fell by 14 per cent, 1.9 per cent per year, between 2000 and 2008 and by 5.6 per cent, 1.9 per cent per year, between 2008 and 2011, as shown in Figure 45.

Figure 45. **The economy-wide emissions intensity has been steadily declining between 2000 and 2011 at a rate of 1.9 per cent per year**

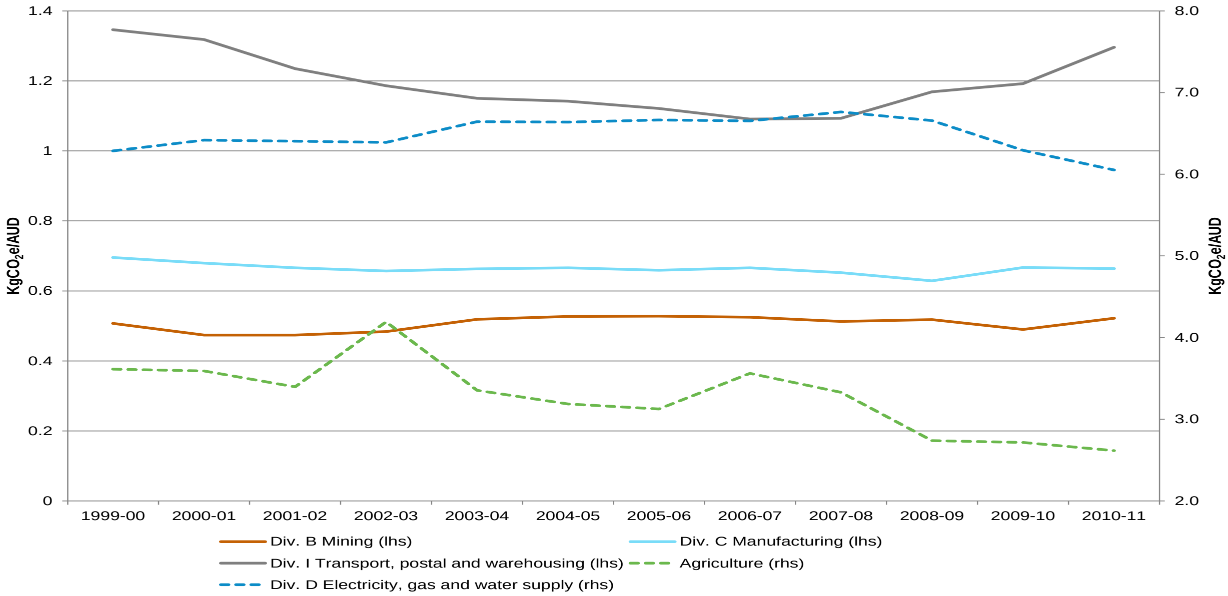


Note: *Overall emissions intensity in economy-wide CO_2e emissions over real GDP in AUD.*

Source: *Vivid Economics based on BREE (2013) and ABS (2013)*

Electricity supply and agriculture have shown the biggest decrease in emissions intensity as shown in Figure 46.

Figure 46. **Agriculture and electricity supply have seen declining emissions intensity in the last period**



Note: *Emissions intensity per sector is CO_2 equivalent gas emissions in kg over sector's real GVA.*

Source: *Vivid Economics based on Australian Government National Greenhouse Gas Inventory (2013) and Australian Government Bureau of Resource and Energy Economics (2013)*

The emissions intensity of manufacturing fell from 0.7 ktCO_2e/AUD in 2000 to 0.66 ktCO_2e/AUD in 2011. In the same period, the emissions intensity of mining increased from 0.51 ktCO_2e/AUD to 0.52 ktCO_2e/AUD and the emissions intensity of commercial and services fell from 0.056 ktCO_2e/AUD to 0.04 ktCO_2e/AUD as shown in Table 21.

Table 21. **Div. D Electricity and Agriculture have seen intensity fall sharply between 2008 and 2011.**

Variable	Emissions intensity ($kgCO_2e$/AUD)		
	2000	**2008**	**2011**
Agriculture	3.613	3.330	2.617
Div. B Mining	0.507	0.513	0.522
Div. C Manufacturing	0.696	0.652	0.664
Div. D Electricity, gas and water supply	6.286	6.763	6.053
Div. I Transport, postal and warehousing	1.346	1.093	1.296
Commercial	0.056	0.042	0.040
Residential	0.065	0.055	0.053

Notes: *Emissions intensity per sector is CO_2 equivalent gas emissions in kt over sector's real GVA; (for residential final consumption expenditure is used instead). Agriculture subsector does not include LULUCF.*

Source: *Vivid Economics based on AGEIS (2013)*

4.4 Decomposition of economy-wide emissions

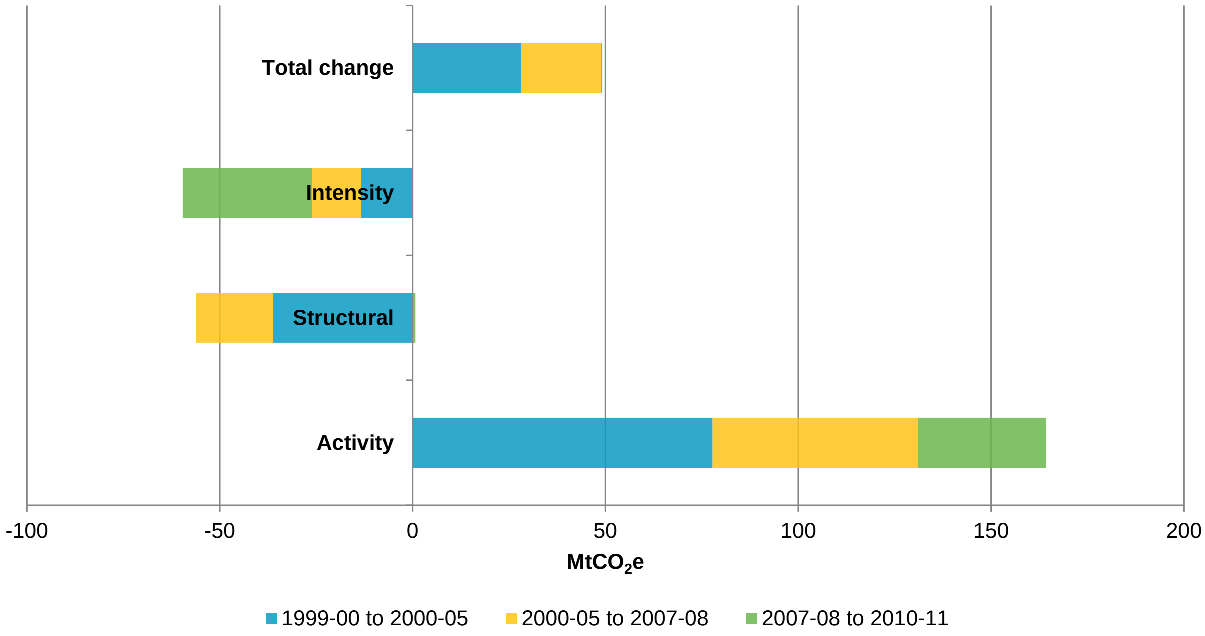
To determine the drivers of changes in economy-wide emissions intensity, the LMDI and Laspeyres decomposition methods are used. For brevity, only the LMDI decomposition results are included in the text. For a treatment of the difference between LMDI and Laspeyres, see Section 6.

The result is a breakdown of the change in economy-wide emissions into three effects:

- **activity effect** (ΔE_{acti}): the change in economic activity across the whole economy;
- **structural effect** (ΔE_{str}): the change in economy emissions due to a restructuring of the shares of subsectors of the economy;
- **intensity effect** (ΔE_{int}): the change in economy emissions due to changes of structure or efficiency within subsectors of the economy.

Restructuring between sectors and subsectors, the structural effect, and efficiency changes within subsectors, the intensity effect, helped to offset higher emissions due to increased economic activity over the whole period, 2000 to 2008. In the last part of the period, from 2008 and 2011, the within subsectors intensity effect was larger than before, implying that subsectors themselves have become less emissions intensive. However, the effect between sectors and subsectors, the structural effect, has in recent years contributed little, in contrast to the period 2000 to 2008, when it gave a stronger effect, as shown in Figure 47 and Figure 48.

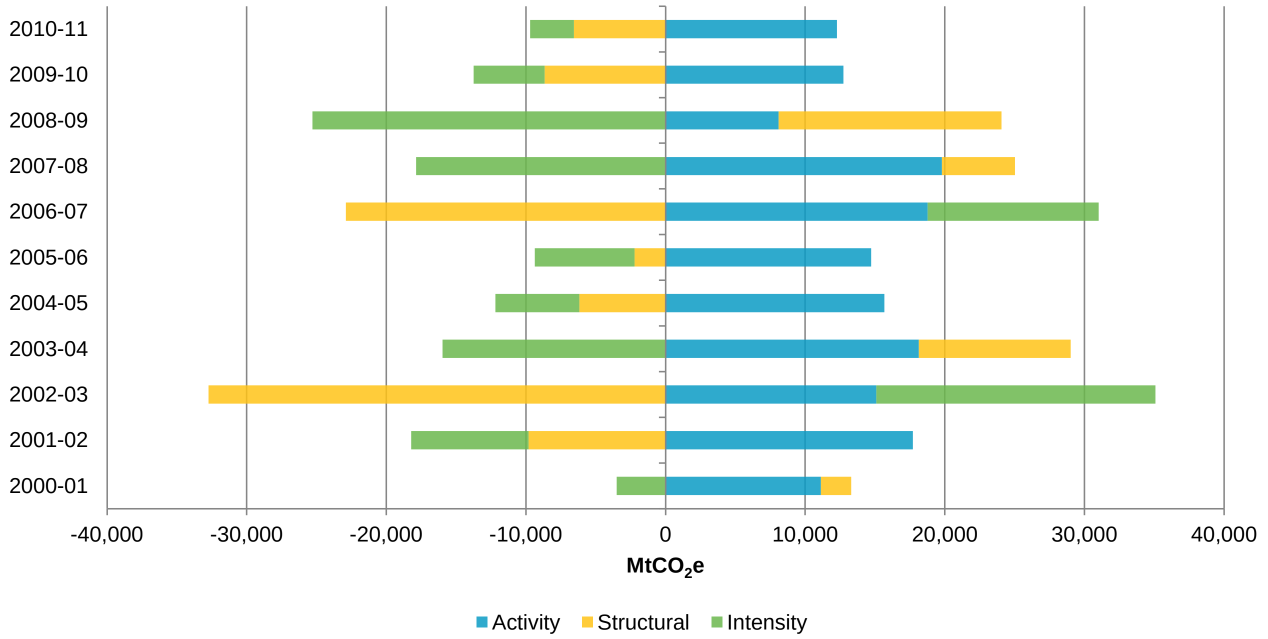
Figure 47. **The intensity effect was greatest from 2008 to 2011, when it contributed a 7 per cent reduction in emissions**



Note: *LMDI decomposition of economy-wide emissions by sectors and subsectors (excluding residential emissions).*

Source: *Vivid Economics based on Australian Government National Greenhouse Gas Inventory (2013) and Australian Government Bureau of Resource and Energy Economics (2013)*

Figure 48. **The intensity effect reduced emissions in almost every year since 2000**



Note: *LMDI decomposition of economy-wide emissions by sectors and subsectors (excluding residential emissions).*

Source: *Vivid Economics based on Australian Government National Greenhouse Gas Inventory (2013) and Australian Government Bureau of Resource and Energy Economics (2013)*

The activity effect slowed down between 2008 and 2011, adding only 6.9 per cent to economy-wide emissions compared with 12 per cent between 2005 and 2008, as shown in Table 22. This reflects the economic slowdown associated with the global financial crisis.

Restructuring from emissions intensive sectors to less emissions intensive sectors reduced economy-wide emissions by 4.7 per cent between 2005 and 2008, but this effect mildly reversed after 2008, when it increased economy-wide emissions by 0.3 per cent.

Individual sectors have become significantly less emissions intensive which, together with a decreased economic growth, have contributed significantly to the slowing down of emissions growth between 2008 and 2011 compared with previous periods as shown in Table 22.

Table 22. **Increased economic activity has been partially offset by structural change and reduced intensity**

		First period	Second period	Third period	Whole period
Effect	**Unit**	**2000 to 2000-05**	**2005 to 2008**	**2008 to 2011**	**2000 to 2011**
Activity	$MtCO_2e$	78	53	33	164
	change over period, %	18	11	6.7	37
Structural	$MtCO_2e$	-36	-20	0.7	-55
	change over period, %	-8.2	-4.2	0.1	-12.5
Intensity	$MtCO_2e$	-13	-13	-36	-60
	change over period, %	-3.0	-2.7	-6.8	-13.5
Total	$MtCO_2e$	28	21	0.3	49
	change over period, %	6.4	4.4	0.1	11

Note: *Subsectoral LMDI decomposition of economy-wide emissions in kt of CO_2 equivalent gases.*

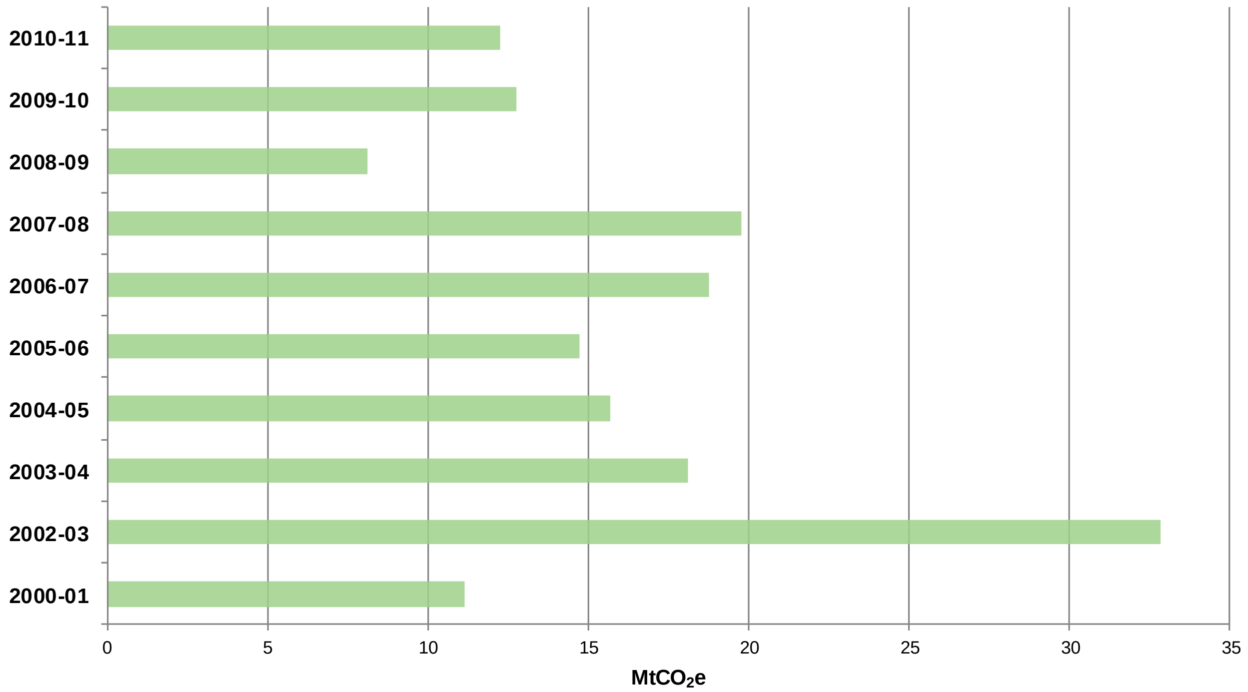
Source: *Vivid Economics based on Australian Government National Greenhouse Gas Inventory (2013) and Australian Government Bureau of Resource and Energy Economics (2013)*

The next three sub-sections 4.4.1, 4.4.2 and 4.4.3 analyse how the structural and intensity effects have influenced economy-wide emissions.

4.4.1 Activity effect

The activity effect has been lower in the period 2008 to 2011 because of the economic slowdown since 2008, as can be seen from Figure 49. The CAGR for the period is 2.9 per cent.

Figure 49. **A lower activity effect between 2009 and 2011 from the global economic slowdown after 2008**



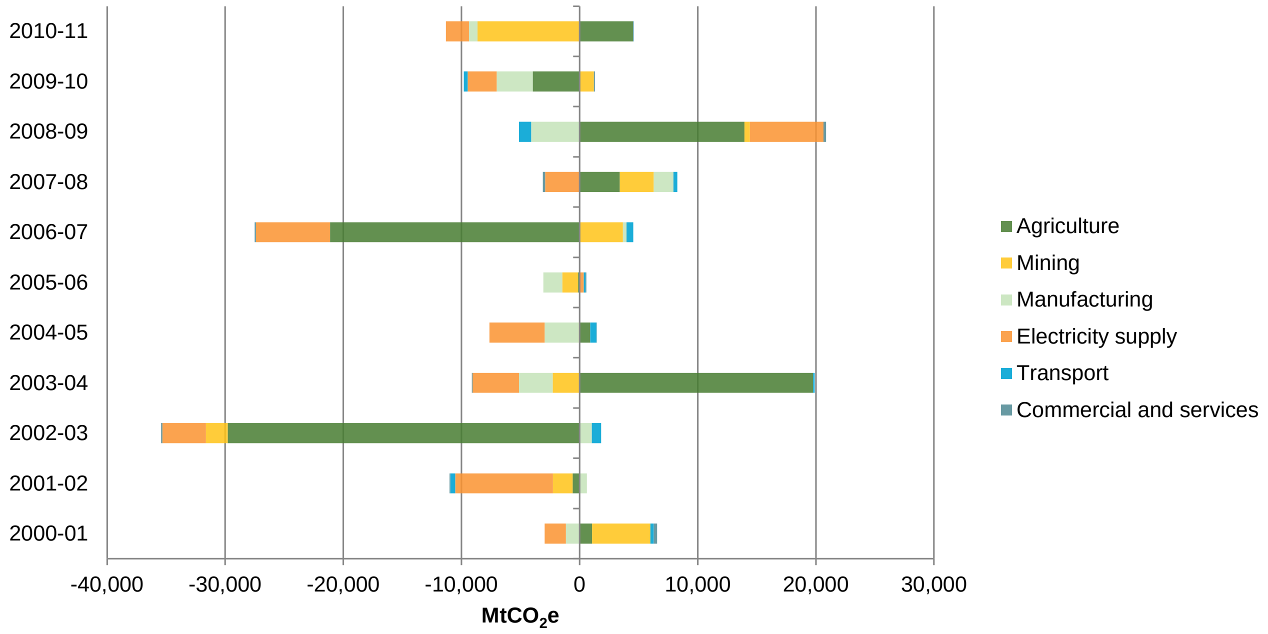
Notes: *LMDI decomposition of economy-wide emissions by subsectors. Activity effect of main sector is recovered by summing relevant subdivisions.*

Source: *Vivid Economics based on Australian Government National Greenhouse Gas Inventory (2013) and Australian Government Bureau of Resource and Energy Economics (2013)*

4.4.2 Structural effect: restructuring between sectors

The structural effect contributed to offsetting higher economic activity through the first two periods until 2008, as shown in Figure 50.

Figure 50. **Agriculture has the largest and most volatile structural contribution to economy-wide emissions**

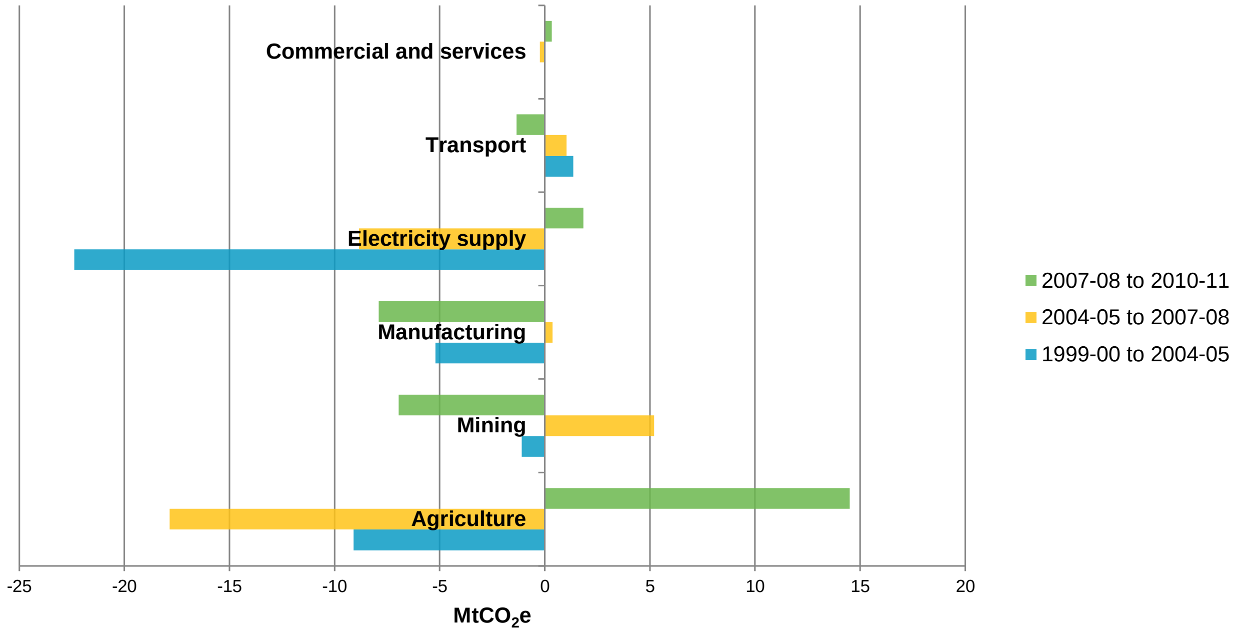


Note: *LMDI decomposition of economy-wide emission, yearly structural effect for main sectors.*

Source: *Vivid Economics based on Australian Government National Greenhouse Gas Inventory (2013) and Australian Government Bureau of Resource and Energy Economics (2013)*

Agriculture, an emissions intensive sector, took a larger share of the economy between 2008 and 2011, which, together with a slightly larger share of electricity in economic output, reversed the structural effect, increasing emissions slightly, see Figure 51. However, over the whole period between 2000 and 2011, restructuring of economic output away from agriculture, electricity supply and manufacturing contributed to a fall in economy-wide emissions.

Figure 51. **Manufacturing and mining have a helpful structural effect in economy-wide gas emissions between 2008 and 2011**



Note: *Contribution of each sector to the structural effect.*

Source: *Vivid Economics based on Australian Government National Greenhouse Gas Inventory (2013) and Australian Government Bureau of Resource and Energy Economics (2013)*

Table 23 shows that the decreasing share of manufacturing in economy-wide output contributed 50 per cent of the total structural effect between 2008 and 2011.

Table 23. **Mining and manufacturing have seen their sub-divisional composition move away from emissions intensive subsectors**

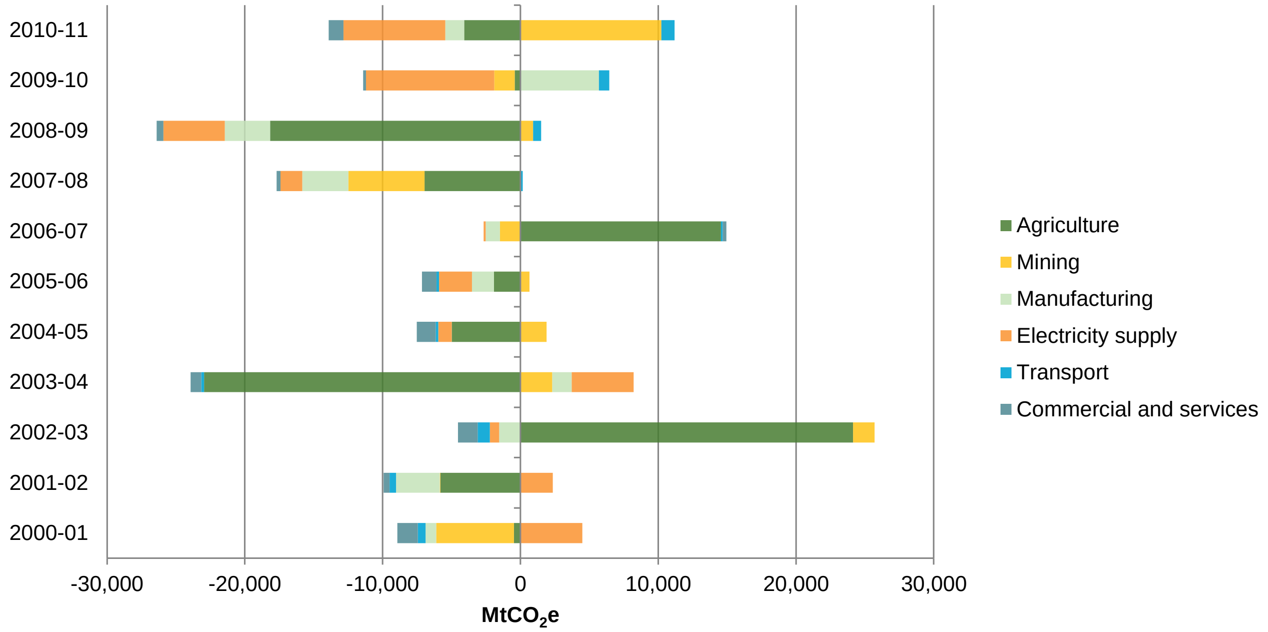
Structural effect		First period	Second period	Third period	Whole period
Sector	**Units**	**2000 to 2006**	**2006 to 2008**	**2008 to 2012**	**2003 to 2012**
Agriculture	$MtCO_2e$	-9	-18	15	-12
	change over period, %	-2.1	-3.8	3.0	-2.8
Mining	$MtCO_2e$	-1	5	-7	-3
	change over period, %	-0.2	1.1	-1.4	-0.6
Manufacturing	$MtCO_2e$	-5	0	-8	-13
	change over period, %	-1.2	0.1	-1.6	-2.9
Electricity supply	$MtCO_2e$	-22	-9	2	-29
	change over period, %	-5.1	-1.9	0.4	-6.7
Transport	$MtCO_2e$	1	1	-1	1
	change over period, %	0.3	0.2	-0.3	0.2

Notes: *LMDI decomposition of economy-wide emissions by subsectors. Structural effect of main sector is recovered by summing relevant subdivisions.*

Source: *Vivid Economics based on Australian Government National Greenhouse Gas Inventory (2013) and Australian Government Bureau of Resource and Energy Economics (2013)*

An increased share of mining in economic output contributed to higher economy-wide emissions between 2000 and 2008. After 2008, the share of mining in the economy, and therefore its contribution to emissions, declined, as shown in Figure 52.

Figure 52. **Electricity supply and agriculture gains have been the main contributors to an emissions decline in the period 2008 to 2011**



Note: *LMDI decomposition of economy-wide emissions, yearly intensity effect for main sectors.*

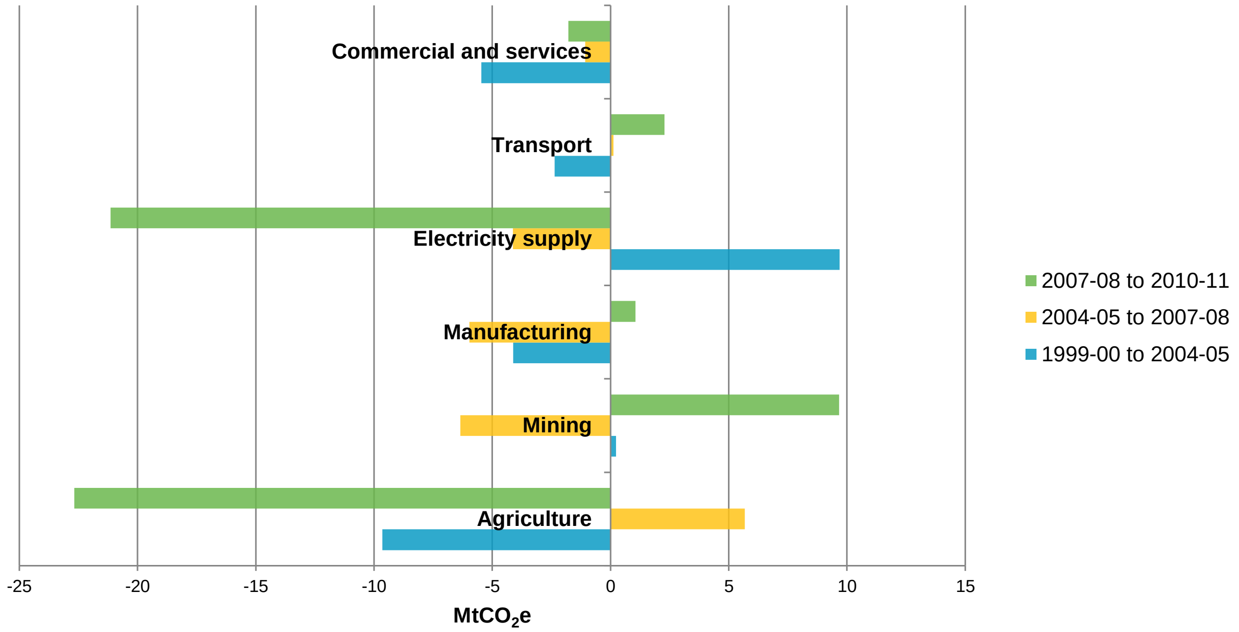
Source: *Vivid Economics based on Australian Government National Greenhouse Gas Inventory (2013) and Australian Government Bureau of Resource and Energy Economics (2013)*

The continuation of decreasing emissions resulting from the structural effect depends on future shifts in the economy away from manufacturing and mining.

4.4.3 Intensity effect: emissions trends within sectors

The emissions intensity of each sector declined between 2000 and 2011 as shown in Figure 53. Agriculture, electricity manufacturing and services contributed the most, and since 2008, only mining and manufacturing have become more emissions intensive.

Figure 53. **Decreasing emissions intensity of electricity supply and agriculture have been the major drivers of declining emissions between 2008 and 2011**



Note: *Intensity effect contribution to economy-wide emissions.*

Source: *Vivid Economics based on AGEIS (2013) and Australian Government Bureau of Resource and Energy Economics (2013)*

The emissions intensity of electricity supply and agriculture declined by 21.4 per cent and 10.5 per cent respectively between 2008 and 2011 and are the main contributors to the intensity effect in that period responsible for -4.6 per cent and -4.3 per cent in intensity effect contribution to total emissions growth, as shown in Table 24. Commercial and services was a further contributor. Manufacturing and mining increased the emissions intensity between 2008 and 2011 by 0.2 per cent and 2 per cent respectively, which is in contrast to the period between 2000 and 2008, where mining and manufacturing, together with services, were the principal contributors to falling emissions intensity.

Table 24. **Agriculture and electricity supply have contributed the most to the fall in emissions between 2008 and 2011 mainly due to improving intensity**

Emissions intensity effect		First period	Second period	Third period	Whole period
Sector	**Units**	**2000 to 2006**	**2006 to 2008**	**2008 to 2012**	**2003 to 2012**
Agriculture	$MtCO_2e$	-10	6	-23	-27
	change over period, %	-2.2	1.2	-4.6	-6
Mining	$MtCO_2e$	0	-6	10	4
	change over period, %	0.1	-1.4	2	0.8
Manufacturing	$MtCO_2e$	-4	-6	1	-9
	change over period, %	-0.9	-1.3	0.2	-2
Electricity supply	$MtCO_2e$	10	-4	-21	-16
	change over period, %	2.2	-0.9	-4.3	-3.5
Transport	$MtCO_2e$	-2	0	2	0
	change over period, %	-0.5	0	0.5	0
Commercial and services	$MtCO_2e$	-5	-1	-2	-8
	change over period, %	-1.2	-0.2	-0.4	-1.9

Note: *LMDI decomposition of economy-wide emissions by subsectors. Intensity effect of main sector is recovered by summing relevant subdivisions.*

Source: *Vivid Economics based on Australian Government National Greenhouse Gas Inventory (2013) and Australian Government Bureau of Resource and Energy Economics (2013)*

Within sectors, there are two effects:

- a restructuring within the sector between more and less emissions intensive subsectors; and
- a change in the emissions intensity of subsectors.

Within manufacturing, a shift towards non-metallic mineral and metal product manufacturing, as shown in Figure 54, increased the contribution of manufacturing to the structural effect.

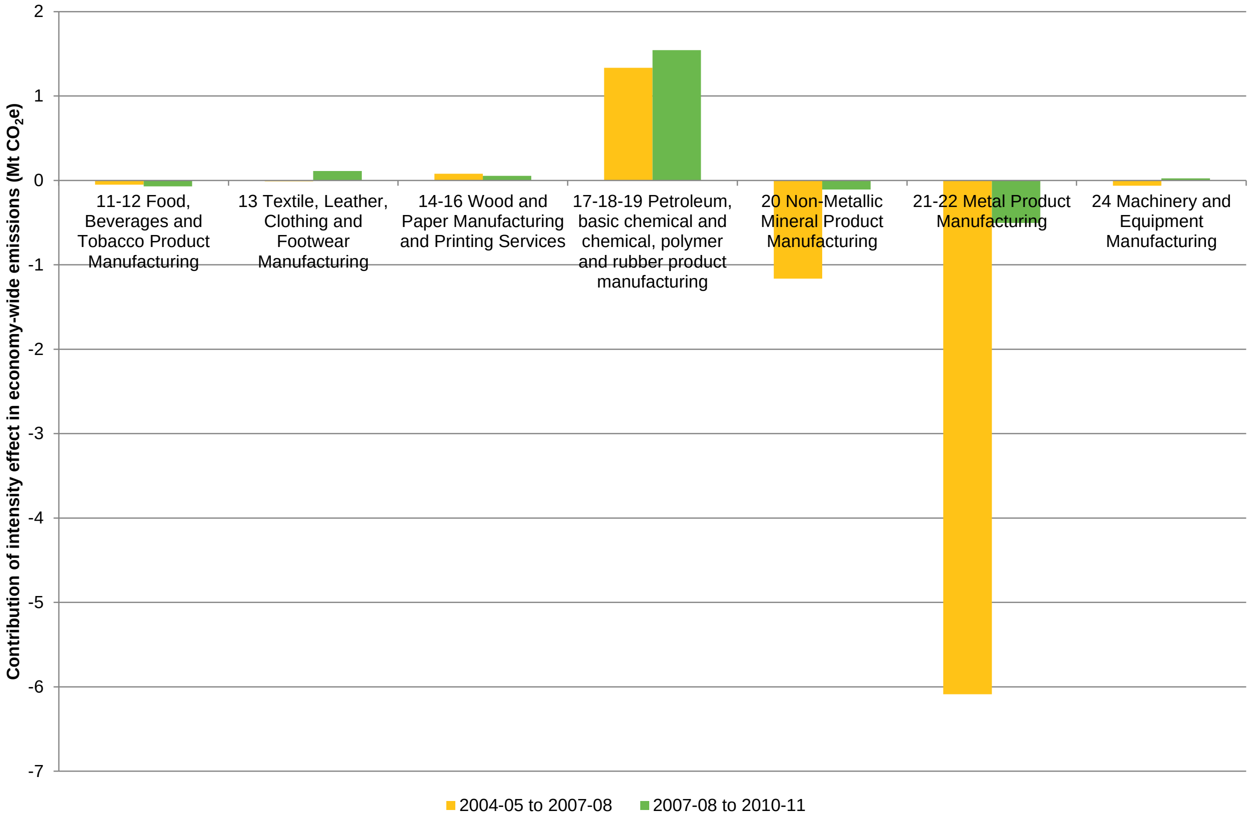
Figure 54. **A restructuring towards metal and non-metallic mineral products within manufacturing pushed up emissions**

Note: *Detailed account of structural effect contribution to total change in economy-wide emissions by subsector.*

Source: *Vivid Economics based on Australian Government National Greenhouse Gas Inventory (2013) and Australian Government Bureau of Resource and Energy Economics (2013)*

Nevertheless, the emissions intensity of non-metallic mineral and metal product manufacturing continued to improve between 2008 and 2011, albeit less than between 2005 and 2008, as shown in Figure 55.

Figure 55. **Manufacturing of metal products and non-metallic mineral products drove down the emissions intensity of manufacturing between 2005 and 2011**

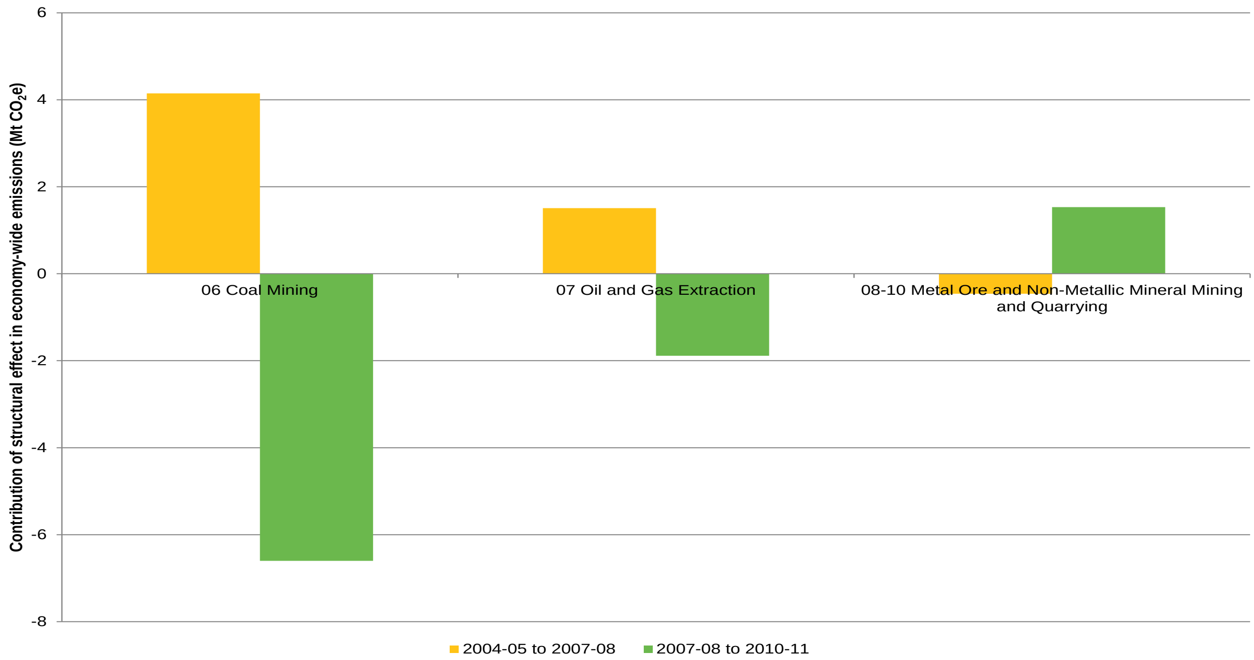


Note: *Detailed account of intensity effect contribution to total change in economy-wide emissions by subsector.*

Source: *Vivid Economics based on Australian Government National Greenhouse Gas Inventory (2013) and Australian Government Bureau of Resource and Energy Economics (2013)*

Within mining, the sector restructured away from coal mining and oil and gas extraction, which has a high emissions intensity, towards metal ore and non-metallic mineral mining and quarrying, which has a lower emissions intensity, yet is still higher than for most sectors of the economy, as shown in Figure 56.

Figure 56. **The structural change within the mining sector since 2008 contributed to a lower emissions intensity of the economy**

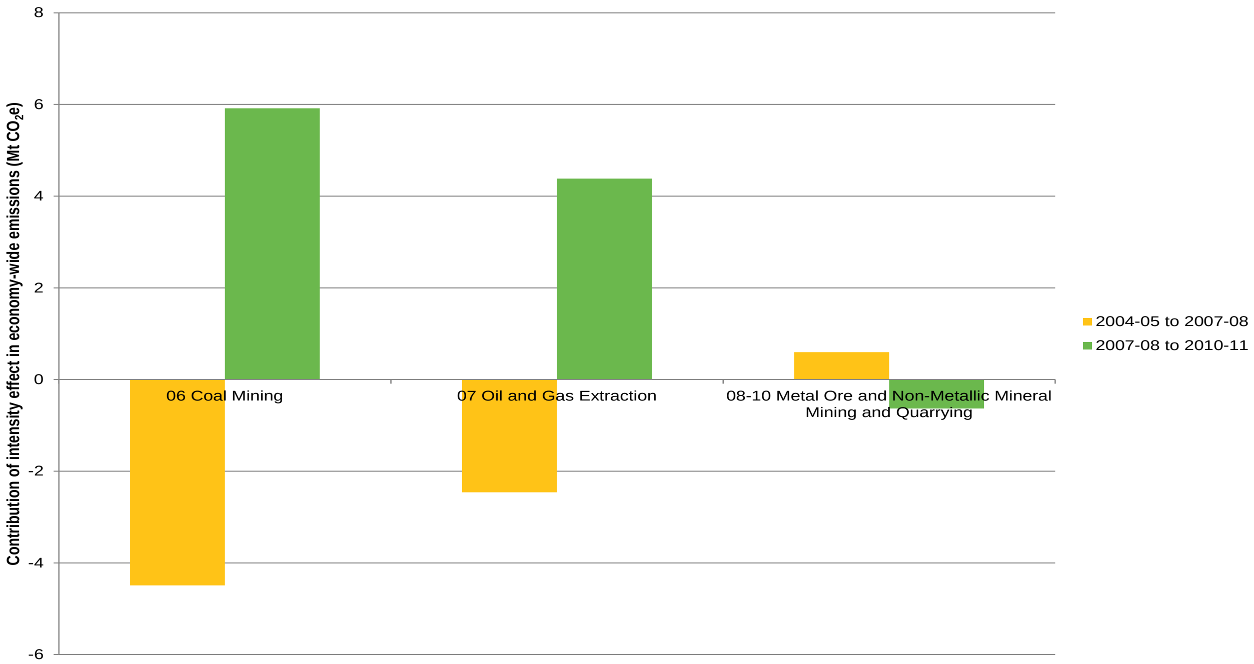


Note: *Detailed account of structural effect contribution to total change in economy-wide emissions by subsector.*

Source: *Vivid Economics based on Australian Government National Greenhouse Gas Inventory (2013) and Australian Government Bureau of Resource and Energy Economics (2013)*

Coal mining and oil and gas extraction have become relatively more emissions-intensive and have driven up the overall emissions intensity of the mining sector between 2008 and 2011, as shown in Figure 56. Metal ore and non-metallic mineral mining and quarrying, on the other hand, has become less emissions-intensive between 2000 and 2011.

Figure 57. **Coal mining and oil and gas extraction increased the emissions intensity of the mining sector and affected the emissions intensity of the economy negatively**



Note: *Detailed account of intensity effect contribution to total change in economy-wide emission by subsector.*

Source: *Vivid Economics based on Australian Government National Greenhouse Gas Inventory (2013) and Australian Government Bureau of Resource and Energy Economics (2013)*

The trend continuation of lower emissions intensity depends mainly on the electricity sector. Within the electricity sector, continuing renewable incentives and further substitution of gas for coal despite projected gas prices increases would be consistent with a further decline of the emissions intensity. The emissions intensity within other sectors further contributes to changes in the overall emissions intensity.

4.5 Summary of results

The main results from the analysis are summarised in Box 4.

Box 4. **Economy-wide emissions increased when LULUCF emissions are excluded**

Total emissions including LULUCF have decreased by 21.4 Mt (3.7 per cent) between 2008 and 2011. This is solely due to a decline in LULUCF emissions, which fell by 23.3 Mt (4 per cent of 2008 emissions), and was partially offset by higher emissions from sectors of the economy, which grew by 1.9 Mt (0.3 per cent of 2008 emissions).

Emissions grew most strongly in mining and transport, by 7.1 Mt (1.2 per cent of 2008 emissions) and 2.6 Mt (0.4 per cent of 2008 emissions) respectively, and residential and other sectors, which grew by 1.1 Mt (0.2 per cent of 2008 emissions) and 0.9 Mt (0.2 per cent of 2008 emissions) respectively. This was almost entirely offset by a decline of emissions from electricity, which fell by 5.2 Mt (0.9 per cent of 2008 emissions), agriculture, which fell by 2.5 Mt (0.4 per cent of 2008 emissions), and manufacturing, which fell by 2.1 Mt (0.4 per cent of 2008 emissions).

5 Conclusion

Trends in electricity generation emissions intensity and economy-wide emissions are influenced by economic activity and policy

Section contents:

This work is an analysis of long term electricity consumption, electricity generation emissions intensity and economy-wide emissions trends

Electricity consumption was static between 2008 and 2012 in response to a combination of factors including increased electricity prices, lower economic growth and, in residential consumption, uptake of solar PV. In the future, the combination of a slowdown in electricity price rises and higher economic growth might cause electricity consumption to grow again.

Declines in electricity generation emissions intensity seen between 2008 and 2011 are due to an increased share of gas and renewables in the generation mix. Future increases in renewables generation depend on the evolution of the M-RET and other policies such as the carbon price. Increased gas generation depends on a basket of factors, among them availability of gas from coal seam gas exploitation, the strength of the carbon price and state-wide efforts such as emissions reduction schemes.

Both falling LULUCF emissions and decreased emissions from electricity generation have been principal contributors to overall economy-wide emissions reductions in recent years.

5.1 Context for the results

The results of this work come from long term statistical analysis. Readers wanting to find discussion of very recent developments, in particular the influence of the carbon price mechanism, are asked to consult other work. Compared with previous work, this work presents a more granular statistical treatment of developments in electricity consumption in the NEM, electricity generation emissions intensity and economy-wide emissions.

The statistical analysis measures trends and identifies the relative importance of the drivers of trends. The work contributes to the discussion of changes in electricity consumption, electricity generation emissions intensity and economy-wide emissions. It identifies how electricity consumption within sectors, especially in the residential sector, has changed over time and what the underlying drivers have been. In contrast, other work such as the AEMO National Electricity Forecast Report does not report results for the residential sector alone. In electricity generation emissions intensity, the relative contributions of fossil fuel mix switching and increased renewables deployment are highlighted as well as how other factors, such as a lower carbon intensity within fuel types, contributed over time. The work details how economy-wide emissions with and without LULUCF emissions have tracked and places the relative emissions reductions achieved from LULUCF alongside changes in other sectors.

5.2 Headline results

While electricity consumption in the NEM has fallen due to lower economic growth, restructuring towards less electro-intensive sectors and improved electricity intensity, the trends differ between sectors. Residential demand remained flat, with an increase in population, but no increase in per capita consumption. The effect of rising final consumption expenditure was offset by downward pressure on electricity consumption from higher electricity prices. Off-grid solar PV consumption made a contribution to lower consumption of on-grid electricity. Manufacturing consumption fell steeply, by 7.6 per cent between 2008 and 2012, fuelled by a decline of economic activity in manufacturing, but commercial and services consumption moved in the opposite direction, rising by 4.2 per cent, showing the effect of greater economic activity in commercial and services sector despite higher electricity prices.

Of the 6.3 per cent improvement in electricity generation emissions intensity after 2008, four fifths was due to a rising share of gas and renewables in generation output, under the influence of policy and market factors such as the availability of gas and of rainfall for hydroelectricity.

The stability of economy-wide emissions excluding LULUCF after 2008 is due to the electricity sector, whose emissions tracked 1 per cent per year below trend economic growth, and reduced emissions intensity in sectors of the economy except mining.

5.3 Discussion of main findings

As is well known, electricity generation is the most important driver of trends in emissions excluding LULUCF. Over recent decades, electricity generation emissions have risen as the economy has expanded but recently that trend has slowed almost to a stop. The factors which have caused the standstill are a mix of market and policy effects. The market effects have been a reduced rate of growth in economic activity during the global financial crisis and greater availability of natural gas. In response, electricity consumption growth has slowed and gas-fired plant have dramatically increased their market share. This has brought down the underlying emissions trend to a level at which strengthened policy measures on renewable, gas and carbon prices have been sufficient to contain emissions growth to close to zero.

The simple arithmetic of increasing economic activity, market effects within the power market and policy will continue to govern emissions trends. The pressures on these factors seem, on balance, to be for an upward trend, if economic growth continues, if gas prices rise faster than coal prices as forecast, and if promises of significant changes to climate policy under a Coalition Government are carried through.

The consumption of electricity has expanded in response to increased economic activity, but economic activity has grown much faster than electricity consumption. This is because Australia has steadily increased the productivity of its electricity use. A major contribution to greater electricity productivity has come from a structural shift away from more energy intensive sectors such as mining and manufacturing towards less intensive sectors such as commerce and services. This is a persistent pattern observed in many developed economies. Energy efficiency will also have played a role, but this work does not attempt to measure its effect.

In recent years, the price of electricity has risen sharply, having a dampening effect on consumption. With forecast increases in the fuel costs of fossil power generation, further price rises are expected, exerting continuing downward pressure on electricity consumption.

The pattern of emissions trends excluding LULUCF closely follows the story of electricity emissions intensity and consumption. This work shows statistically that emissions trends are driven by economic activity and changes in the composition of the economy, and the contribution of policy, principally through the power sector, is also clear. The same drivers are at work in both emissions in general and in electricity generation: unsurprising since electricity is an input in almost all activities which release emissions directly.

5.4 Concluding remarks

This work looks backwards rather than forwards, but it shows that for those tasked with drawing up projections and forecasts, there are both market and policy effects to consider. Those effects drive changes in electricity consumption, in electricity emissions intensity and in economy-wide emissions and the contributions of each are visible in the statistical and descriptive analysis. Policy has been a significant influence since 2008, indeed a more identifiable and probably stronger influence since that date than it was before, principally through renewable energy support policies. Market conditions favourable to low emissions growth have contributed to a remarkable period of stable non-LULUCF emissions in Australia.

In working out the level of policy effort which would achieve a given trend in emissions in Australia, the key questions will be:

- How will future market conditions influence the balance of output between types of fossil fuel-fired electricity generation?
- Will renewable energy policy maintain the recent pace of investment in new renewable energy capacity?
- Will the structural trends in the economy towards the commercial and services sector be stable and persistent, or will there be a resurgence in manufacturing and mining?
- How fast will the economy overall grow?

6 Methodology

The approach to decomposition and driver quantification

Section contents:

The decomposition analysis reveals the results of changes in economic activity, restructuring of the economy and changes in the intensity of economy-wide sectors and is flexible to capture how the fossil fuel mix, renewables, and factors like fuel efficiency and carbon intensity of power plants influenced electricity generation emissions intensity.

The trend analysis allows identification and estimation of the relative contribution of drivers of each residential, commercial and services and manufacturing consumption.

This section describes the statistical techniques used to perform these analyses.

'The aim of index decomposition is to break down the total change in an aggregate series over a period of time into a set of underlying components.'

6.1 Index decomposition

Breaking down changes into specific effects

The aim of index decomposition is to break down the total change in an aggregate series over a period of time into a set of underlying components. It shows the contribution of each component to the change in the aggregate. For example, given a change in electricity consumption, the change is attributed to:

– **activity effect:** overall activity (GDP) effect;
– **structural effect:** sector share in the overall level;
– **intensity effect:** sector intensity of electricity use.

The **activity effect** captures the contribution of economic output to electricity consumption. An increase in economic activity and consumption across all sectors and regions will always lead to higher electricity consumption. This effect captures the contribution of economic activity to electricity consumption, when both structure of the economy and the sectoral intensities remain constant. The general level of economic activity is measured by GVA (Gross Value Added) for industrial sectors and income or final consumption for residential sector.

The **intensity effect**: an increase (decrease) in a sector's intensity, electricity consumption in GWh/gross value added in AUD, cause electricity consumption to rise (fall). A change in the intensity of use will typically be the effect of structural change within a sector, technology employed or asset utilisation. Over time, electricity intensity is expected to decline (improve) as the introduction of more efficient technology leads to higher output or GVA for each unit of energy input, but structural changes can cause intensity to increase or decrease. There can also be increases if a new technology involves the mechanisation of part of a production process or, in the residential sector, if there is a greater use of resources on activities that consume electricity.

The **structural effect** captures changes in the balance between sectors of the economy. A sector's share of aggregate activities is measured as the ratio of the sector's GVA over the sum of all activities. A shift in sector shares from low (high) electricity intensity to high (low) electricity intensity sectors will cause an increase (decrease) in electricity consumption even if the general activity level and sectoral intensities remain constant.

The analysis uses chain volume measure of activity. Although chain volume measures poses the problem that economic activities are not additive, it offers a clear advantage over the alternatives, namely nominal measures and deflated nominal measures. The first of these produces a decomposition that contains inflation, which obscures some of the real effects, while the application of a deflator results in a biased picture because of changes in relative prices. In particular, if there is a relative price decrease in manufacturing, the resulting deflated nominal GVA will underestimate manufacturing real GVA and produce an upward bias in the intensity of use (Electricity consumption/GVA).

The decomposition can be written as:

$$\Delta E_{tot} = E^T - E^0 = \Delta E_{act} + \Delta E_{str} + \Delta E_{int}$$

where:

- E_{tot} is the total change in electricity consumption;
- ΔE_{act} is change due to activity factor;
- ΔE_{str} is the change due to changing structure of the economy that is changes in sectoral shares; and,
- ΔE_{int} is due to the intensity effect.

The Logarithmic Mean Divisia Index (LMDI) and Laspeyres methodologies can both isolate the contribution of each factor. In the description that follows, the explanation addresses their use in electricity consumption by sector or region.

6.1.1 Laspeyres

Laspeyres measures the impact of a factor on the variable of interest by allowing it to vary, while keeping all other factors fixed at the value of a base year. Considering the change in electricity consumption (E) from period 0 to period T, the Laspeyres method decomposes changes into the following three effects:

- $E^T - E^0 = \Delta E_{tot} \approx \Delta E_{act} + \Delta E_{str} + \Delta E_{int}$

- $\Delta E_{act} = (Q^T - Q^0) \sum_i S_i^0 I_i{}^0$
- $\Delta E_{str} = \sum_i Q^0 S_i^T I_i{}^0 - \sum_i Q^0 S_i^0 I_i{}^0$
- $\Delta E_{int} = \sum_i Q^0 S_i^0 I_i{}^T - \sum_i Q^0 S_i^0 I_i{}^0$

where:

- Q is the level of overall activity;
- Q_i is the level of sector/region *i* activity;
- E_i is electricity consumption of sector/region i;
- $S_i = Q_i/Q$ is the share of sector/region i; and
- $I_i = E_i/Q_i$ is the intensity of sector/region i.

Each term in the summation corresponds to the sector specific contribution to the overall effect. The sectors classification is:

- Division A: Agriculture, Forestry and Fishing;
- Division B: Mining;
- Division C: Manufacturing;
- Division D: Electricity, Gas, Water & Waste services;
- Div. I Transport, Postal and Warehousing;
- Commercial and Services;
- Residential.

The regional decomposition encompasses all states.

The methods are refined with additional interaction terms to yield a perfect decomposition. The Laspeyres method can produce residuals caused by the interaction between changes of factors. It is important to obtain as perfect decomposition as possible since any residuals would leave a change in electricity that is unexplained. The 'refined Laspeyres decomposition' is designed to keep the residual equal to zero, by using joint creation, equal distribution principle to allocate the interactions among the main effects'. The refined formula for activity effect then becomes:

– $\Delta E_{act} = (Q^T - Q^0)\sum_i S_i^0 I_i^0 + \frac{1}{2}(Q^T - Q^0)\left(\sum_i\left(S_i^T - S_i^0\right) I_i^0 + \sum_i S_i^0\left(I_i^T - I_i^0\right)\right) + \frac{1}{3}\sum_i (Q^T - Q^0)\left(S_i^T - S_i^0\right)\left(I_i^T - I_i^0\right)$

with similar formulae for the other effects into which the variable of interest is decomposed, see (Ang & Zhang, 2000) for details.

6.1.2 Logarithmic Mean Divisia Index (LMDI)

LMDI is based on the logarithm mean growth rate of factors of interest so each factor contribution is the logarithmic change in the factor multiplied by a weight that represents the logarithmic mean of the change of electricity consumption. Starting with the identity:

– $E = \sum_i E_i$

where total electricity consumption E equals the sum of electricity consumption by sectors E_i. Then each sector's consumption can be decomposed as:

– $\mathrm{E_i} = \mathrm{Q}\frac{\mathrm{Q_i}}{\mathrm{Q}}\frac{\mathrm{E_i}}{\mathrm{Q_i}}$

The last expression introduces matching terms in the numerator and denominator of the fraction so that the identity remains valid after cancelling out. This manipulation is introduced in order to analyse the factors that are thought to be important. These factors are:

– Q, a measure of aggregate activity such as GVA;
– $\mathrm{Q_i}$, a measure of sectoral/regional activity;
– E_i/Q_i, a measure of intensity; and,
– Q_i/Q, the share of a sector/region.

The LMDI decomposition is:

– $E^T - E^0 = \Delta E_{tot} = \Delta E_{act} + \Delta E_{str} + \Delta E_{int}$

– $\Delta E_{act} = \sum_i w_i \log\frac{Q^T}{Q^0}$
– $\Delta E_{str} = \sum_i w_i \log\frac{S_i^T}{S_i^0}$
– $\Delta E_{int} = \sum_i w_i \log\frac{I_i^T}{I_i^0}$
– $w_i = \frac{E_i^T - E_i^0}{\log E_i^T - \log E_i^0}$

Unlike the Laspeyres, the LMDI is a perfect decomposition so it leaves no residuals, see (Ang, 2005) for more details.

The key difference between the Laspeyres and LMDI is that Laspeyres uses weights based on data from a single base year, while the LMDI uses the average of the data of the two years. Both the Laspeyres and LMDI perform reasonably well. The IEA recommends both methods, which gives a range of estimates of effects. The IEA advocates the suitability of these two methods:

- Laspeyres for its ease of understanding, especially to non-experts, but with the drawback of having an interaction term;
- LMDI for its theoretical soundness, see (Trudeau, 2012).

In this study, both decompositions are used, to increase robustness. The methods do not give very different answers, but their respective results do not lend themselves to direct comparison and cannot act as an upper or lower bound for each other. The same methodologies are used to decompose CO_2 emissions intensity of electricity generation and total emissions.

6.1.3 Decomposing electricity consumption

Electricity consumption growth is explained by the three effects given in the relationship:

$$\Delta E_{tot} = E^T - E^0 = \Delta E_{act} + \Delta E_{str} + \Delta E_{int}$$

The factors affecting electricity consumption are:

- *Activity effect:* a general increase (decrease) in industrial production and/or residential consumption over a period which results in an increase (decrease) in electricity consumption, if the composition of the economy and use intensity remain the same;
- *Structural effect:* electricity consumption falls (rises) if there is reallocation of production from (to) high energy intensive to (from) low energy intensive sector, again while keeping general activities and energy intensities at a constant level;
- *Intensity effect:* if nothing else changes, a fall (rise) in the intensity of use, for efficiency reason or otherwise, will lead to lower (higher) consumption of electricity.

6.1.4 Decomposing electricity emissions intensity

Both Laspeyres and LMDI methods are used to decompose the CO_2 emissions intensity from electricity generation. To decompose the emissions intensity of electricity generation, the following factors are considered:

- the share of electricity generated from fossil fuel in total electricity;
- the share of electricity from each fossil fuel type in total fossil fuel electricity;
- the inverse of fuel efficiency, that is, converting fossil fuel into electricity;
- the emissions intensity of each fossil fuel input.

The emissions intensity can be written as:

– $\frac{EEm}{E} = \sum_i \frac{E_{ff}}{E}\frac{E_{ft(j)}}{E_{ff}}\frac{E_{in}}{E_{ft(j)}}\frac{EEm_{in}}{E_{in}}$

where:

– EEm is total CO_2 emissions from electricity generation (in kilotonnes);
– E is total electricity generated (in GWh);
– E_{ff} is electricity generated from fossil fuels (in GWh);
– E_{ft} is electricity generated by each type of fossil fuel (black coal, brown coal and natural gas in GWh);
– $E_{in}$is the energy input (in PJ) of each fossil fuel type; and,
– $EEm_{in}$is the CO_2 emissions from each fossil fuel type input (in kilotonnes).

Given this breakdown, the methods described above compute the contribution of each factor. The factors affecting the emissions intensity are:

– *renewable share effect*: an increase (decrease) in electricity generated from fossil fuel relative to total electricity output results in higher (lower) CO_2 emissions per unit of output. The renewable cost of renewable and fossil power and strength of policies drive this factor;
– *fossil fuel mix:* within fossil fuel generation, a shift from black coal to natural gas, for example, will lead to lower intensity. The effect is driven by changes in the relative prices of fossil fuels, by policy and by availability of plant;
– *conversion efficiency:* this measures units of fossil fuel input per unit of electricity output and the higher it is the more emissions intense electricity generation becomes. This factor changes if new more efficient electricity generation plants are introduced and older less efficient plants are decommissioned;
– *carbon intensity:* each fossil fuel input contains an amount of useful thermal energy per tonne of CO_2 released upon combustion. This changes if the fuel quality changes, particularly the balance between carbon, hydrogen and water in coal, and the CO_2 carried within natural gas.

6.1.5 Decomposing economy-wide level of gas emissions

The decomposition follows the same structure as the electricity consumption decomposition and breaks down emissions into an activity, structural and intensity effect.

Total gas emissions can be written as:

– $E\mathrm{m} = \sum_\mathrm{i} \mathrm{Q}\frac{\mathrm{Q_i}}{\mathrm{Q}}\frac{\mathrm{Em_i}}{\mathrm{Q_i}}$

where:

– Em and Em_i are the aggregate and sectoral gas emissions;
– Q is aggregate activity level; and,
– Q_i is the sector activity level.

The effects are akin to electricity consumption drivers: the activity effect measured by GVA and final consumption expenditure shows the contribution of economic activity. Structural effects measured by a sector's activity share of aggregate activities captures changes in emissions directly attributable to shifts between sectors. Finally, the intensity factor isolates the improvement or worsening performance of sectors emissions which are related to restructuring within the sector or technical change, that is, changing efficiency.

6.2 Trend analysis since 2008

Identifying and quantifying electricity consumption drivers in sectors

The second part of the analysis explains some of the conclusions from the decomposition analysis. The focus is on the period after 2008.

An Autoregressive-Distributed-Lag (ADL) model is used to analyse long term trends in electricity consumption. The ADL model is a dynamic regression model that is flexible enough to encompass many types of dynamic relationships such as Error Correction Model (ECM) or Partial Adjustment Model (PAM). It also estimates jointly the short run dynamics and long run relationship. It is advocated in previous peer reviewed academic work and is widely used in similar analyses. Pesaran, Shin, & Smith, 2001, advise the use of this methodology to model equilibrium relationships in economics, and Madlener, Bernstein, & Gonzalez, 2011, used the ADL in modelling electricity consumption. They also give a comprehensive survey of the methods use in modelling energy consumption.

The advantages of this method rests on it ease of interpretation, robustness to time series properties of the data and robustness to endogenous variable bias. There is also another advantage in that the bounds testing procedure for the existence of a long run relationship (cointegration) is valid whatever the time series properties of the data. The bounds testing is valid whether all the series are stationary, non-stationary or a combination of the two. In the presence of structural breaks, there can arise a great deal of uncertainty about these properties. The model also permits the inclusion of different number of lags of the explanatory variables, which makes the estimation more efficient, by using a general to specific modelling framework. Pesaran et al., 2001, show that the ADL method yields consistent estimates of the long run coefficients, which are asymptotically normal. However, if structural breaks are not accounted for then the estimates of the long run coefficients will be biased. This potential problem is dealt with by including structural breaks that are identified through an analysis of their contribution to model fit. The method can be sensitive to lag selection.

The ADL model is defined as:

- $x_t = \ a_0 + d_0 t + \sum_{i=1}^{m} a_i D_{it} + d \quad D_t t + \sum_{i=1}^{q} B_{1i} x_{t-i} + \sum_{i=0}^{q} B_{2i} Z_{t-i} + \epsilon_t$

- x_t is the dependent variable, electricity consumption by sector;
- Z_t is a vector of explanatory variables that are thought to be important; and,
- D_t is either level or impulse dummy variable to pick up structural breaks.

The dependent variable is a function of its own lagged values as well as contemporaneous and lagged values of the explanatory variables. The dependent and explanatory variables are allowed to be both stationary and non-stationary. Although the short run and long run dynamics are nested within the ADL, it is better to specify the ADL equation as an unconstrained Error Correction Model. The advantages of doing so are ease of interpretation and ease of testing restrictions on the long run coefficients directly, such as testing for cointegration.

The analysis starts by considering a general unconstrained Error Correction Model

- $\Delta x_t = \ a_0 + d_0 t + \sum_{i=1}^{m} a_i D_{it} + d \ \ D_t t + b_1 x_{t-1} + \ b_2 Z_{t-1} + \sum_{i=1}^{q} c_{1i} \Delta x_{t-i} + \sum_{i=0}^{q} c_{2i} \Delta Z_{t-i} + \epsilon_t$

where $a_{\mathrm{i}}, d_i, b_i, c_{1i}$ and c_{2i} are model coefficients and Δ is the first difference operator.

The model coefficients $a_{\mathrm{i}}, d_i, b_i, c_{1i}$ and c_{2i} are estimated by Ordinary Least Squares (OLS) and if the model is well specified, Pesaran et al (2001) show that these are consistent and asymptotically normal. As noted above the model estimates the short run dynamics of the dependent variable by including its own lags and the lags of other relevant explanatory variables. Also, the ECM specification directly recovers the long run relationship through the error correction term:

- $b_1 x_{t-1} + \ b_2 Z_{t-1}$

Which then give the long run relationship up to a constant term as:

- $x_t = -\frac{b_2}{b_1} Z_t$

The analysis proceeds by estimating a general form of the equation above, choosing a sufficient lag structure. A number of breaks are included based on a formal regression analysis, Bai and Perron (1998), to identify potential break dates through consideration of model fit. The robustness of the estimated equation ultimately depends on these estimated breaks. The regression is re-estimated while excluding insignificant lags of differenced data.

The long run relationship is tested in several ways. Based on Pesaran et al. (2001), cointegration and long run relations are addressed by testing the hypothesis that the coefficients of the level variables are jointly equal to zero, that is:

- $H_0: b_1 = b_2 = 0$
- $H_1: b_1 \neq 0, b_2 \neq 0$

The use of an *F-test* is advocated and depending on whether the variables are stationary or not the resulting *F-stat* is compared to some bounds. The bounds are tabulated in Pesaran et al., 2001, and the lower and upper limits correspond to whether all the variables are stationary or all the variables are non-stationary respectively.

The modelling is conducted in the following steps:

- check variables for stationarity and use OLS regression with breaks to identify potential break dates;

- estimate a general unconstrained ECM model and carry out diagnostic checks for autocorrelation, heteroskedasticity and specification;
- sequentially delete insignificant variables if the t-stat is too small and its omission does not lead to substantial change in the coefficient of the remaining variables;
- impose equality constraint in order to reduce number of estimated coefficients;
- model checking via diagnostic checks and parameter constancy;
- use of bounds testing to confirm the long run relationship exists.

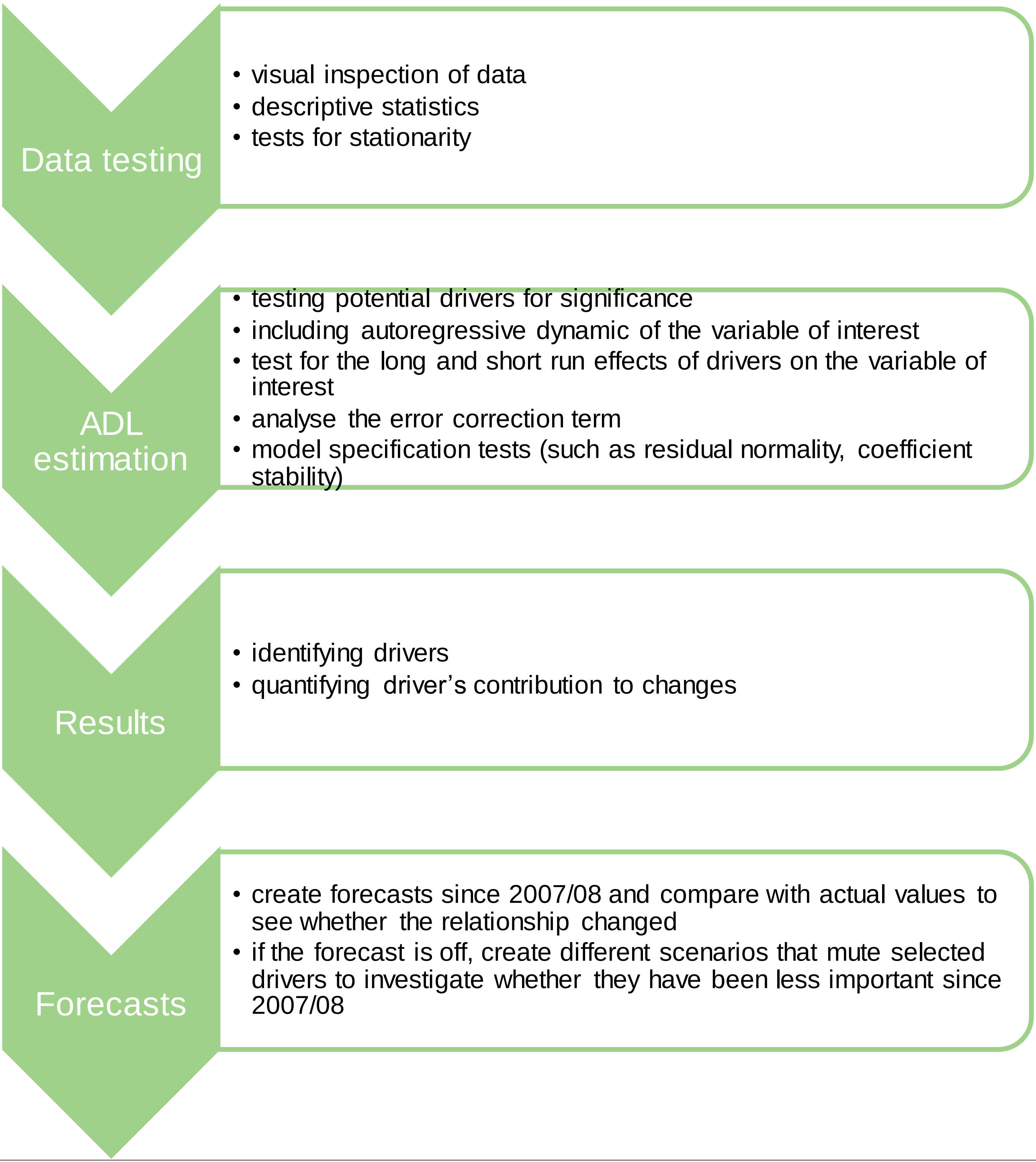
Model estimates are also checked against other published work in the same field. Particularly the price elasticity is very unstable and only reasonable estimates (as determined by other published work) are considered.

Once a model is estimated for the sample ending in 2007, forecasts for the period 2008 to 2012 are generated for the actual evolution of the explanatory variables. These forecasts are then compared to actual data along with different scenarios. For each model one of the explanatory variables is assumed to stay fixed at the 2007 level and a new forecast of the dependent variable is generated, scenario definition are given below. These forecasts constitute counterfactuals which can shed light on the contribution of each explanatory variable to the forecast. Actual data is compared to these scenarios in order to identify any pattern that is not corroborated by the model.

A forecast error can be the product of structural unpredictable errors, estimation errors and post estimation breaks. Whereas there is not much that can be done about the former two, breaks in the trend are something that can indicate how the behaviour of the dependent variable may have changed.

There an additional experiment that is carried out. It is to decompose the forecast of the dependent variable, for example electricity consumption, into its main components, which are in the ADL model, the effect of the explanatory variables (prices and activities), dynamics and residuals. The effect of an explanatory variable, for example electricity prices is then derived as the difference between the scenario that assumes no changes in any explanatory variable (baseline) and the scenario that assumes solely a change in electricity prices. This method of isolating the effect of one explanatory variable is descriptive only since it is not innocuous to assume that changing one variable only is valid since explanatory variables are correlated. Although not statistically exact, the experiment gives an idea about the size of the change in the explanatory variable and the size of the response of the dependent variable (via the elasticity coefficient).

Figure 58. **The trend analysis tests the data and builds a robust model to arrive at the final results**



Source: *Vivid Economics*

The scenarios that are of interest in the analysis are:

- scenario 0 – actual: forecast based on activity variable (GVA/FCE) and electricity price taking their actual course;
- scenario 1 – fixed factors: forecast based on all explanatory variables fixed at their 2007 level. This is the baseline against which the effect of the drivers is explained;
- scenario 2 – activity effect: forecast based on changing activity drivers and other factors fixed at 2007 level. The difference between this forecast and benchmark will gives an idea of the activity effect; and
- scenario 3 – price effect: forecast based on changing electricity price and keeping activity variable fixed at 2007 level. This recovers the effect of changing prices compared to benchmark.

The models are then re-estimated using the full available sample ending in 2012 to see whether the coefficient estimates change. Similar forecasts to the above scenarios are generated, using the new coefficient estimates, showing whether the relative contribution of drivers is the same for the model to 2007 and the model to 2012. Differences between the two models could suggest a change in behaviour after 2007.

7 Data

The data is collected from official, public sources and is disaggregated to sector level

Section contents:

7.1 Data sources

For electricity consumption and generation the Australian Energy Statistics (AES) database published by the Bureau of Resources and Energy Economics (BREE) is the main source of data, since the AES is the main official source of energy data. The database is very extensive and includes breakdown of consumption data by sector (corresponding to Australian and New Zealand Standard Industrial Classification (ANZSIC) codes) and by state. The 2013 data vintage was used, which revises some previous data, most notably industrial electricity consumption.

Gas emissions data was obtained from The Australian Greenhouse Emissions Information System (AGEIS). This is the main database for emissions data. The data for emissions due to electricity generation and economy-wide emissions exists from 1990 to 2012 apart from Division A: Agriculture, Forestry and Fishing which is only available from 2008. The data for the subsector Agriculture exists from 1990.

Macroeconomic data was obtained from the Australian Bureau of Statistics (ABS), OECD database and DataStream. An extensive database of macroeconomic, population and weather variables was collected and used and detailed in Table 25.

Table 25. **The Bureau of Resources and Energy Economics, the National Greenhouse Gas Inventory (AGEIS) and the Bureau of Statistics are main data sources.**

Variable	Source	Variable type, unit	Breakdown	Period available	Frequency
Energy consumption	Australian Bureau of Resources and Energy Economics	Consumption by industry and fuel type, PJs	Industry at National and State level	1973-74 to 2011	Annually
Electricity generation	Australian Bureau of Resources and Energy Economics	Generation by fuel, GWh	National	1990 to 2012	Annually
CO_2 emissions from electricity generation	AGEIS	Gg/Kt CO_2	National	1990 to 2011	Annually
Greenhouse gas emissions in economy	AGEIS	Gg/Mt CO_2-equivalent	National & State level	1990 to 2011	Annually
Greenhouse gas emissions by sector	AGEIS	Gg/Mt CO_2-equivalent	National	1990 to 2011	Annually
Energy prices	IEA WDI	Retail and wholesale price index of coal, natural gas, oil products, electricity	National level	1978 to 2012	Annually and quarterly
Electricity – PPI	Australian Bureau of Statistics	Index	National level	March 1970 to March 2013	Quarterly
Electricity - CPI	Australian Bureau of Statistics	Index	National & State level	September 1980 to March 2013	Quarterly

GDP	Australian Bureau of Statistics	Chain volume measures & current prices; trend, seasonally adjusted and original; $m	National level	September 1959 to March 2013	Quarterly
Final consumption expenditure	Australian Bureau of Statistics	Chain volume measures & current prices; trend, seasonally adjusted and original; $m	National level	September 1959 to March 2013	Quarterly
Gross fixed capital formation	Australian Bureau of Statistics	Chain volume measures & current prices; trend, seasonally adjusted and original; $m	National level	September 1959 to March 2013	Quarterly
State final demand	Australian Bureau of Statistics	Trend, seasonally adjusted, original; $m	State level	September 1985 to March 2013	Quarterly
Gross state product	Australian Bureau of Statistics	Chain volume measures, current prices; $m	State level	June 1990 to June 2012	Annually
Sectoral Gross value added (GVA)	Australian Bureau of Statistics	Gross value added, chain volume measures; $m	National & State level	Varying start dates (1974/1985) to March 2013	Annually
Gross state product	Australian Bureau of Statistics	Chain volume measures, current prices; $m	State level	June 1990 to June 2012	Annually
Household final consumption expenditure (HFCE)	Australian Bureau of Statistics	Chain volume measures & current prices; trend, seasonally adjusted and original; $m	National & State level	September 1980 to March 2013	Quarterly
HFCE: household appliances	Australian Bureau of Statistics	Chain volume measures & current prices; trend, seasonally adjusted and original; $m	National level	September 1959 to March 2013	Quarterly
HFCE: household appliances - vehicles	Australian Bureau of Statistics	Chain volume measures & current prices; trend, seasonally adjusted and original; $m	National level	September 1959 to March 2013	Quarterly
HFCE: household appliances - fuels	Australian Bureau of Statistics	Chain volume measures & current prices; trend, seasonally adjusted and original; $m	National level	September 1959 to March 2013	Quarterly
CPI and PPI (components)	Australian Bureau of Statistics	Trend, seasonally adjusted, original; $m	State level	September 1985 to March 2013	Quarterly
Industrial production index	Australian Bureau of Statistics	Index	National	January 1974 to March 2013	Quarterly
Melbourne/Westpac leading index of economic activity	DataStream	Index seasonally adjusted	National	January 1960 – December 2012	Quarterly
Building approvals: new houses	DataStream	Number	National	January 1971 – December 2012	Quarterly
Weather and other seasonal factors	Australian Bureau of Meteorology	Number of hot and rainy days per year	State level	1910 - 2013	Annually

Population and population density	Australian Bureau of Statistics	Number of persons; number of persons per km^2	National & State level	June 1981 – September 2012	Quarterly
Population	Australian Bureau of Statistics	Number	National & State level	1960 - 2012	Annually
Urban population	World Development Indicators	Number	National	1960 - 2012	Annually
Employment	OECD Database	Number	National	January 1980 - March 2012	Annually
Employment in service sector	OECD Database	Number	National	January 1986 – December 2009	Annually
Average household size	Australian Bureau of Statistics	Average number of persons per household	National & state level	1991-2011	Every 5 years

Note: *Annual data has been used for the analysis.*

Source: *Vivid Economics*

7.2 Data issues

Bureau of Resources and Energy Economics (BREE) data was subject to an adjustment in 2012 that revised historical data until in 2003 (Clare Stark, Penney, & Feng, 2012). As a consequence substantial breaks in the data for all sectors, particularly manufacturing, appear in the year 2003. The index decomposition will be sensitive to the breaks, therefore only results since 2004 are reported and analysed. For trend models this poses a more direct problem, which is dealt with by the introduction of appropriate dummy variables.

BREE data is inconsistent to the degree that the published figures for total electricity consumption diverge from the sum of electricity consumption over all sectors in 2010 and 2011 (for sectoral data). The use of disaggregated data is preferred as it is more consistent with other data sources.

BREE data is not consistent to the degree that the published figures for electricity consumption of manufacturing in Australia is different from the sum of manufacturing consumption over all states between 2010 and 2012. State level data is not reliable as it does not show the recent decline in consumption in the NEM region. This was dealt with by taking Australia-wide data and subtracting from it data for the states of Western Australia and Northern Territory. Given the relative size of these two states any data error is likely going to be relatively small. WA manufacturing consumption shows an increase in the period noted above, which is at odds with the whole of Australia data.

BREE data for commercial and services sector consumption jumps in the year 2012. This is probably the result of data error signalling that appropriate care should be used in analysing the data. An adjustment is proposed to minimise the effect of this anomaly, by constructing an alternative consumption figure equivalent to an intensity of use (Electricity consumption/commercial and services sector GVA) similar to the previous year (2011). The adjusted consumption figure is therefore constructed as the GVA for the commercial and services sector multiplied by the previous year’s electricity intensity of use. This will probably still overstate the consumption since there is a general downward trend in the electricity intensity of commercial and services sector. However, given the upward anomaly it is better to be on the conservative side.

Electricity production data by types of fuel shows inconsistent pattern in the period 2002. Electricity generation from black coal decreased substantially, while the black coal energy input increased slightly. The total electricity generation was stable by the fact that gas fired electricity generation increased substantially. This makes the analysis of electricity generation emissions intensity problematic in the period 2000 to 2005.

Appendix

Unit root testing

Table 26. **Electricity consumption in levels is non-stationary in all sectors**

	Variable in levels		Variable in first difference	
Sector	Intercept	Intercept and trend	Intercept	Intercept and trend
Residential	0.63	0.49	0.00*	0.00
Commercial and services	0.82	0.49	0.00*	0.00
Manufacturing	0.36	0.98	0.01	0.00*

Note: *Electricity consumption time series properties. P-values from Augmented Dickey-Fuller unit root test are reported, the testing regression is estimated between 1990 and 2012. * indicate preferred time series specification. Schwarz Information Criterion was used for lag selection.*

Source: *Vivid Economics based on BREE (2013)*

ADL equations

Table 27. **Manufacturing equations show consistent long run estimates of price and GVA elasticities**

	NEM		NEM		Australia	
	1991-92 to 2007		1991-92 to 2012		1976-77 to 2012	
Manufacturing Equations	**Coefficient**	**p value**	**Coefficient**	**p value**	**Coefficient**	**p value**
Constant	-0.22	(0.04)	-0.34	(0.02)	-0.26	(0.00)
electricity consumption $_{t-1}$ - gva $_{t-1}$	-0.52	(0.03)	-0.82	(0.02)	-0.44	(0.00)
price $_{t-1}$	-0.29	(0.01)	-0.37	(0.02)	-0.28	(0.00)

Δ gva $_{t}$	0.99	(0.01)	0.50	(0.14)	0.66	(0.00)
Δ electricity consumption $_{t-1}$	0.30	(0.06)	0.13	(0.54)	0.02	(0.88)
Δ gva $_{t-1}$	-0.60	(0.05)	0.03	(0.92)	0.15	(0.36)
Δ price $_{t-1}$	0.38	(0.03)	0.27	(0.30)	0.19	(0.13)
Level Dummy $_{83}$	NA	NA	NA	NA	0.07	(0.03)
Level Dummy $_{83}$ * time trend	NA	NA	NA	NA	-0.01	(0.00)
Level Dummy $_{02}$	-0.07	(0.03)	-0.11	(0.01)	-0.10	(0.00)
Impulse Dummy $_{03}$	-0.18	(0.00)	-0.16	(0.00)	-0.19	(0.00)
			Long run elasticities			
gva $_{t-1}$	**1.00**		**1.00**		**1.00**	
p $_{t-1}$	**-0.56**		**-0.45**		**-0.63**	

Cointegration test (null hypothesis is cointegration)						
	Test statistic	Upper bound	Test statistic	Upper bound	Test statistic	Upper bound
F stat for Cointegration	**5.54**	**[5.06]**	**4.59***	**[5.06]**	**15.23**	**[5.06]**
GVA long run coefficient test						
		p value		p value		p value
Test of long run coefficient of GVA		**0.27**		**0.20**		**0.55**
Diagnostic check						
Heteroskedasticity		0.83		0.27		0.04*
Auto correlation		0.20		0.82		0.41
Ramsey RESET test		0.14		0.04*		0.10

Note: *Estimates of ECM models and their p values. All of Australia model is presented for comparison. Bounds testing indicates there is evidence of cointegration at 10 per cent level. Restricting long run coefficient of GVA to 1 is supported by data. * indicates test statistic reject null hypothesis at 10 per cent level. Bound value from Pesaran, Shin, & Smith (2001). The null hypothesis of the long run GVA coefficient test is that it is equal to zero. The Null of the heteroskedasticity and autocorrelation are the residuals are not heteroskedastic and not auto correlated. Ramsey RESET test assumes no miss-specification under the null.*

Source: *Vivid Economics*

Table 28. **Commercial equations show consistent long run estimates of price and GVA elasticities**

	NEM		NEM		Australia	
	1991-92 to 2007		1991-92 to 2012		1976-77 to 2012	
Commercial Equations	**Coefficient**	**p value**	**Coefficient**	**p value**	**Coefficient**	**p value**
Constant	-1.48	(0.00)	-1.27	(0.05)	-1.09	(0.01)
electricity consumption $_{t-1}$- gva $_{t-1}$	-0.54	(0.00)	-0.47	(0.04)	-0.36	(0.00)
price $_{t-1}$	-0.22	(0.00)	-0.22	(0.13)	-0.17	(0.03)
nvhd $_{t-1}$	0.04	(0.00)	0.03	(0.28)	0.02	(0.19)
Δ electricity consumption $_{t-1}$	0.26	(0.00)	0.13	(0.33)	0.10	(0.26)
Δ gva $_{t-1}$	1.02	(0.00)	0.81	(0.06)	0.58	(0.02)
Δ price $_{t-1}$	0.15	(0.03)	0.22	(0.17)	0.07	(0.37)
Level Dummy $_{83}$	NA	NA	NA	NA	0.16	(0.26)
Level Dummy $_{83}$ * time trend	NA	NA	NA	NA	0.004	(0.44)
Impulse Dummy $_{83}$	NA	NA	NA	NA	-0.07	(0.00)
Level Dummy $_{00}$	-0.03	(0.01)	-0.03	(0.24)	-0.03	(0.01)
Impulse Dummy $_{00}$	-0.02	(0.00)	-0.02	(0.35)	NA	NA
Impulse Dummy $_{03}$	0.11	(0.00)	0.11	(0.00)	0.11	(0.00)
Δnvhd $_{t}$	NA	NA	NA	NA	0.01	(0.10)

Long run elasticities						
gva $_{t-1}$	**1.00**		**1.00**		**1.00**	
p $_{t-1}$	**-0.42**		**-0.47**		**-0.47**	
Weather $_{t-1}$	**0.081**		**0.059**		**0.046**	
Cointegration test						
	Test statistic	Upper bound	Test stat	Upper bound	Test stat	Upper bound
F stat for Cointegration	**37.94**	**[5.06]**	**3.23***	**[5.06]**	**6.28**	**[5.06]**
GVA long run coefficient test						
		p value		p value		p value
Test of long run coefficient of GVA		**0.85**		**0.64**		**0.89**
Diagnostic check						
Heteroskedasticity		0.91		0.91		0.85
Auto correlation		0.15		0.13		0.01*
Ramsey RESET test		0.54		0.21		0.61

Note: *Estimates of ECM models and their p values. All of Australia model is presented for comparison. Bounds testing indicates there is evidence of cointegration at 10 per cent level. Restricting long run coefficient of GVA to 1 is supported by data. * indicates test statistic reject null hypothesis at 10 per cent level. Bound value from Pesaran, Shin, & Smith (2001). The null hypothesis of the long run GVA coefficient test is that it is equal to zero. The Null of the heteroskedasticity and autocorrelation are the residuals are not heteroskedastic and not auto correlated. Ramsey RESET test assumes no miss-specification under the null.*

Source: *Vivid Economics*

Table 29. **Residential equations show consistent long run estimates of price and GVA elasticities**

	NEM		NEM		Australia	
	1991-92 to 2007		1991-92 to 2012		1976-77 to 2012	
Residential Equations	**Coefficient**	**p value**	**Coefficient**	**p value**	**Coefficient**	**p value**
Constant	1.06	(0.01)	0.97	(0.01)	1.20	(0.00)
electricity consumption $_{t-1}$	-0.70	(0.01)	-0.64	(0.00)	-0.85	(0.00)
income $_{t-t}$	0.48	(0.01)	0.44	(0.01)	0.58	(0.00)
price $_{t-1}$	-0.10	(0.36)	-0.04	(0.32)	-0.05	(0.03)
Δ electricity consumption $_{t}$	-0.19	(0.18)	-0.05	(0.50)	-0.08	(0.05)
Level Dummy $_{83}$	NA	NA	NA	NA	0.17	(0.00)
Level Dummy $_{83}$ * time trend	NA	NA	NA	NA	0.03	(0.00)
Impulse Dummy $_{304}$	0.04	(0.00)	0.04	(0.00)	0.04	(0.00)
			Long run elasticities			
income $_{t-1}$	**0.69**		**0.69**		**0.68**	
p $_{t-1}$	**-0.15**		**-0.06**		**-0.06**	

Cointegration test						
	Test statistic	Upper bound	Test stat	Upper bound	Test stat	Upper bound
F stat for Cointegration	**3.60***	**5.06**	**4.13***	**5.06**	**17.48**	**5.06**
GVA long run coefficient test						
		p value		p value		p value
Long run coefficient of GVA test		**0.85**		**0.64**		**0.89**
Diagnostic check						
Heteroskedasticity		0.22		0.04		0.45
Auto correlation		0.84		0.61		0.94
Ramsey RESET test		0.71		0.92		0.55

Note: *Estimates of ECM models and their p values. All of Australia model is presented for comparison. Bounds testing indicates that there is evidence of cointegration at the 10 per cent level. Restricting long run coefficient of GVA to 1 is supported by data. * indicates test statistic reject null hypothesis at 10 per cent level. Bound value from Pesaran, Shin, & Smith (2001). The null hypothesis of the long run GVA coefficient test is that it is equal to zero. The Null of the heteroskedasticity and autocorrelation are the residuals are not heteroskedastic and not auto correlated. Ramsey RESET test assumes no miss-specification under the null.*

Source: *Vivid Economics*

Long run coefficients

Table 30. **Consumption Models for NEM region 1990-2007**

	Price	GVA/FCE	Weather
Manufacturing 2007 [2012]	-0.56 [-.45]	1.00 [1.00]	
Commercial and Services 2007 [2011]	-0.42 [-0.47]	1.00 [1.00]	0.08 [0.06]
Residential 2007 [2012]	-0.15 [-0.07]	0.69 [0.69]	

Note: Long run elasticity coefficients of different ADL models

Source: Vivid Economics

Table 31. **Consumption Models for Australia 1990-2012**

Sector	Price	GVA/FCE	Weather
Manufacturing 2007 [2012]	-.64 [-.64]	1.00 [1.00]	NA
Commercial and Services 2007 [2011]	0.45 [-0.47]	1.00 [1.00]	0.04 [0.04]
Residential 2007 [2012]	-.14 [-0.07]	0.63 [0.68]	NA

Note: Long run elasticity coefficients of different ADL models

Source: Vivid Economics

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Contact us:

Vivid Economics Limited
The Media Village
131-151 Great Titchfield Street
London W1W 5BB
United Kingdom

T: +44 (0)844 8000 254

E: enquiries@vivideconomics.com

Company Profile

Vivid Economics is a leading strategic economics consultancy with global reach. We strive to create lasting value for our clients, both in government and the private sector, and for society at large.

We are a premier consultant in the policy-commerce interface and resource- and environment-intensive sectors, where we advise on the most critical and complex policy and commercial questions facing clients around the world. The success we bring to our clients reflects a strong partnership culture, solid foundation of skills and analytical assets, and close cooperation with a large network of contacts across key organisations.