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Power Down

Why is electricity consumption decreasing?

Institute Paper No. 14
December 2013
ISSN 1836-8948

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TAI

Institute Paper

Acknowledgments

I would like to thank Dr. Richard Denniss for his feedback, particularly in relation to the economic analysis, and the reliable and efficient Institute staff for their support throughout the publishing process. I am also grateful for the editing support provided by Susanna Nelson.

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Summary

Until 2010 – for well over a century, through two world wars and the Great Depression – the quantity of electricity used in Australia each year was greater than the year before. In the three years since 2010, the quantity used each year has been less than the year before, and there is no evidence of a reversal in this trend in the coming months. The electricity consumption decrease has been relatively large in the National Electricity Market (NEM), which covers the five eastern states and the ACT, but is also occurring in WA. Specifically, NEM demand in the financial year to 2013 was almost eight terawatt hours (TWh), or 4.3 per cent lower than in the peak year of 2009.

Why is this important? If electricity consumption in the NEM had continued to grow from 2005 onward at the same rate as it had for the previous twenty years, consumption would have been about 37 TWh higher in 2013 than it actually was. This difference is equal to the output of almost 5,000 megawatts (MW) of coal fired generation capacity, which is just less than the combined capacity of Bayswater plus Eraring in NSW or, in Victoria, Loy Yang A plus Loy Yang B plus Hazelwood. All of the decline in consumption has in fact been at the expense of coal-fired generators, with the result that many are now barely profitable. Greenhouse gas emissions fell by 9.2 Mt CO_2-e, roughly two per cent of Australia's total emissions, in 2012 alone.

Commentators have advanced many reasons to explain the fall in consumption of electricity, including milder summer weather, growth in electricity supplied by rooftop photovoltaics, increased uptake of solar water heating, and reduced output from the manufacturing sector of the economy. This paper examines the evidence to support these arguments and a number of other possible explanatory factors.

In summary, the three largest factors contributing to the recent dramatic changes in demand for electricity are:

- the impact of (mainly regulatory) energy efficiency programs,
- structural change in the economy away from electricity intensive industries, and
- since 2010, the response of electricity consumers, especially residential consumers, to higher electricity prices.

Australia's first mandatory regulatory energy efficiency measures were introduced in the late 1990s, in the form of Mandatory Energy Performance Standards (MEPS) for refrigerators and freezers. Since then, MEPS have been extended to a very wide range of residential and commercial appliances and equipment, and analogous energy efficiency requirements have been applied to new buildings. It is estimated that these measures have, in total, reduced demand for electricity in 2013 by over 13 TWh, or 37 per cent of the total 'shortfall'. The appliance and

equipment MEPS measures account for most of this reduction; some of the other measures, such as the state programs, have made only very small contributions.

Between October 2011 and September 2012, three major industrial electricity users, all in NSW – the Port Kembla steelworks, the Kurri Kurri aluminium smelter and the Clyde oil refinery – were partially or completely shut down. These closures removed approximately 3.6 TWh of annual electricity consumption from the NEM, which is about 10 per cent of the 37 TWh ‘shortfall’. But detailed analysis of successive annual public reports of National Greenhouse and Energy Reporting System (NGERS) data shows that, other than the companies linked to the above closures, electricity consumption over the three years from 2010 to 2012 was remarkably constant. While there was negligible growth, there was no decline, let alone a ‘collapse’, as some more excitable commentators have claimed. ABS National Accounts data of value added by economic sector convey a similar picture – manufacturing output in real terms has been fairly constant. This means that, as is well known, manufacturing is gradually declining as a share of the total economy, but is not markedly declining in absolute terms.

Looking further back in time, however, it can be seen that for several decades, ending around 2006, there was steady growth in Australian output of primary metals, such as aluminium and other electricity intensive commodities. Since 2006 there has been no growth – and, very recently, absolute decline, as described above. Over and above the absolute decline caused by the closures, the lack of growth in output of electricity intensive commodities is contributing to lack of growth in demand for electricity, amounting to about 14 per cent of the 37 TWh ‘shortfall’. Declining manufacturing output overall is not, in general, causing an absolute fall in demand.

A further contribution to the declining demand for electricity supplied by major generators – the basis on which electricity demand is usually tracked – has been the growth in output from rooftop photovoltaics and other small, distributed generators. This growth has contributed about 13 per cent of the ‘shortfall’.

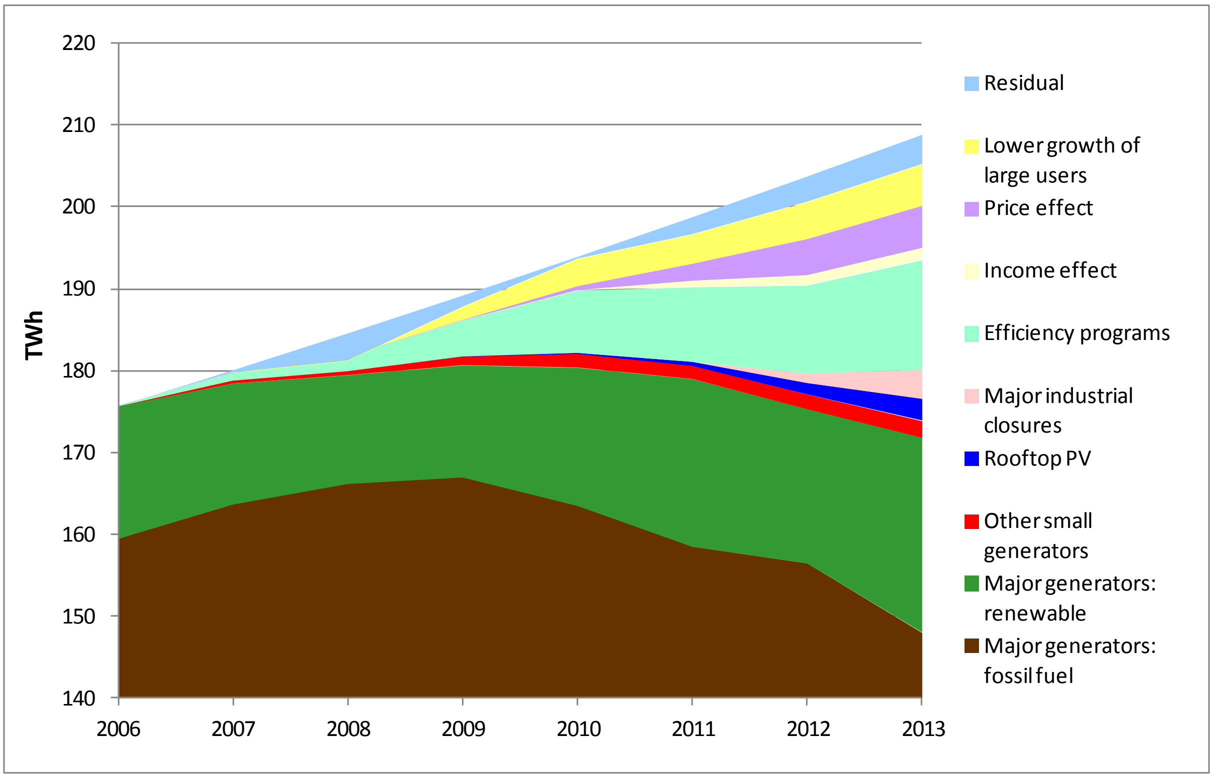
When all the above contributions to reduced electricity demand are added to actual demand, starting in 2006, it is found that total notional demand resulting from this modelling closely tracks the historical trend growth in electricity demand, up to 2010. Since then, however, there has been a marked departure from trend. From 2010 to 2013 a widening gap between the modelled demand for electricity services and the historical projected demand emerges. This gap can be completely accounted for by introducing consumer response to higher electricity prices into the model. This report finds that the price response explains 19 per cent of the demand ‘gap’ in 2013.

The most interesting finding of this part of the modelling is the abrupt change in consumer responsiveness to higher prices after 2010. It is surely not a coincidence that 2009-10 was the year in which the possible effect of a carbon price on electricity prices became a major national political issue, and in which increasing political attention was also paid to the rapid increases in electricity prices already occurring, mainly because of higher network costs. Electricity prices remain a major preoccupation of political debate. The hypothesis is that the political attention being paid to electricity prices led consumers to pay more attention than they had previously done to their expenditure on electricity. When they did, they responded by reducing their consumption, so as to limit what they were spending, and the outcome showed up strongly in the total electricity demand figures from 2011 on. Powerful evidence to support the latter contention is found in the recently published ABS *Energy Account* data, from which it can be calculated that real average annual household expenditure on electricity grew strongly until 2009-10, since when it has barely increased, despite continuing large increases in electricity prices. It appears that residential electricity consumers have managed to completely offset the effect of higher prices on their household budgets by reducing consumption.

Finally, it has been suggested that, over the last few years, summer weather in most parts of Australia has been, on average, less hot, and that therefore less electricity was being consumed for air conditioning, thereby reducing total demand. Complete analysis of all NEM states over nine summers and winters from 2005 to 2013 shows that the relationship between seasonal electricity consumption and the severity of seasonal weather has followed the same trend as total electricity demand. Comparable seasonal weather over the past three or four years has been associated with progressively lower electricity consumption. Milder weather may affect year-on-year changes in consumption, but it is not driving the longer-term downward trend in demand.

The overall findings of the study are summarised in the Figure below. It shows, at the top, the level which electricity demand would have reached if demand had continued to grow at historic rates, and, beneath that, the contribution of each major factor which has reduced actual demand for electricity below that level. It also shows how major renewable generators, mainly hydro and wind, have increased their share of electricity sent out by NEM generators

Contribution of the various factors to reduced demand for electricity in the NEM since 2006



This study is not intended to be a basis for projecting possible future demand for electricity – however, the findings point to a number of changes in the drivers of increased electricity consumption, most of which seem likely to persist, and perhaps even strengthen. The logical conclusion is that, although growth in electricity consumption may resume in the next few years, it will be at much lower annual rates than those that prevailed for more than a century up to about 2004.

1 Introduction

Over the last three or four years, the quantity of electricity supplied to consumers by the Australian electricity supply industry has fallen year on year: in 2009-10 it was very slightly less than in 2008-09, in 2010-11 it fell by a larger amount and in 2011-12 by yet more.[1] Other data, discussed later in this paper, suggest that the fall in demand accelerated again in 2012-13.

Sustained year-on-year falls in demand for electricity are entirely without precedent in the history of the Australian electricity supply industry. From 1904, the year for which the earliest reasonably comprehensive statistics are available, until 1983, the total volume of electrical energy supplied each year never fell from one year to the next, even during the height of the Great Depression in the 1930s.[2] Throughout this whole long period, steady increases in the consumption of electricity were accompanied by almost equally steady falls in the real price of electricity to consumers. In the early 1980s, a surge of new investment by electricity supply authorities saw real price increases for several successive years.[3] In 1982-83 there were small reductions in annual consumption in NSW, Victoria, Tasmania and the ACT, and in 1983-84 consumption fell in SA. In each case, however, growth in consumption resumed the following year and continued uninterrupted until 2008-09. Moreover, in the early 1980s there was no year in which total Australia-wide consumption fell, whereas now total national consumption is falling, as is consumption in every individual state and territory.[4]

Figure 1 shows annual consumption for financial years in the National Electricity Market (NEM) and in the South West Interconnected System (SWIS). Consumption is measured as total energy sent out by generators in each of the two systems; the relevance of using 'sent out' as a measure is discussed in the next section of this paper. The NEM covers all electricity supplied in Queensland, NSW, Victoria, Tasmania and SA, with the exception of Mt. Isa and a few other very small isolated systems in western Queensland. The SWIS is the main electricity supply system in WA – it extends as far east as Kalgoorlie, but does not include the Pilbara region. Note that data from the sources used for this graph, which are the most complete, consistent and accurate of the available data sets, are not available for earlier years. For the NEM, the reduction from the peak year,

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[1] Energy Supply Association of Australia (2013) *Electricity Gas Australia 2013*.

[2] Saddler, H (1987) *Minerals and Energy*, in Vamplew, W, ed, 'Australians: Historical statistics', Fairfax, Syme & Weldon Associates, Sydney.

[3] Simshauser, P and Catt, A (2011) *Dividend policy, energy utilities and the investment megacycle*, AGL Applied Economic and Policy Research, Working Paper No.28 – Dividends. <http://www.aglblog.com.au/>

[4] Demand continued to grow in WA up to 2010-11, but the most recent data indicates that it has fallen slightly in the last two years.

which was 2008-09, to 2012-13 is 4.7 per cent, and, for the SWIS, the reduction from the peak year of 2010-11 to 2012-13 is 2.4 per cent.

Figure 2 shows total and per capita annual electricity consumption trends for the NEM only, on an index number basis. It can be seen that on a per capita basis electricity consumption reached its maximum two years earlier than it did in total terms. Clearly, therefore, the changes which have led to the decline in demand started up to eight or more years ago, but have only become unambiguously apparent with the downturn in total demand over the last two or three years.

Figure 1: Annual electricity sent out in the NEM and the SWIS

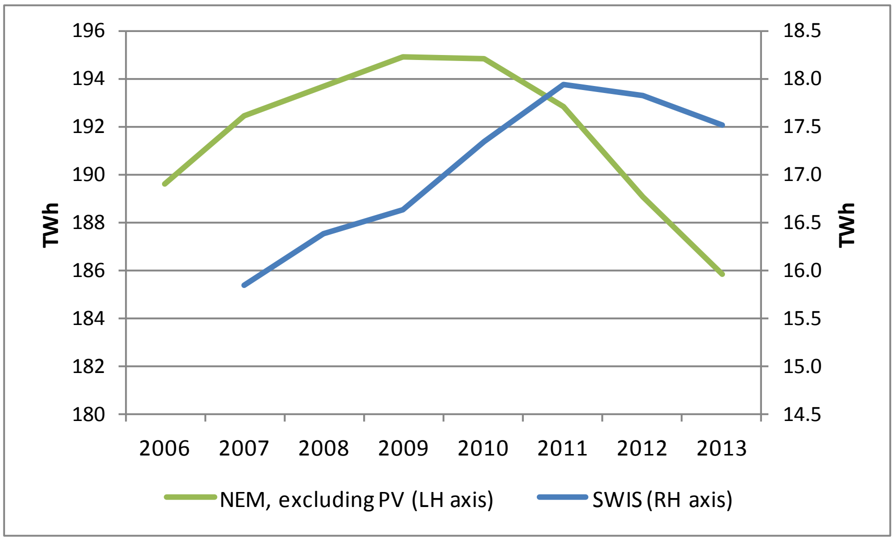


Figure 2: Trends in total and per capita annual electrical energy consumption in the NEM

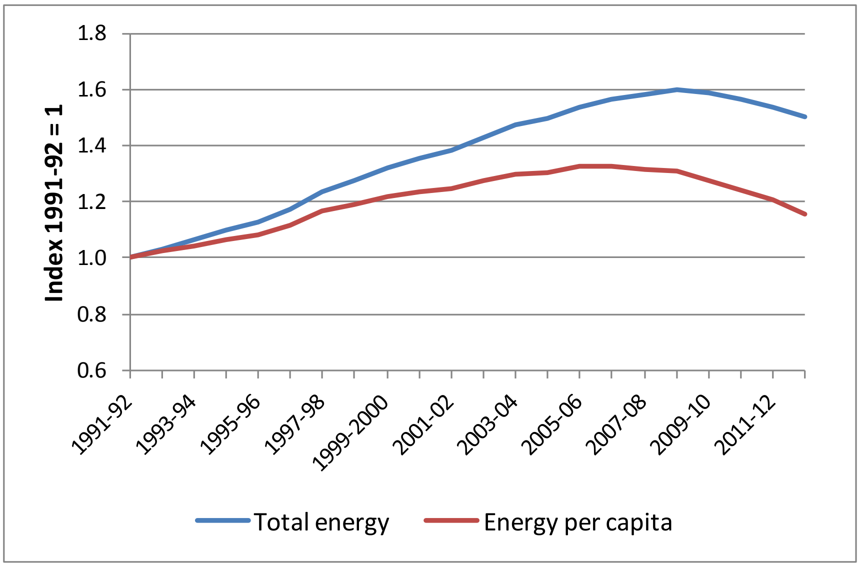
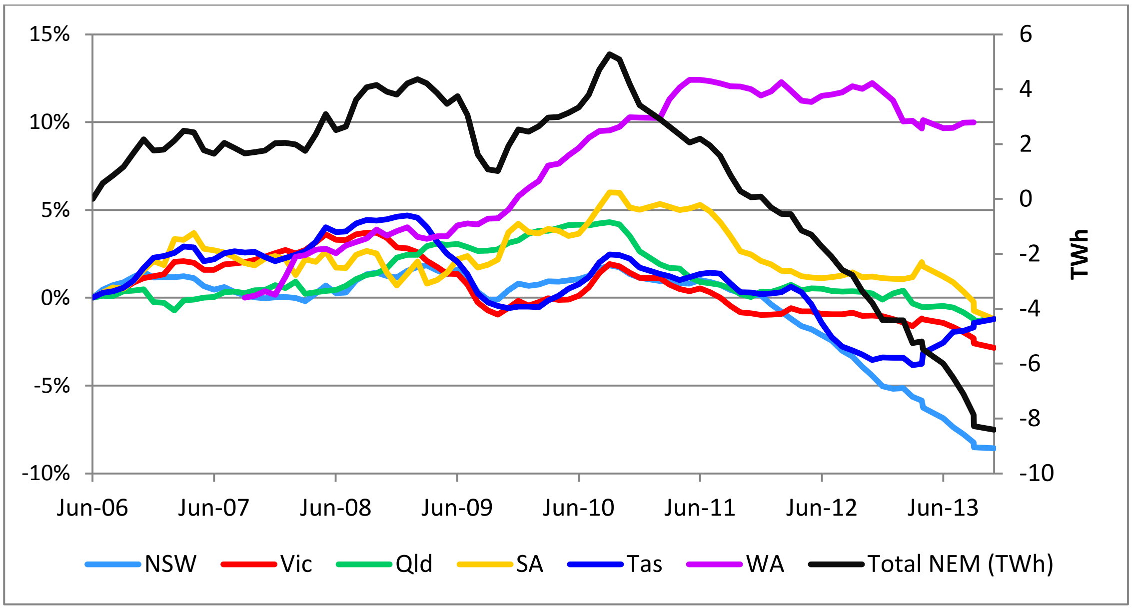


Figure 3 shows relative changes in electricity consumption in each state region in the NEM on a monthly moving annual basis. This approach eliminates the effect of seasonal changes in consumption, which dominate individual month-on-month changes, but it does include any effects on consumption caused by particularly severe or particularly mild summers and winters. Plotting relative rather than absolute numbers makes changes in the smaller regions much clearer on the graph. Figure 3 also shows the absolute change in consumption in the NEM, again on a monthly moving annual total basis.

Figure 3: Relative changes in sent out electricity in each state

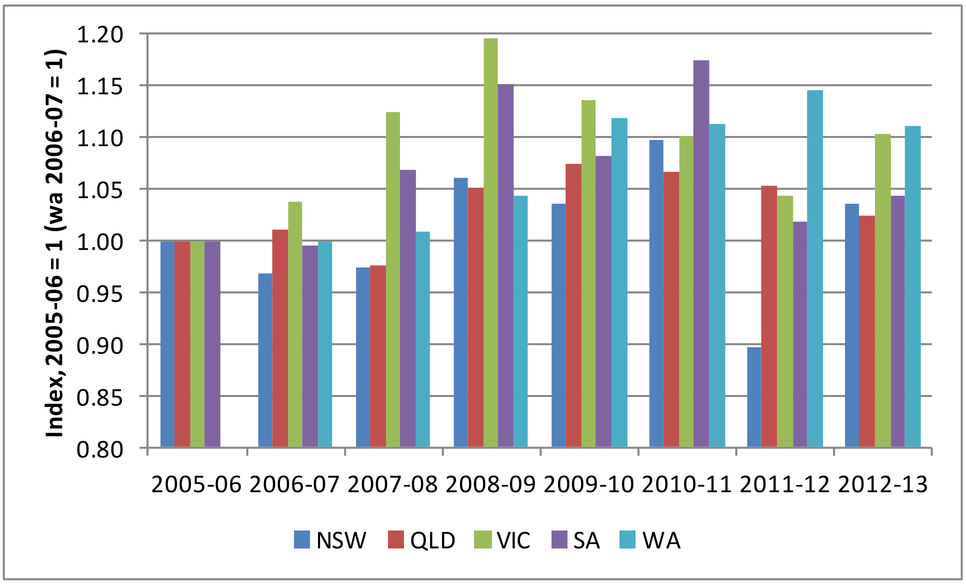


Source: Pitt&Sherry[5]

Figure 4 shows annual peak demand in each state region, excluding Tasmania. In the electricity supply industry the word 'demand' has a particular meaning; it refers to the instantaneous power being supplied or consumed. It is peak demand that determines the required capacity of transmission and distribution systems, and also the total generation capacity required to be available. In all state regions except Tasmania, annual peak demand occurs in summer, driven by electricity used for air conditioning on very hot days (in NSW peak demand occasionally occurs in winter).

[5] Pitt&Sherry, 2013a. *Cedex Electricity Update* <www.pittsh.com.au/cedex>

Figure 4: Trends in annual peak electricity demand in each state



Source: Data taken from Australian Energy Regulator, 2013a and Independent Market Operator, 2013

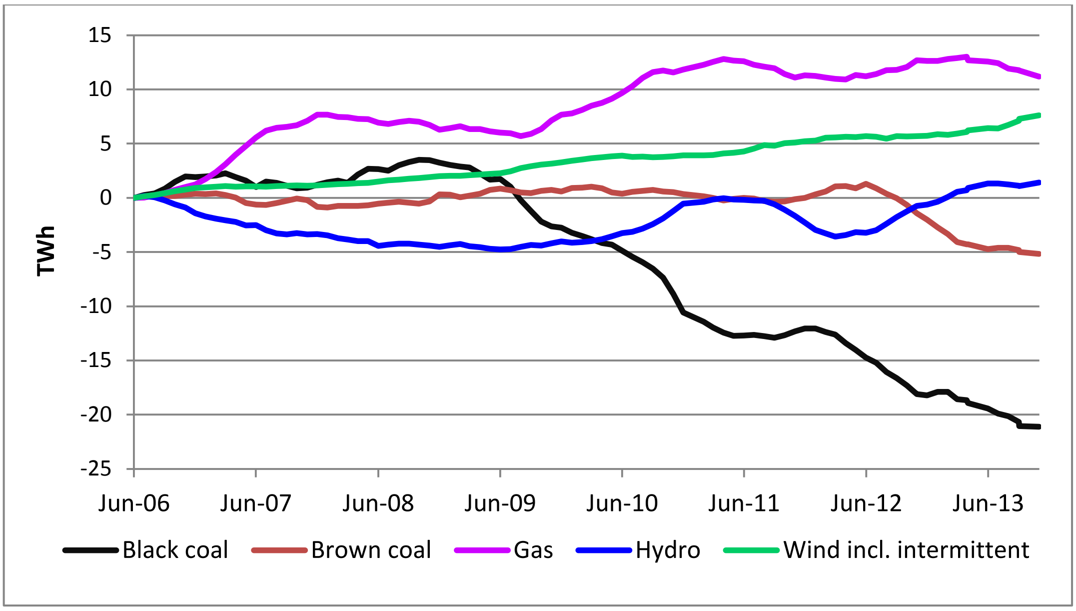
A few years ago, the year-on-year growth of peak demand was considerably greater than year-on-year growth in total annual energy consumption – this can be seen when Figure 3 and Figure 1 are compared. It was widely expected by electricity industry planners and managers that rapid peak demand growth would continue for some years. Accordingly they made plans to greatly increase the transmission and distribution capacity and sought and received authorisation from the price-regulating bodies to recover the cost of this investment in 'poles and wires' – and transformers and switchgear – in the prices they charged electricity consumers. The cost of new investment in transmission and distribution systems has been by far the largest contributor to the large increases in electricity prices experienced over the past five years, as is now widely acknowledged, though sometimes ignored or even denied for political reasons.

The data in Figure 4 suggest that in the last three years annual peak demand has been falling, not increasing. When will this additional capacity, which is now built and for which all electricity consumers are paying – and will continue to pay for some years to come – be required? Will it ever be required? Understanding why electricity consumption and demand have been falling will help to answer these multi-billion dollar questions.

To find the answers to these questions, it is important to understand what has been happening over the past three years. Without understanding the past, there can be no sound basis for projecting what may happen in the future. The objective of this paper is to gain greater understanding of that past, rather than to seek to suggest what the future may be.

That said, falling consumption of electricity is already having major impacts on the economics of all parts of the electricity supply industry, and also on Australia's total greenhouse gas emissions. While total consumption, and hence the total requirement for electricity generation, have been falling, the quantities of electricity supplied by gas, hydro and wind generators have been rising. All the required reduction in generation has come from coal – and especially black coal – generators, with the consequence that a number of smaller, older power stations have been withdrawn from the market over the last year or so. The decline of coal is shown clearly in Figure 5, for the NEM.

Figure 5: Changes in electricity generation in the NEM by fuel type



Source: Pitt&Sherry[6]

Falling electricity consumption has not only reduced the total quantities of electricity supplied by coal-fired generators, it has also contributed to dramatic reductions in average spot prices in the NEM wholesale market. Table 1 shows these prices in each NEM region since the peak years of 2007-08 and 2008-09, through to 2011-12, and also for 2012-13, when they increased sharply because of the carbon price. Although in the short term the prices that generators actually receive for electricity supplied are largely determined by the array of hedging contracts they hold, over the longer term market competition means that hedge prices have to adjust in line with the spot market.

[6] Pitt&Sherry, 2013a. *Cedex Electricity Update* <www.pittsh.com.au/cedex>

Table 1: Annual volume weighted spot prices in the NEM ($/MWh)

Region	NSW	Queensland	Victoria	SA	Tasmania
2007-08	44	58	51	101	57
2008-09	43	36	49	69	62
2009-10	52	37	42	82	30
2010-11	43	34	29	42	31
2011-12	31	30	28	32	33
2012-13	56	60	61	75	49

Sources: 2007-08 to 2011-12, Australian Energy Regulator[7]; 2012-13, author's calculations from AEMO data

The financial position of network (transmission and distribution) businesses is also being undermined. Although most of their costs are fixed, in the form of interest and depreciation charges against their very large stock of assets, they earn most of their income by means of a per-kilowatt hour charge on consumption of the electricity they supply. As regulated monopoly businesses, they have some freedom to increase prices so as to protect revenue in the face of declining throughput volumes, though the extent of this freedom depends on the precise form of the various regulatory decisions. But, all else being equal, as prices are increased they run the risk that consumers will further reduce their electricity consumption, thereby setting up a negative feedback loop, which is sometimes rather colourfully described as a 'death spiral'.[8]

Finally, a very significant consequence of the fall in electricity supplied by coal-fired generators has been a sharp reduction in greenhouse gas emissions. According to official government greenhouse gas inventory data, Australia's emissions from electricity generation fell by 9.2 megatonnes of carbon dioxide emissions in the year from December 2011 to December 2012, equivalent to 4.7 per cent. This decrease was so large that it entirely offset the increases over the same period from almost all other emission source categories. Consequently, Australia's total greenhouse gas emissions fell by 0.2 per cent over the year.[9]

[7] Australian Energy Regulator (2012) *State of the Energy Market 2012* <http://www.aer.gov.au/sites/default/files/State per cent20of per cent20the per cent20Energy per cent20market per cent202012 per cent20- per cent20Complete per cent20report per cent20(A4).pdf>

[8] Simshauer, P and Nelson, T (2011)

[9] Department of the Environment (2013a) *Quarterly Update of Australia's National Greenhouse Gas Inventory: December 2012.* <http://www.climatechange.gov.au/climate-change/greenhouse-gas-measurement-and-reporting/tracking-australias-greenhouse-gas-emissio-0/quarterly-update-australias-national-greenhouse-gas-inventory-march-13>

Figure 6 shows the trend of annual electrical energy sent out by generators in the NEM since the beginning of the 1990s. After recovery from the slowdown caused by the 1990 recession, demand grew at an average annual rate of 3.3 per cent for the whole period from 1992 to 2004. It then slowed dramatically. Figure 6 also shows what consumption would have been if growth had continued at a rate of 2.5 per cent per annum from 2004 to 2013, and also what the Australian Energy Market Operator (AEMO) forecast, as recently as 2010, consumption would be over the following three years.[10] To understand what has been happening over the last few years, it is necessary to understand not only the causes of the absolute reduction from the peak, but also the causes of the much larger fall from the earlier trend. As already noted, this trend had been in place for the entire period since World War 2 and, in fact for even longer than that. The entire departure from long-term trend is shown as a 'wedge' between the top and the bottom lines in Figure 6. The width of this wedge between actual and projected electricity consumption in 2013 is 37 TWh, which equals the annual output of almost 5,000 MW of coal-fired generation capacity. This is just less than the capacity of Bayswater plus Eraring in NSW or, in Victoria, Loy Yang A plus Loy Yang B plus Hazelwood.

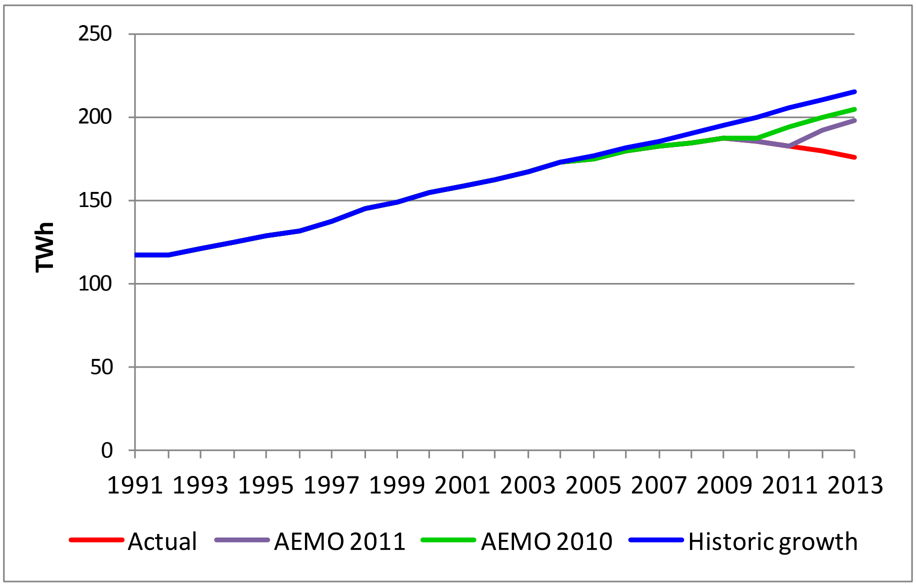
Commentators have advanced many reasons to explain the fall in consumption of electricity. One of the more balanced and comprehensive contributions has come from the Australian Energy Regulator.[11]

> *... weaker demand from the manufacturing sector; the increasing use of rooftop PV generation; and customers responding to rising electricity costs by adopting energy efficiency measures such as solar water heating. Additionally, consecutive summers of below average temperatures capped peak demand by reducing the use of air conditioners … (p. 46)*

[10] Australian Energy Market Operator (2013a) *2010 Electricity Statement of Opportunities*. <http://www.aemo.com.au/Electricity/Planning/Archive-of-previous-Planning-reports/2010-Electricity-Statement-of-Opportunities>

[11] Australian Energy Regulator (2012) *Op. cit.*

Figure 6: Actual annual energy sent out by generators in the NEM since 1991, and three projections



Source: Calculated by the author from Energy Supply Association of Australia (annual series) and Australian Energy Market Operator (2012), (2013b) and (2013c)

The remainder of this paper examines the evidence for these and a number of other possible explanatory factors. It does so by approaching the issue from both the 'bottom up' and the 'top down' perspectives. The former method seeks to estimate the size and timing of a number of individual factors, each contributing a 'wedge' to the total fall in demand from the previous trend growth. The latter examines the possible overall effect of electricity prices and of consumer income on demand for electricity.

The Australian Energy Market Operator (AEMO), as part of its long-term generation market and transmission investment planning functions, prepares each year the *Electricity Statement of Opportunities* (for generation requirements) and the *National Transmission Development Plan*. Supporting each of these documents is a substantial electricity forecasting exercise, to which, in the last couple of years, AEMO has committed increased resources. For 2013 AEMO has examined recent trends in a number of 'bottom up' factors as well as undertaking a 'top down' econometric study – therefore, in some of the ground it traverses, this paper follows AEMO. But since it seeks only to provide deeper understanding of what has been happening in the recent past, and does not aim to forecast the future, this paper is able to go into considerably more detail than AEMO, at least in its published material. That said, the data that AEMO has made publicly available is clearly, by a wide margin, both the most detailed and the most reliable aggregate statistical information about Australian electricity supply and demand and the analysis described in this paper is heavily reliant on it, as described in the next section.

2 Data sources used

The changes in demand with which this paper is concerned, while large in absolute terms, are quite small in relative terms, especially at the level of year-on-year changes. Use of accurate and consistent data sets is therefore a necessary foundation for the quantitative analysis reported in this paper. It is also essential to understand the different measures of electricity supply and electricity demand used by the various organisations publishing the relevant data. Consequently, this section of the paper starts with a discussion of data and data sources, before moving on to consider data pertaining to some specific sources of electricity generation.

As previously noted, AEMO, as part of its long term generation market and transmission investment planning functions, has published a large volume of its detailed underlying analyses and data. Unlike many of the other publicly available sources of data, the AEMO data does not suffer from changes in coverage or definitions of individual data items over the time series covered, nor does it display any striking discontinuities in successive year-on-year values. The same can be said of the very much more limited data available for WA from the Independent Market Operator (IMO). Unfortunately, neither source contains a long historical record; the complete AEMO data are available from 2005-06 on and the IMO data, on an annual basis, only from September 2007.

The other data sources used for this paper are the annual statistics published by the Energy Supply Association of Australia (ESAA) and the annual *Australian Energy Statistics*, produced by the Bureau of Resource and Energy Economics (BREE).

Unless otherwise stated, most data used in this paper are annual and for financial years, which are identified by the end year.

Perhaps the most important source of the problems that arise with all these data sources is that there are a number of different ways of measuring ‘electricity supply’ and ‘electricity demand’. Most of the measures are to a greater or lesser degree incomplete, because of difficulty of obtaining all the data needed to make them complete, and the fact that different organisations use different measures, and most of them periodically change the scope of what they include in the measures they publish. This is usually done with the laudable aim of making the measures used more complete, but it usually also has the unfortunate effect of introducing a break or discontinuity into a data series. A brief definition and description of the most frequently used measures follows.

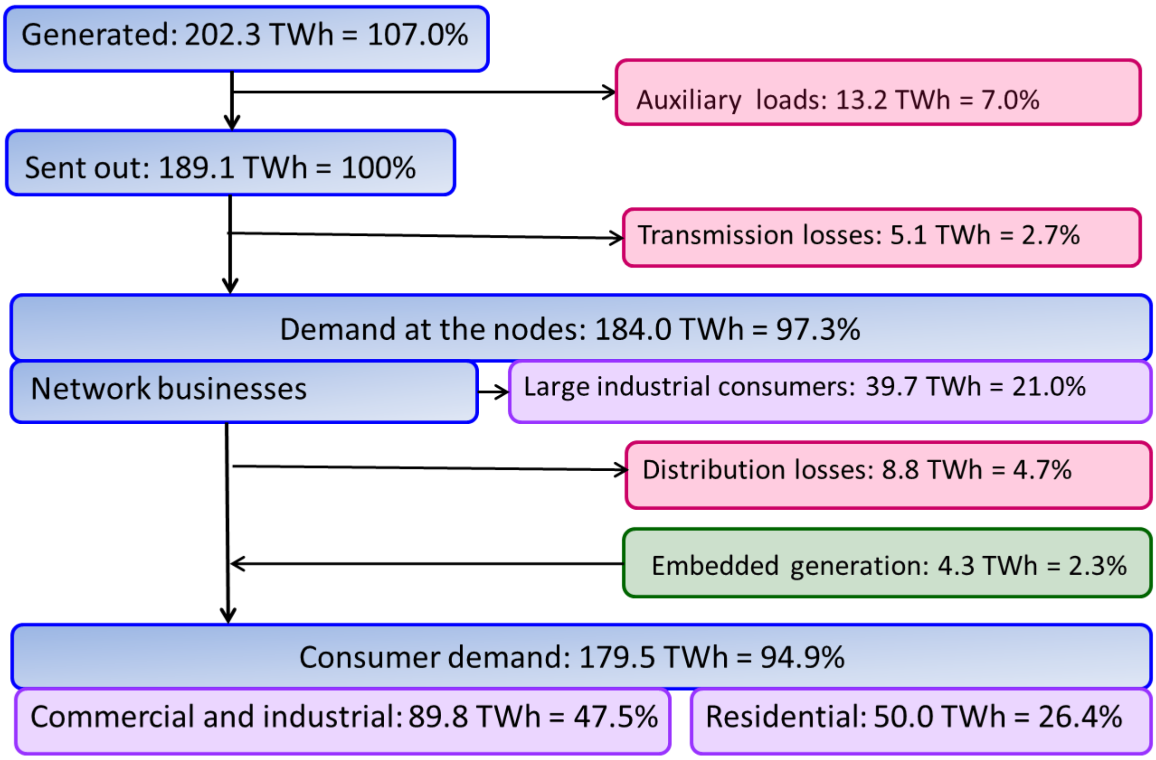
Electrical energy generated (usually shortened to ‘electricity’ or ‘energy generated’, or just ‘generation’) is the quantity of electricity produced in a given time period by generators, measured at the output terminal of each generating machine. Some of this output is used in the power stations, to drive, for example, pumps, fans, conveyors and crushers – collectively called auxiliaries. Auxiliary loads are typically up to nine per cent of electricity generated for a brown coal power station, five per cent for a black coal station, two to three per cent for a gas fired power station, and effectively zero for hydro and wind power stations. These are large numbers in the context of changes in total electricity demand of a few per cent per year.

Electricity sent out is equal to electricity generated minus auxiliary load. Hence, as the name suggests, electricity sent out is the total quantity of electricity leaving the power station. For the purposes of the sort of analysis described in this paper, it is by far the more useful measure of electricity supplied. The numbers plotted in Figure 1 above are for electricity sent out in each of the two systems. This is the only system-wide data available for the SWIS, so using this measure places the two data series on a precisely comparable basis.

Electricity supplied to consumers is what it says, and is equal to electricity sent out minus losses in transmission and distribution. Transmission and distribution losses in Australia typically average between six and seven per cent of electricity sent out in total. While, in principle, obtaining data on electricity supplied should be reliable and accurate – because it is just the sum of all the meter records over a year – in practice it is not so simple. Complications include the fact that some consumption is not metered, and so has to be estimated, that estimates also have to be made of quantities supplied during the period between the last meter reading for each customer during the year and the end of the year, and that electricity retailer billing systems, from where consumption data is obtained, contain many errors.

Figure 7 shows the relationship between the various measures and quantities, using data for 2011-12 and expressing all quantities as a percentage of electricity sent out by major generators.

Figure 7: Flows of electrical energy in the NEM, 2011-12



Sources: Australian Energy Market Operator (2013c), Energy Supply Association of Australia (annual), author's calculations

A further complication is that not all sources of generation are covered by statistical collections. Until a few years ago data was collected only for electricity supplied by the large centralised power stations formerly operated by the various state government electricity supply authorities. As technologies have changed and many new small distributed sources of generation have emerged, data for generation by various groups or categories of these new generation sources have progressively been added. Such additions, while welcome, are also a major source of discontinuities in data series.

Aggregate data sets published by AEMO in support of its *National Electricity Forecasting Report*[12] for each state in the NEM and the total NEM include:

[12] Australian Energy Market Operator (2013b) *National Electricity Forecasting Report (NEFR) 2013*. <http://www.aemo.com.au/Electricity/Planning/Forecasting/National-Electricity-Forecasting-Report-2013>

- electricity generated by major generators
- auxiliary loads
- electricity sent out by major generators
- transmission (but not distribution) losses
- electricity generated by rooftop photovoltaics
- electricity generated by other small generators,
- electricity consumption, disaggregated into two groups:
    - major industrial consumers, and
    - residential, commercial and small industrial consumers.

The other extremely important data source provided by AEMO is the electricity market data, most of which is available for each 30-minute trading interval in the NEM wholesale market. For analysis reported in this paper, the data has been accessed through the NEM Review subscription service, which downloads all the data from AEMO, and enables aggregation and interrogation of the complete data set. Data for Tasmania is available only from May 2005, when Tasmania joined the NEM following the commissioning of the BassLink transmission cable. Data for the mainland states is, in general, available back to the start of the NEM in December 1998, with the exceptions noted below against each data category. Data for the smaller ('non-scheduled') generators, however, is available only from the start of 2006, which means that there is a small discontinuity in the generation data series at that time. The main data series include the following:

- electricity generated by every generator in the system of capacity greater than 30 MW (and a number smaller than 30 MW), available from the start of the NEM in 1998, with the exceptions noted above
- total demand (consumption) by NEM region (which is each of the five states, with the ACT being part of NSW), available from July 2004
- energy flows through the interconnectors between regions, available from the start of the NEM in 1998 or from the date of commissioning the interconnector concerned
- spot prices in each pool (region) available from the start of the NEM.

For WA, the IMO publishes a single figure for each 30-minute trading interval for total electricity sent out by generators in the SWIS. The first day in this series is 21 September 2006, so the first full year for which data are available is 2007-08. These are the only IMO data used. Market price data are also available, but because the market design differs in important ways from the structure of the NEM, prices are not directly comparable, and so have not been used.

Data sets published by the ESAA for each state, including WA and the NT, and Australia in total include:

- total electricity generated,
- total electricity sent, and
- electricity consumption, disaggregated into three groups:
    1) residential consumers,
    2) commercial and industrial consumers, and
    3) unmetered consumption.

Data sets published by BREE for each state and nationwide include the total electricity consumption in each state, disaggregated by economic sector, including electricity used by the electricity supply industry itself, as auxiliary loads and transmission and distribution losses.

As an illustration of the difficulties presented by apparent inconsistencies between data sources, Figure 7 shows estimates from each of the three sources for annual electricity consumption by consumers, that is, excluding the electricity industry itself, for each year since 2005-06. The ESAA and BREE each publish estimates of electricity consumption. The AEMO data sets listed above only allow the calculation, as a single combined number, of consumption-plus-distribution losses. A separate estimate of distribution losses has been made, by back calculation from the Scope 2 emissions of the various network businesses, as contained in their respective NGERS public reports.

It can be seen that the BREE figures are consistently higher than those from the other two sources. The difference is probably explained by the more comprehensive coverage of the BREE estimates, which include two additional categories of electricity consumption.

Electricity consumed beyond major grids

As it happens, BREE (2013) has recently published an estimate of such electricity consumption across Australia in 2011-12;[13] the effect of adjusting for this consumption in the NEM states in 2011-12 is shown in Figure 8.

Consumption of self-generated – mainly co-generated – electricity at industrial sites

BREE includes in its consumption total all electricity that all consumers, both on- and off-grid, generate at their own sites. It has reported these quantities separately for the past three years. The fact that off-grid self-generated electricity is included in both categories and cannot be separately identified causes some double

[13] Bureau of Resource and Energy Economics (2013a) *Beyond the NEM and the SWIS: 2011-12 regional and remote electricity in Australia*, Canberra, October <http://www.bree.gov.au/publications/rare/doc/BREE-Regional-and-remote-electricity-201310.pdf>

counting, which almost certainly explains why the adjusted BREE consumption estimate is lower than the two other figures.

Figure 8: Estimates by different organisations of annual electrical energy supplied to consumers in the NEM

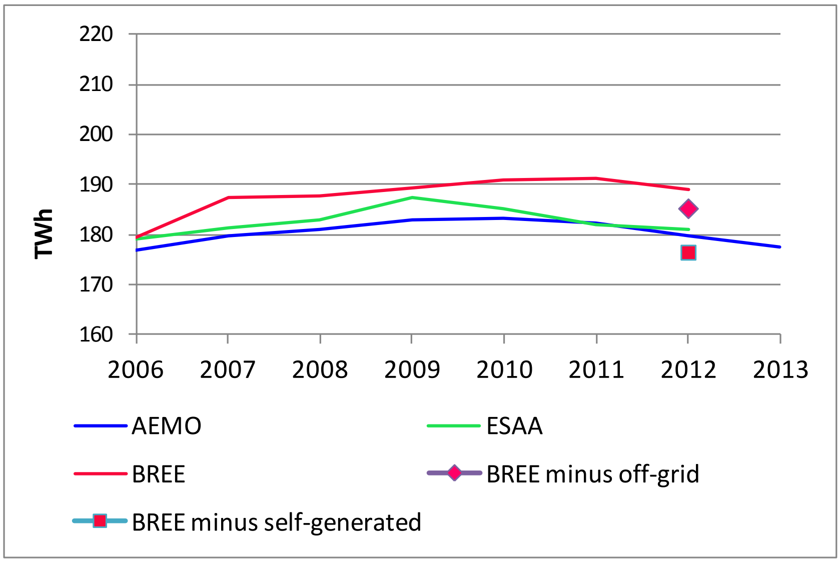
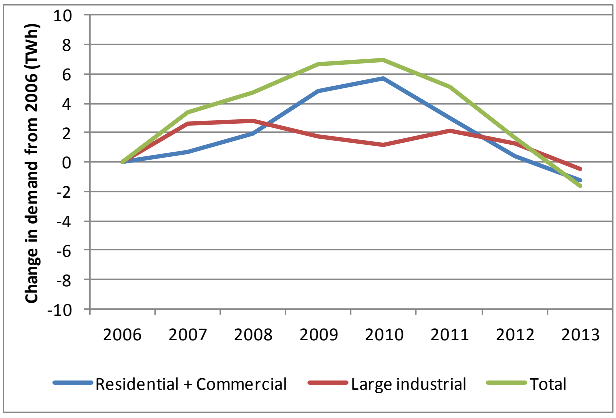
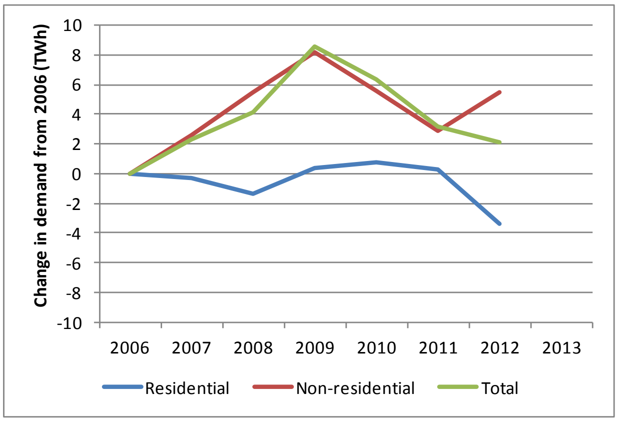


Figure 8 shows the split of total demand in the NEM between the two customer groups used by AEMO and the ESAA. Noting that the ESAA data run only until 2012, there are nevertheless clear inconsistencies between the two data sets. In all the analyses reported in this paper, data from AEMO – and, where relevant, IMO – have been used in preference to the other sources.

Figure 9: Changes in annual electricity demand since 2006, AEMO data (left) and ESAA data (right)



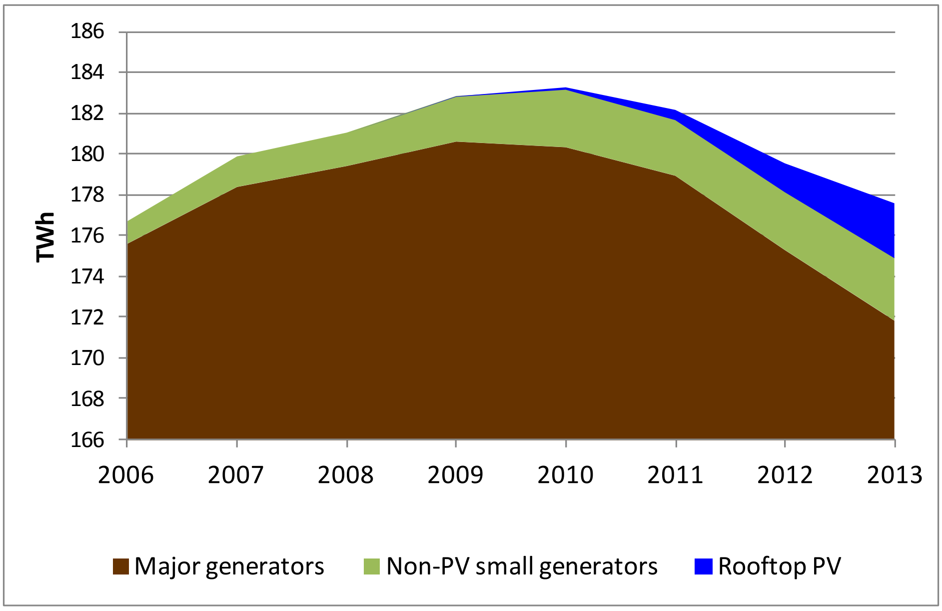


3 Rooftop photovoltaics and other new sources of electricity supply

The objective of this section is to quantify the contribution of changes in electricity supplied by rooftop photovoltaic (PV) systems, and other types of small distributed generators, to the apparent decline in demand. Making use of the various AEMO data sets listed above, Figure 10 has been constructed to show the contributions of rooftop photovoltaics and of other small generators to total electricity demand. The three data series are as follows.

- 'Major generators' is the quantity of electricity produced by the major NEM generators that is used by consumers, i.e. it is equal to electricity sent out minus transmission and distribution losses.
- 'Non-PV small generators' include a wide variety of generators including run of the river hydro plants, small (and older) wind farms, landfill gas plants, bagasse cogeneration plants at sugar mills and other, mainly gas fuelled cogeneration plants at small industrial sites and in a wide variety of different buildings. As the graph shows, some generation from these plants has been in place for a long time but, according to the AEMO data, their output has increased almost threefold since 2006. In 2012-13 they supplied 1.6 per cent of total consumption.
- 'Total demand including PV' includes the contribution of rooftop photovoltaics as well, and thus plots total consumption of electricity by consumers in the NEM. The data indicate that in 2012-13 photovoltaics supplied 1.4 per cent of consumption.

Figure 10: Trend in supply by embedded generators within the NEM



Overall, the effect of adding these small generators to the supply from major NEM generators is to reduce the apparent decline in electricity consumption. While supply by major generators fell by 4.7 per cent from the peak in 2008-09, total consumption fell by only 3.2 per cent from the changed peak year of 2009-10.

When interpreting these data it is important to recognise a subtle but important difference in the way the two sets of small generators are estimated. Generation by PV is estimated from very detailed data on installed capacity of PV systems by postcode by month, available from the Clean Energy Regulator, taking account of solar radiation input applicable to each location. The total therefore includes the total output from all the systems installed, including both the electricity consumed on site and the electricity exported to the network. By contrast, output data for cogeneration plants is derived from meter records and includes only electricity that is exported. The current economics of cogeneration in Australia strongly favour sizing a new cogeneration plant so that it only supplies the host facility and seldom if ever has surplus electricity to export. Consequently the data here under-estimate, to an unknown degree, electricity supplied by cogeneration plants. The implication is that, from the perspective of the electricity network, electricity supplied to the host establishment is identical to a reduction in demand resulting from enhanced energy efficiency. Since there is no comprehensive or systematic data on the operation of cogeneration plants, their total contribution to the apparent reduction in electricity demand, while larger than indicated by Figure 9, is unknown and, with current data, unknowable.

That said, for the analyses described in the rest of this paper, total consumption will be defined as consumption including that supplied by small generators, i.e. the top line in Figure 10. Furthermore, it is clear from the data described here that increased output from rooftop PV and other small generators can explain only a small part of the reduced demand for electricity supplied by large generators. Most of the reduction must have come from reductions in 'true' demand, that is, in reductions in the consumption of electricity to supply energy services. A key question to be answered, therefore, is whether this has been caused by reduced demand for energy services or by reduced use of energy to provide a given level of energy services, i.e. greater electricity use efficiency, or a mixture of both. Answering this question is of fundamental importance in designing future energy and greenhouse emissions policy. The remainder of this paper attempts to provide an answer.

4 The effect of changing weather on electricity demand

Space heating and cooling demand, in both residential and commercial buildings, accounts for a significant proportion of total electricity consumption. Consequently, total electricity demand is affected by day-to-day and season-to-season changes in weather conditions. The precise relationship between weather and electricity demand varies between states, depending on both the average climate across the state and, for the winter relationship, on the share of electricity, compared with gas, in meeting total space heating demand. The relationship also depends on the share of electricity consumption that is linked to residential and commercial buildings. States where large industrial users, such as aluminium smelters, account for a larger share of consumption will be less sensitive to weather, all else being equal. For many years – indeed, decades – the relationship was so stable that electricity supply businesses in each state were able to use forecast temperatures to make very accurate short-term estimates of future electricity demand. The period ahead for which such estimates could be made was limited by the accuracy of weather forecasts, not by the nature of the modelled relationships between temperature and demand for electricity.

It has been suggested that declining electricity demand over the past few years can be explained, at least to a significant extent, by the fact that summers and/or winters have been milder than in previous years. The same explanation, with respect to the summer alone, has been used to explain the fact that annual peak demands have also been lower than in earlier years, as shown in Figure 2.

Two separate analyses, one for total energy and one for peak demand, were undertaken to test this hypothesis. Separate analyses were undertaken for each state.

Analysis of changes in total seasonal electrical energy consumption

For total energy, two separate tests, one for summer and one for winter, were undertaken. The tests involved examining the year-by-year relationship between total electrical energy consumed in each state over the months December to March, for summer, and May to August, for winter. In every state, and in every year covered by the analyses, these were the months with the highest seasonal electricity consumption; that is, for summer, electricity consumption in March was consistently more than in the previous November, and, for winter, consumption in May was consistently more than in the following September.

The energy consumption used was NEM region demand, as obtained from AEMO data. Regional demand takes account of total electricity generated in each region and also the net flows across interconnectors to neighbouring regions. These interconnector flows are quite substantial – consistently around 10 per cent or more of total demand in both Queensland, which is a net exporter to NSW, and NSW, which is a net importer from both Queensland and Victoria. SA is generally a net importer from Victoria and Tasmania was for long periods a net importer from Victoria, but more recently has been a net exporter to Victoria. This data series is only available back to 2005-06, so there are a limited number of data points for each state.

Weather is quantified in terms of cooling degree days, for summer, and heating degree days, for winter. Degree days are calculated by taking the difference between the average daily temperature for each day and a reference temperature. The reference temperature used for summer cooling is 23 degrees Celsius, so that if average daily temperature is 25 degrees Celsius on a hot summer day, that day will add two degree days to the total. If the average daily temperature is below 23 degrees Celcius, then degree days are zero. Degree days are calculated for each day across the whole four months of summer and then summed to give an annual total. A similar procedure is used for winter heating, with the reference temperature set at 18 degrees Celsius; if the average daily temperature is above 18 degrees Celsius, then degree days are zero.

These two reference temperatures, which are related to commonly adopted thermostat set points, have been used for many years in load forecasting by the electricity industry and in specifying heating and cooling energy requirements for buildings.

For each state, total degree days were calculated from Bureau of Meteorology weather station records for a weather station close to the state capital city; stations at either RAAF bases or airports were used in each case. It is interesting to note that in every state except Queensland winter heating degree days are significantly larger, in absolute terms, than cooling degree days and total electrical energy consumed during the winter months has been, up until now, significantly larger than summer electrical energy consumption.

The results of these energy analyses for the three major states are shown in the following graphs.

Figure 11: Relationship of seasonal electricity consumption to seasonal weather in NSW: summer (left) and winter (right)

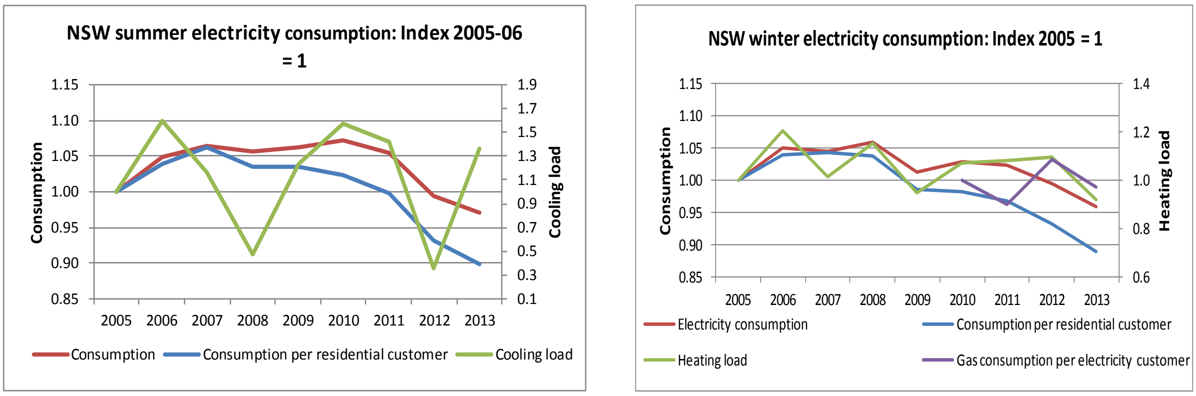


Figure 12: Relationship of seasonal electricity consumption to seasonal weather in Victoria: summer (left) and winter (right)

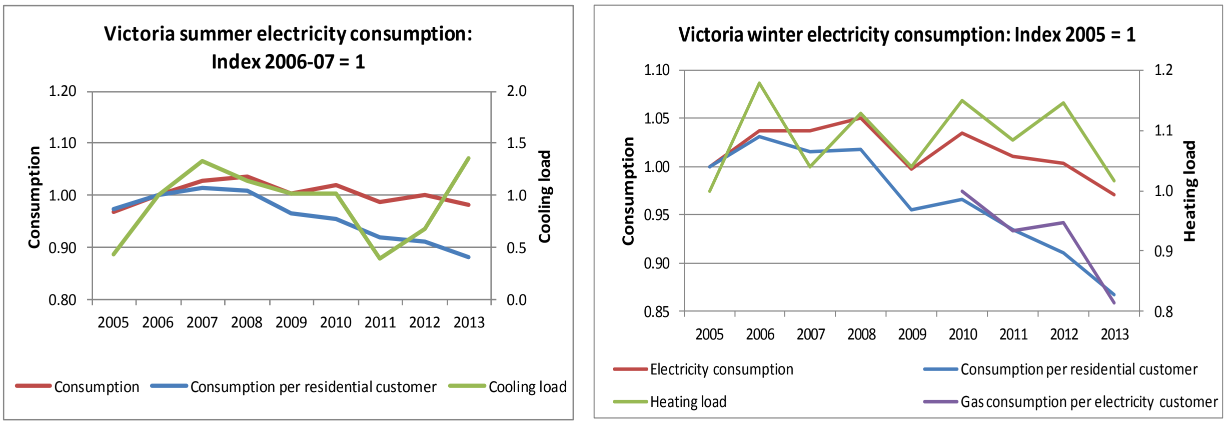
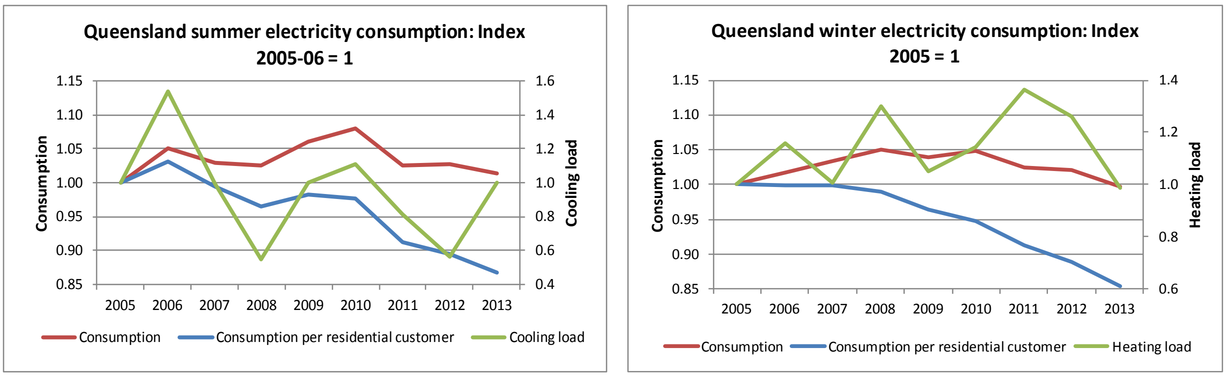


Figure 13: Relationship of seasonal electricity consumption to seasonal weather in Queensland: summer (left) and winter (right)



In all three states and in both summer and winter, per capita seasonal electricity consumption has been falling steadily since about 2007 or 2008.

In summer in all three states both per capita and total consumption was markedly lower in 2012-13 than in equivalently hot summers a few years earlier. Electricity is the only source of energy used for cooling, so this result is unequivocal; less energy is being used now for summer space cooling than was the case a few years ago. Whether this reduced electrical energy consumption has been caused by greater energy use efficiency, or consumer acceptance of a reduced level of cooling, or a mixture of both is unknown.

In winter, similar reductions in electricity consumption for a given space-heating requirement are also evident. But since gas is an alternative fuel for space heating to electricity – especially in Victoria, where it is the dominant fuel and, to a somewhat lesser extent, in NSW – it is necessary to look at trends in both electricity and gas seasonal consumption. The required data for gas have been available only since June 2009. The data suggest that there may have been some substitution of gas for electricity, but that energy consumption for space heating has nevertheless declined independently of the severity of the winter. Gas is not a significant heating fuel in Queensland, so it has not been included in the analysis.

Analysis of changes in summer peak electricity demand

The possible effect of changing weather on summer peak demand was examined separately in each state by plotting seasonal peak alongside the difference between the daily maximum temperature and a 23-degree-Celsius reference temperature on the day that the peak occurred. It should be noted that in some cases that day was the hottest of the year, but it was not in every year in every state. The experience of the electricity supply industry is that seasonal peak demand usually occurs in the late afternoon of a day coming towards the end of a run of several days of very high temperatures, including days when it has been very hot overnight.

Figure 14: Trends in NSW summer peak demand and maximum temperature

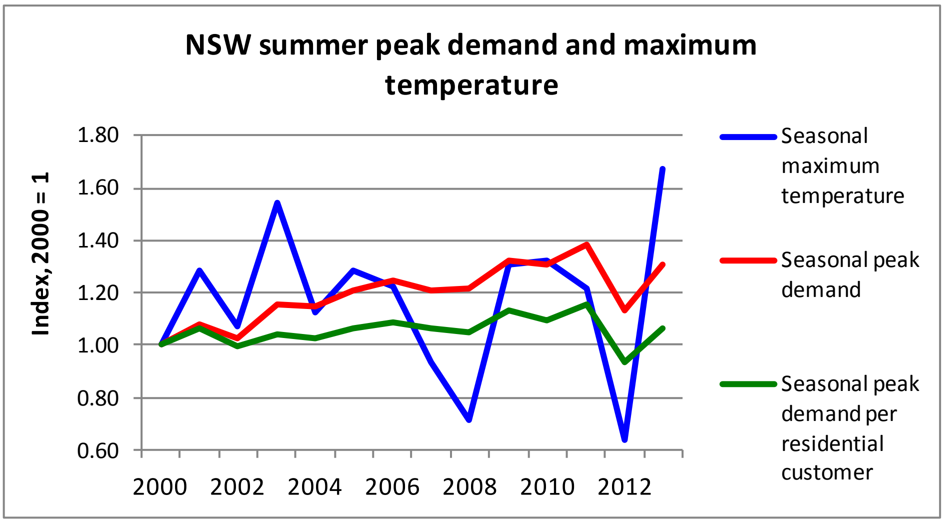


Figure 15: Trends in Victoria summer peak demand and maximum temperature

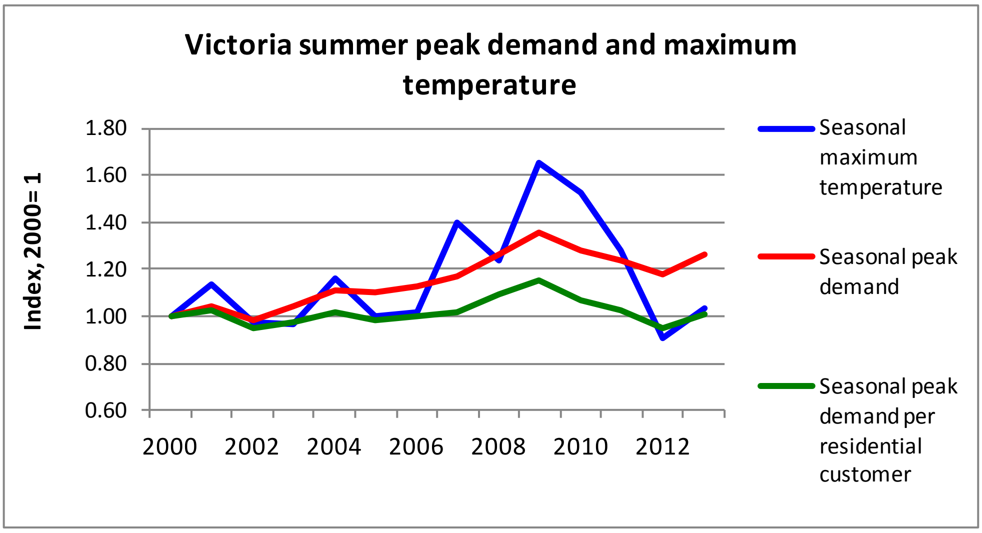
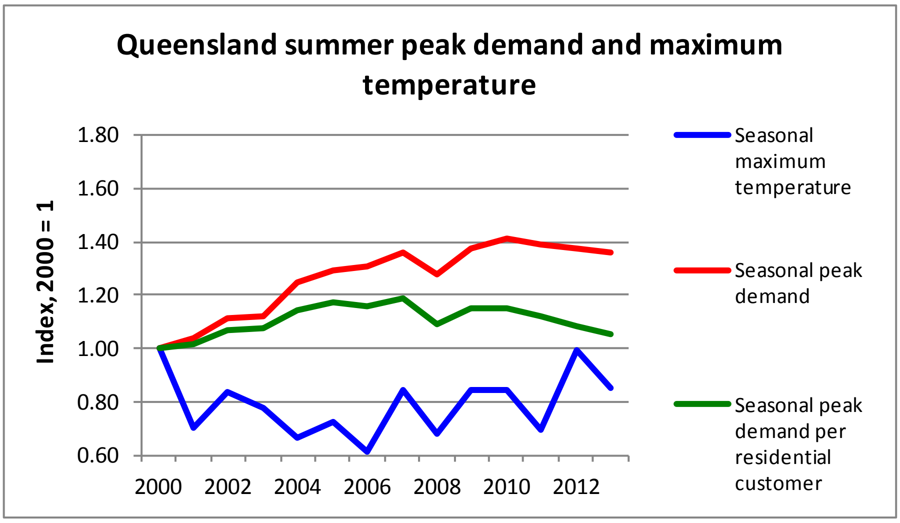


Figure 16: Trends in Queensland summer peak demand and maximum temperature



Unlike the seasonal total energy data, these peak demand data do not show a decisive break in the relationship between weather and demand for electricity, except possibly in Queensland. In NSW some decline in peak demand per capita, relative to temperature, is apparent, but this is probably attributable, in the main, to reduced demand from three large industrial users and quite unrelated to weather (see below). In Victoria there is no clear evidence of any significant decrease, relative to temperature, in peak demand per capita.

Conclusions

This analysis demonstrates a clear declining trend in seasonal per capita electricity consumption unrelated to the severity or otherwise of the season. The trend is apparent in both summer and winter. Milder weather can explain some of the year-on-year changes in seasonal electricity demand, with winter 2013 being a particularly clear example. But there is no systematic shift to milder winters or summers that can account for the longer-term downward trend in per capita electricity consumption. Changing weather does not therefore explain the steady decrease in electricity demand.

On the other hand, there is no strong evidence of a change in the relationship between summer peak demand and the severity of weather on the day on which the peak occurred each year in each state. It is important to recognise, however, that there is certainly no evidence of an increasing trend per capita. What this suggests is that use of air conditioning by the whole population of electricity users, both commercial and residential, may have reached saturation level. The great majority of commercial buildings have of course been actively cooled for many years. For residential buildings, surveys conducted by the ABS[14] show that in that year the national proportion of dwellings with active cooling had reached 73 per cent, up from 59 per cent in 2005. In SA, WA, Victoria and Queensland the proportions reached respectively 91 per cent, 86 per cent, 76 per cent and 73 per cent. Only in NSW, with 64 per cent, and perhaps Queensland, would there seem to be significant potential for further growth in active cooling. If the levelling of growth in active cooling is sustained, annual peak demands, normalised for the maximum temperature of the day concerned, can be expected to grow no faster than population.

The differences between trends in seasonal electrical energy consumption and summer peak demand can best be explained by changes in consumer energy using practices. Improved thermal performance in buildings – for example, upgraded insulation and more shading – will improve thermal comfort and reduce the requirement for heating and cooling energy at times of milder outside temperatures. At times of extreme temperatures, however, and noting that the peak system demand may last for only five minutes, maximum air conditioning input will still be required.

Consumer behavioural change will have the same effect. Changing thermostat set points to run buildings slightly warmer in summer and cooler in winter will reduce energy consumption but not peak demand, as will choosing not to heat or cool at all when temperatures are milder.

Finally, the efficiency (measured by the Coefficient of Performance – COP) of air conditioners has increased considerably over the past decade. It has been estimated that the sales-weighted average efficiency of air conditioners sold in Australia increased by 15 per cent in the four years from 2003 to 2007.[15] It is understood that there have been further significant improvements since 2007. These efficiency improvements have a two-fold effect on the quantities of electricity used for air conditioning. Firstly, more recent growth in the number of air-conditioned dwellings increases electricity demand more slowly than equivalent growth a decade ago. Secondly, as old air conditioners are replaced in dwellings that have used air conditioning for some years, electricity used for cooling by the dwelling falls significantly, all else being equal.

Overall, therefore, there is no evidence that milder seasonal weather is contributing to reduced demand for electricity in either summer or winter. There is

[14] Australian Bureau of Statistics (2011) *Environmental Issues: Energy Use and Conservation, Mar 2011*. Cat. No. 4602.0. <http://www.abs.gov.au/ausstats/abs@.nsf/mf/4602.0.55.001>

[15] EnergyConsult (2011) *Decision Regulatory Impact Statement: Minimum Energy Performance Standards for Air Conditioners: 2011*. Issued by the Equipment Energy Efficiency Committee under the auspices of the Ministerial Council on Energy. <http://www.energyrating.gov.au/products-themes/cooling/air-conditioners/documents-and-publications/>

evidence, however, that many electricity consumers are adopting energy-efficient space heating and cooling practices and behaviours.

5 Manufacturing industry activity and electricity demand

According to the *Australian Energy Statistics,*[16] manufacturing accounts for about 30 per cent of total electricity consumption, as do the commercial and services sectors, while the residential sector uses about 28 per cent and mining about eight per cent. In recent public commentary on electricity demand, claims have been made that a ‘collapse’ in manufacturing activity is the main reason that electricity demand has fallen. What lies behind these claims? Are they correct?

There can be little doubt that the claims have been inspired by the partial or complete closure of three major electricity intensive manufacturing establishments in NSW over the last two years. In October 2011 BlueScope Steel closed one of the two blast furnaces at its Port Kembla steelworks, together with associated steel furnace, rolling mill and other operations, reducing its steel output from the site by roughly half. It also closed a rolling mill at Westernport in Victoria. In January 2012 Hydro Aluminium closed one of the two potlines at its Kurri Kurri aluminium smelter near Newcastle. The second and last potline was closed in September 2012. In the same month Shell closed its Clyde oil refinery, in Sydney. None of these closures was surprising. BlueScope steel relied on export sales to take almost half the output from Port Kembla, and the severe effect of the appreciating Australian dollar on its export competitiveness was widely recognised. The Clyde refinery dated back, in parts, to the 1920s and was very small by the standards of modern oil refineries. The Kurri Kurri aluminium smelter was well over 40 years old and also very small by modern standards. Both operations were hit by the high dollar; for Clyde it made competing imported petroleum products relatively cheaper and for Kurri Kurri it reduced the price received for its exported aluminium.

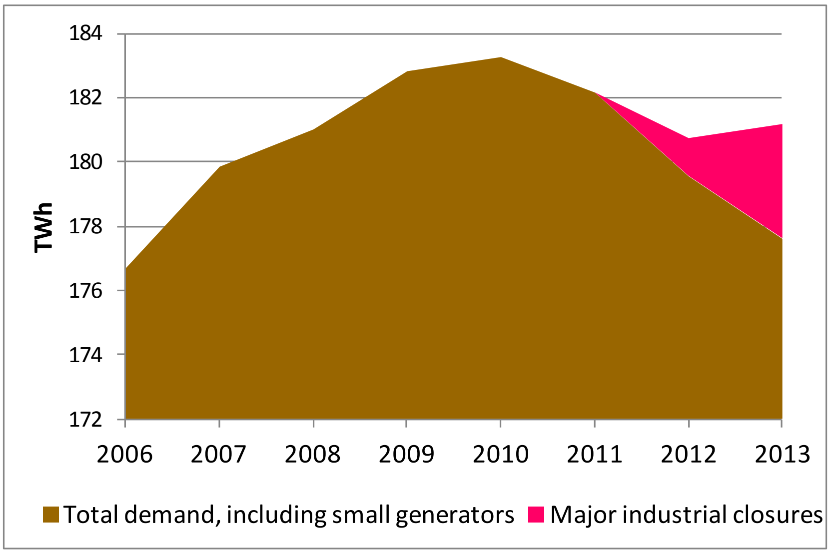
The approximate capacity of these sites at full production can be estimated from the public reports of the respective companies under the National Greenhouse and Energy Reporting Scheme (NGERS). Companies are required to report total Scope 2 emissions from their activities each year – Scope 2 emissions are those emissions attributable to the generation of electricity used by the company concerned. Scope 2 emissions factors are the weighted average emissions intensity of all electricity supplied in each state in the NEM, including the effect of imports and exports, calculated each year by the Department of Climate Change. Dividing the estimated changes in emissions following the closures by the emission factor for NSW gives an estimate of the consequent reduction in electricity demand. The result is shown in Figure 17. Virtually all of this reduced

[16] Bureau of Resource and Energy Economics (2013b) *2013 Australian energy statistics data.* <http://www.bree.gov.au/publications/aes-2013.html>

consumption has occurred in NSW and this explains why total electricity demand has fallen much faster in NSW than in any other state.

These closures are the most extreme manifestation of a significant change in the trend of output of Australia's primary metal production industries, particularly those that depend on electricity intensive processes, over the past few years. For Australia, the most important of these by far is aluminium; others include copper and zinc. All Australia's aluminium smelters and all of its copper and zinc refineries are located in the NEM states. Production of all three of these metals grew almost continuously from the early 1990s to around 2006, associated with increasing real prices. Statistics compiled by the Bureau of Resource and Energy Economics[17] show that over the whole period from 1991 to 2008 the average annual rate of growth of production was 2.8 per cent for aluminium, 4.1 per cent for copper and 2.6 per cent for zinc. In 2005 and 2006 prices increased spectacularly, but by 2009 had, with the partial exception of copper, fallen again almost as spectacularly. Production followed prices with the consequence that there has been no significant change since 2008.

Figure 17: Effect of major industrial closures on demand for electricity in the NEM



Lack of pre-2006 data on electricity demand by large users, as defined by AEMO, makes it impossible to estimate how fast large user demand grew over that period. Between 2006 and 2007 it actually grew by seven per cent. The trend in actual consumption by large industrial consumers, as reported by AEMO, is shown in Figure 18. The Figure also shows the reduction in consumption caused by the major industrial closures, and what demand would have been had it

[17] Bureau of Resource and Energy Economics (2013c) *Resources and Energy Statistics: Annual 2012.*

continued to grow from 2006 at an annual rate of 2.8 per cent, equal to the rate of growth of aluminium production.

Figure 18: Actual and hypothetical electricity demand by large users in the NEM

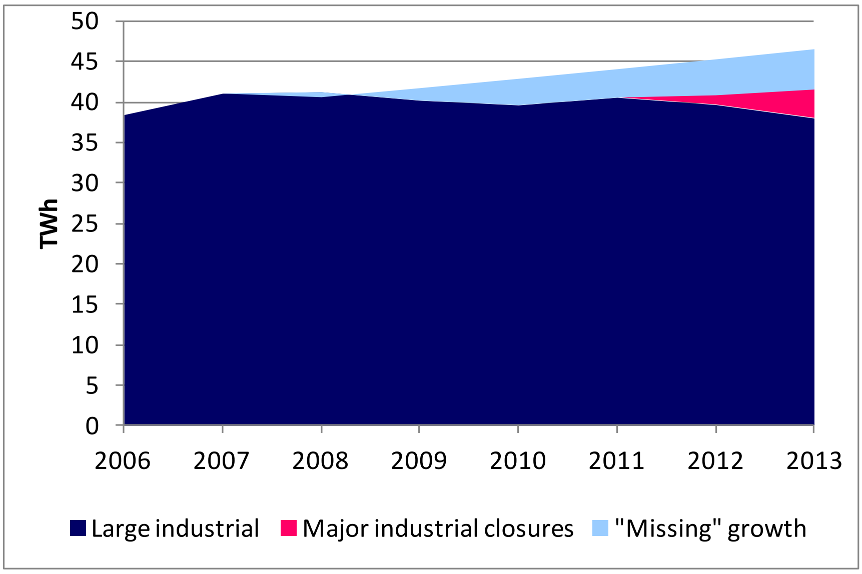


Figure 18 provides the starting point for examining the next question addressed in this section: has electricity consumption been affected by other less publicised cutbacks in manufacturing activity? The Figure shows that, were it not for the major closures, consumption by large users would have shown a small increase over each of the last three years.

A more detailed analysis of electricity consumption by manufacturing industries was undertaken by again using the Scope 2 emissions data contained in the NGERS public reports. There are now four years of public reports, from 2008-09 to 2011-12. The first year is of limited use, because in that year the reporting threshold was at a high level and many large electricity users were not required to report. The approach adopted was, firstly, to exclude the three companies discussed above from the analysis. Electricity generation, transmission and distribution businesses were also excluded. Then the remaining 100 largest Scope 2 emitters in 2009-10 and 2011-12 were identified and compiled into a list for each year. Scope 2 emissions for the top 100 were 65.0 Mt CO_2-e in 2009-10 and 65.5 Mt CO_2-e in 2011-12.

It is recognised that Scope 2 emissions are only a proxy for electricity consumption, and cannot be reliably used to estimate electricity consumption for any individual reporting entity unless, as in the three cases already discussed, it is known where the business has its main operations. For 100 reporting entities, however, reporting Scope 2 emissions equal to about half Australia's total Scope 2 emissions from non-residential electricity consumers (and over one third of total electricity consumption-related emissions), the geographical distribution of electricity consumption has a much higher probability of being representative of the distribution of total consumption. This is why the use of a state consumption-weighted national average emissions factor to convert Scope 2 emissions to electricity consumption is an acceptably reliable way to proceed. Scope 2 emission factors in each year were taken from the National Greenhouse Accounts Factors[18] and were used in conjunction with ESAA data on state electricity consumption to calculate a national weighted average Scope 2 emission factor for each year. This has decreased steadily over the period examined here, from 0.90 t CO_2-e in 2009-10 to 0.88 in 2010-11 and 0.866 in 2011-12.

It was found that there were only five businesses among the top 100 in 2009-10 that were not also in the top ten in 2011-12 and, of course, vice versa. Annual Scope 2 emissions of the last company in the 2009-12 list were 126.7 kt CO_2-e and the corresponding figure for the 2011-12 list was 131.2 kt CO_2-e. A summary of results is shown in Table 2 below. The change from 2010-11 to 2011-12 is very clear.

Table 2: Scope 2 emissions as reported in NGERS by large, non-electricity industry consumers of electricity, and estimated electricity consumption

	2009-10	2010-11	2011-12	Change 2009-10 to 2010-11	Change 2010-11 to 2011-12
Largest 100 in 2009-10					
Emissions (Mt CO_2-e)	65.0	66.3	65.3	+ 2.0 per cent	- 1.6 per cent
Electricity (TWh)	72.2	75.4	75.4	+ 4.4 per cent	0.0 per cent
Largest 100 in 2011-12					
Emissions (Mt CO_2-e)	64.8	66.4	65.5	+ 2.3 per cent	- 1.3 per cent
Electricity (TWh)	72.0	75.5	75.6	+ 4.7 per cent	+ 0.2 per cent

Source: Calculated by the author from data contained in Clean Energy Regulator (2013)

In order to investigate these changes further, the companies were categorised by their main sectors of activity. Just under a half (46 in 2009-10, 45 in 2011-12) were predominantly manufacturing and a quarter (23 in 2009-10, 21 in 2010-11) were in service sector activities, such as retailing, banking and entertainment or accommodation. Summary results for the two sectors are shown in the following tables.

[18] Department of the Environment (2013b) *Australian national greenhouse accounts: National Greenhouse Accounts Factors.* <http://www.climatechange.gov.au/climate-change/greenhouse-gas-measurement-and-reporting/tracking-australias-greenhouse-gas-emissions/national-greenhouse-accounts-factors per centE2 per cent80 per cent94july-2013>

Table 3: Scope 2 emissions as reported in NGERS by large, non-electricity industry consumers of electricity, and estimated electricity consumption, by industry sector

	2009-10	2010-11	2011-12	Change 2009-10 to 2010-11	Change 2010-11 to 2011-12
Manufacturing sector: 46 in 2009-10					
Emissions (Mt CO_2-e)	44.6	45.2	44.5	+ 1.4 per cent	- 1.5 per cent
Electricity (TWh)	49.6	51.4	51.4	+ 3.7 per cent	0.0 per cent
Services sector: 22 in 2009-10					
Emissions (Mt CO_2-e)	7.57	7.42	7.14	- 1.4 per cent	- 3.9 per cent
Electricity (TWh)	8.41	8.44	8.25	+ 0.9 per cent	- 2.4 per cent

Source: Same as previous Table

None of these data support an argument that reduced consumption by industry in any sector (other than from the three companies previously discussed) was a major contributor to the decline in electricity consumption, at least up to the end of 2011-12. There clearly has been, however, a near cessation of demand growth and, in the case of the group of service sector businesses, an actual decline. The latter is particularly interesting, because of the identities of the large businesses that have contributed to the apparent reduction in consumption in 2011-12. They include three of the four major banks, large commercial property businesses such as Westfield, Mirvac and GPT, and retailers including Myer and Harvey Norman. These businesses have all been growing in terms of total turnover, so their reduction in electricity consumption cannot be attributed to any kind of 'collapse'. It appears, therefore, that the energy efficiency programs they have all been undertaking are beginning to show results at the economy-wide scale.

This conclusion is consistent with the broadly based data contained in the National Accounts.[19] Estimates of annual value added at constant prices by the mining and manufacturing sectors of the economy has been tracked over the ten years from 2002-03 to 2012-12 inclusive. Manufacturing has been aggregated into four groups.

[19] Australian Bureau of Statistics (2013a) *Australian National Accounts: National Income, Expenditure and Product, Jun 2013.* Cat. No. 5206.0, Table 8 <http://www.abs.gov.au/AUSSTATS/abs@.nsf/productsbyCatalogue/52AFA5FD696482CACA25768D0021E2C7?OpenDocument>

- Machinery and equipment accounted for about 20 per cent of manufacturing value added in 2012-13 and is not a large user of electricity (not electricity intensive).
- Food beverages and tobacco accounted for about 22 per cent of manufacturing value added and is roughly twice as electricity intensive as machinery equipment.
- Process industries, comprising wood and paper products, chemicals, non-metallic mineral products, and metal products accounted for about 48 per cent of manufacturing value added and are, as a whole, extremely electricity intensive (more than 10 times as electricity intensive as machinery and equipment), accounting for 87 per cent of total manufacturing electricity consumption in 2011-12.
- Other industries, comprising textile, clothing and footwear and printing and recorded media accounted for about 10 per cent of value added and have about the same electricity intensity as food, beverages and tobacco.

A ‘collapse’ in manufacturing output would show up as a decline in sectoral value added in one or more of these sectors. If it occurred in the process industry sector it would have an appreciable effect on electricity consumption. In the figures below, value added in these sectors is shown in both absolute and index number terms. Mining has been included for comparison. It can be seen that there has been a decline in other manufacturing, but an offsetting increase in machinery and equipment, while the other sectors have been almost constant or declined very slightly. Most significantly, process industries were almost constant for the five years prior to 2012-13 and recorded a drop of two per cent in that year. This is presumably mainly caused by the aluminium and steel industry closures discussed above; the resultant reduction in electricity consumption is in fact a fall of more than six per cent in process industry electricity consumption. There has, therefore, been no observable reduction in activity by electricity-intensive manufacturing other than those two high profile closures.

Figure 19: Trends in value added in major manufacturing and mining industry sectors

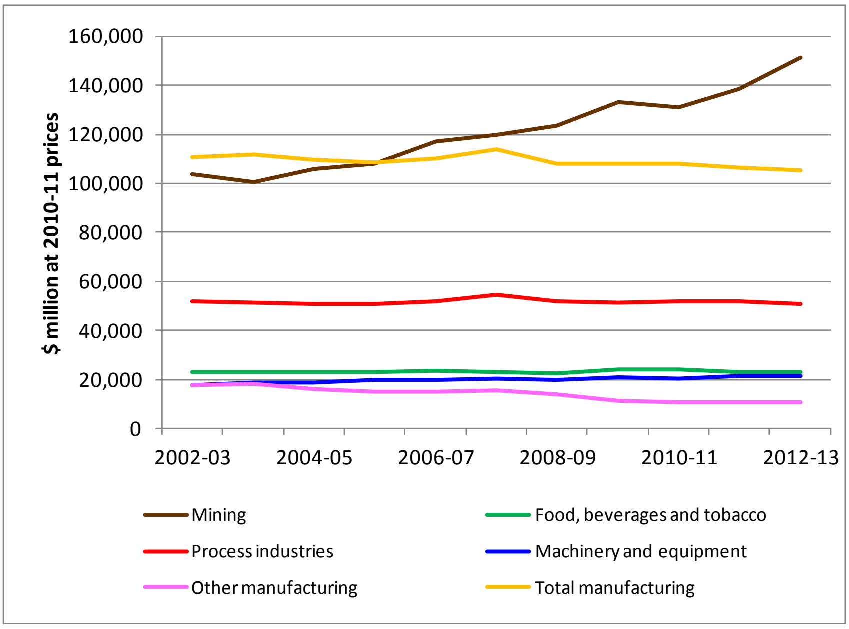
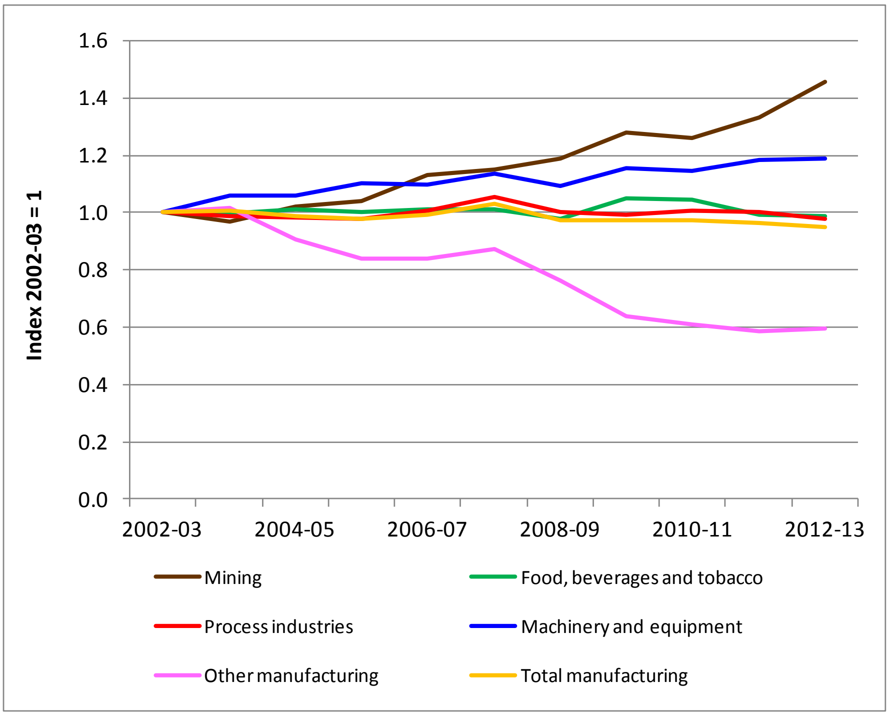


Figure 20: Relative changes in value added in major manufacturing and mining industry sectors



The fact that machinery and equipment manufacturing, the least electricity- (and also other energy-) intensive sector of manufacturing, has been growing slowly while the rest of manufacturing has been roughly constant or declining, demonstrates a structural shift within Australian manufacturing – however, the shift is small and slow. Over the long term it will, if maintained, have a modest impact on the pattern of Australian demand for electricity, but its contribution to the current decline in demand is negligible.

Finally, the mining sector has of course been growing strongly, but the impact of this growth on electricity demand is modest for two reasons. Firstly, mining is not a particularly electricity-intensive activity – it is more electricity intensive than machinery and equipment manufacturing but less electricity intensive than food, beverages and tobacco. Secondly, much of the electricity consumed by mining projects is self-generated at remote, off-grid locations – or in the case of the Pilbara and Mount Isa, on small local grids. This electricity consumption is of course not included in reported demand in either the NEM or the SWIS, where the analysis in this paper is focused.

6 The impact of energy efficiency programs

For nearly fifteen years Australian governments have been mandating regular increases in the efficiency of a steadily widening range of energy-using appliances, equipment and structures. They have also established programs that subsidise actions that replace very electricity intensive water heating technologies with less electricity intensive alternatives and support the accelerated uptake of certain types of electricity efficient equipment and devices. The reductions in electricity consumption, relative to a hypothetical 'without program' baseline, have been quantified for each of these policies and programs. This chapter draws together the results of the various published quantifications to estimate what the overall contribution to reducing demand for electricity has been.

The measures quantified fall into five groups:

- various subsidies to support the uptake of solar and heat pump water heaters,
- the Equipment Energy Efficiency (E3) program,
- building energy efficiency measures in the Building Code of Australia (BCA),
- the Home Insulation Program (HIP, often pejoratively referred to as 'pink batts'), and
- electricity retailer mandatory energy efficiency improvement programs in Victoria, NSW and SA.

A sixth possibly important measure that has not been included is the Energy Efficiency Opportunities Program (EEO). This requires businesses that use very large quantities of energy to conduct regular assessments of opportunities for increased energy efficiency in their operations and to report annually to the government. The company's annual report must include a summary for publication. A number of good summary reports of outcomes of the program as a whole have been generated and these include estimates of energy savings that are additional to the savings that would have occurred in the normal course of business-as-usual operations – a subset of total reported energy savings. Yet there are a several strong reasons for excluding EEO. Firstly, public reporting concerns only total energy, with electricity not separately identified, and rough calculations suggest that the majority of savings may be in gas, not electricity. Secondly, there is no geographical specificity of where the savings occurred and it seems possible that a disproportionate amount may be in WA. Thirdly, it is probable that some of the savings are at major industrial sites where much of the electricity consumed is co-generated, not purchased from the grid. For these reasons, it is not possible to make a reliable estimate of how much of the additional electricity savings attributable to EEO are in the form of electricity from the NEM.

Each of the five groups of measures included in the analysis is briefly described in turn, together with the sources of data used to estimate the group's contribution to reducing electricity demand.

The installation by households of solar and heat pump water heaters is subsidised through the Small Renewable Energy Scheme (SRES) and formerly through its predecessor the Mandatory Renewable Energy Target (MRET) program. Under these programs, each system installed receives a subsidy proportional to the quantity of electricity it is deemed to displace, relative to an electric resistance water heater, over a ten-year peri`od. The subsidies are paid at the time of installation and are funded by electricity retailers and thus, ultimately, by consumers of electricity as a whole. Additionally, at various periods over the years covered by this analysis, both the federal government and some state and territory governments provided additional subsidies sourced directly from their consolidated revenues. The result of these various subsidies was an increase, above the rate prevailing prior to the start of the MRET in 2001, in the rate of installation of solar and heat pump water heaters.

Estimates of electricity consumption savings have been made from data contained in the REC Registry, operated by the Clean Energy Authority, which shows the number of certificates, each corresponding to 1 MWh saved, created by water heater installations in each year. It is assumed that all systems installed last the full 10 years of deeming, so that in each year, for 10 years from the year of installation, electricity consumption savings are one tenth of the number of certificates issued in the initial year. It follows that consumption savings will grow steadily over the period, even though the number of new installations is relatively steady, which it has been except for a strong upsurge between 2008 and 2010. REC Registry data are available by state/territory, so that the installation in the NEM can be precisely quantified.

The E3 program is a joint initiative of the Australian, Commonwealth, State and Territory governments and the New Zealand government. The national program was established in 1992, although the first regulations relating to the efficiency of electrical equipment and appliances sold in Australia were introduced at a state level in 1986, when the first requirements for energy efficiency labelling for refrigerators and freezers were introduced in NSW and Victoria.[20] The first Minimum Energy Performance Standards (MEPS) were introduced for residential (refrigerators/freezers and electric water heaters), industrial (three-phase electric motors) and commercial (fluorescent lamp ballasts) appliances and equipment between 1999 and 2003.[21] Since then a very wide array of other appliances and

[20] Equipment Energy Efficiency Program (2011) *Achievements 2009/10* <http://www.energyrating.gov.au/>

[21] George Wilkenfeld and Associates (2009) *Prevention is Cheaper than Cure - Avoiding Carbon Emissions through Energy Efficiency* <http://www.energyrating.gov.au/>

equipment has been subject to MEPS and it is the consumption reductions attributable to MEPS that have been quantified.

Estimates of the reductions in electricity consumption attributable to the E3 program are taken from George Wilkenfeld and Associates.[22] This study is a meta-analysis, which draws together the estimates contained in the Regulatory Impact Statements (RISs) for all relevant individual categories of appliances and equipment to which energy efficiency regulations have been applied, and places them on a consistent basis. It is understood that an updated report along similar lines has recently been completed, but is yet to be made publicly available. While the study presents electricity consumption reduction estimates for all individual equipment categories, it does not disaggregate the results by state. For this analysis, which is confined to the NEM, all results have been multiplied by 0.85, which approximates to the average NEM share of total national electricity consumption over the period of the study. The results are separated into residential and non-residential categories of appliances and equipment. The largest contributors to residential sector consumption reductions to date are refrigerators and freezers, electric water heaters, lighting (the incandescent globe phase-out), air conditioners and televisions. The largest contributors to non-residential sector consumption reductions are lighting, air conditioners, electric motors, and fluorescent lamps and ballasts. Distribution transformers have been excluded from the published savings estimates, because more efficient transformers reduce electricity losses in distribution networks, and do not affect electricity use by consumers.

Regulations affecting the energy performance of buildings are slightly more recent than those relating to appliances and equipment. The ACT introduced a requirement for cavity wall insulation in new houses in 1991 and a requirement for all new houses to achieve a minimum 4-star energy performance in 1996. The latter was adopted by all other states and territories in 2003, through the Building Code of Australia (BCA). Requirements were extended to new commercial buildings in 2006 and the stringency of residential building requirements was increased.[23] Requirements for both residential and commercial buildings were made more stringent again in 2010. Making buildings more energy efficient reduces the quantities of input energy to achieve acceptable indoor comfort levels. These measures apply only to new buildings – and, in some circumstances, to major refurbishments of commercial buildings. A meta-analysis of estimated savings, using much the same approach as used for the study of appliances and equipment, was recently completed by pitt&sherry.[24] The results from that study

[22] Ibid.

[23] Australian Building Codes Board (2013) <http://www.abcb.gov.au/en/major-initiatives/energy-efficiency>

[24] Pitt&sherry (2013b) *Final report: Quantitative assessment of energy savings from building energy efficiency measures*. Department of Climate Change and Energy Efficiency.

are used here. The savings are considerably smaller than those attributable to the appliance and equipment efficiency measures, in part because of the much slower turnover of the building stock and in part because the largest energy savings nationally are for space heating, for which, again nationally, gas is the dominant fuel. These results are available on a state/territory basis, so exact numbers are used for the NEM.

Under the Home Insulation Program, a large number of poorly insulated or completely uninsulated houses had their ceiling insulation significantly upgraded. Ceiling insulation makes a larger contribution to improving the energy efficiency of the building shell than any other upgrade measure. Estimates of the likely energy savings for space heating and cooling, disaggregated by state/territory and by fuel (electricity and gas) have been made by Energy Efficient Strategies and the company provided the specific data required for this analysis.[25]

Three states have electricity retailer mandatory energy efficiency improvement programs in place. These programs are the Victorian Energy Efficiency Target scheme (VEET), the NSW Energy Savings Scheme (ESS) and the SA Residential Energy Efficiency Scheme (REES). Estimates of electricity savings from VEET were inferred from reported emissions reductions from electricity measures contained in scheme annual reports.[26] From 2009 to 2011 the largest source of savings was the replacement of incandescent lamps with CFLs. Savings attributed to this action were counted for only the first year, to avoid double counting with the E3 program savings estimates, of which mandatory incandescent lamp replacement forms a large part. Until now the ESS has been confined to electricity and its performance is directly reported in electrical energy units. The most recent available data is contained in the report for the 2011 calendar year.[27] Total savings are smaller than from VEET. Savings from REES are smaller still and are mainly attributed to lamp replacements, with double counting uncertainties. Estimates of electricity savings for this scheme have therefore not been included in the analysis.

The total effect of adding the reductions in electricity consumption attributable to all these energy efficiency programs to total NEM electricity consumption is shown in Figure 21. In many respects a more meaningful way of presenting the effect of these consumption reductions is to show them in relation to residential and

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<http://ee.ret.gov.au/final-report-quantitative-assessment-energy-savings-building-energy-efficiency-measures>

[25] R. Foster (2013) *Pers. comm*..

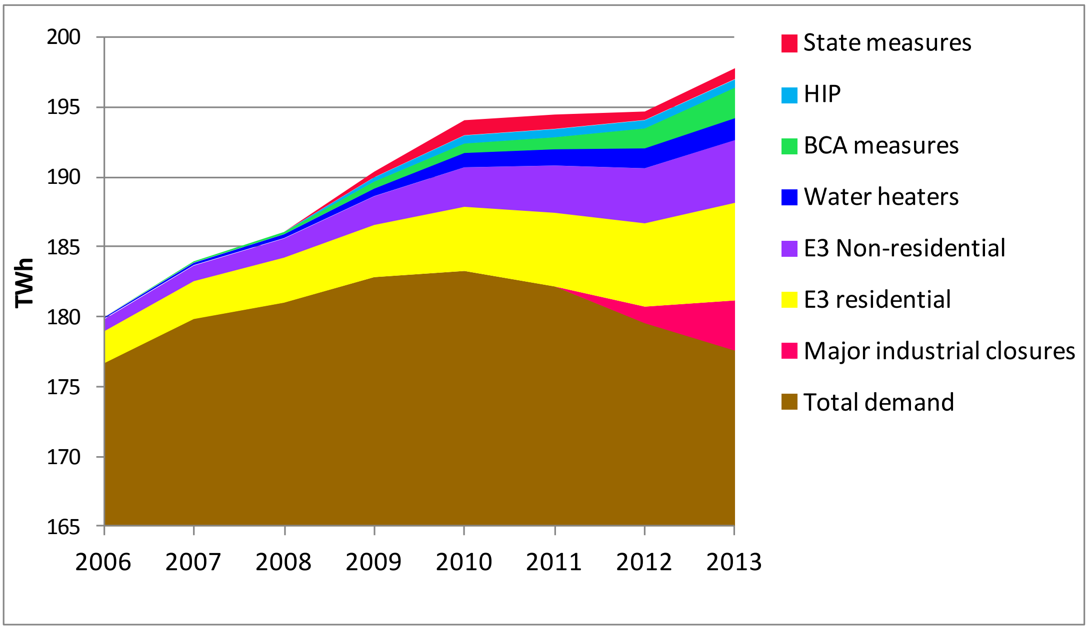
[26] Essential Services Commission (2013) *Victorian energy efficiency target scheme: Performance report 2012*. <https://www.veet.vic.gov.au/Public/Public.aspx?id=Publications>

[27] Independent Pricing & Regulatory Tribunal (2012) *Compliance and operation of the NSW Energy Savings Scheme during 2011*. <http://www.ipart.nsw.gov.au/Home/Industries/Energy_Savings_Scheme/Compliance_and_Operation_of_the_NSW_Energy_Savings_Scheme_during_2011_-_July_2012>

commercial consumption, as defined by AEMO, i.e. excluding large industrial consumers. Few if any of the electricity consumption reductions described in this section affect consumption by large industrial users. Similarly, distributed generators do not supply electricity to large industrial users – they draw all their consumption from large generators. Figure 22 shows the parts of the two major components applying to residential and commercial demand, as defined by AEMO.

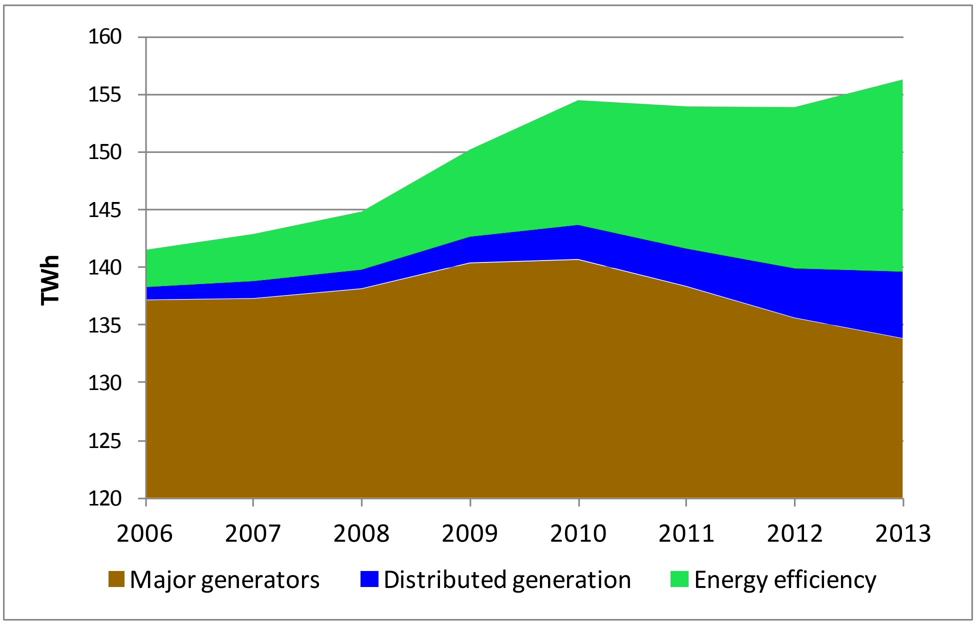
It is useful to think of the grand total – of electricity supplied and of electricity not supplied because of increased efficiency – as demand for, or consumption of, electricity services. The total consists of both megawatts (hours) and 'negawatts', to use the term coined by Amory Lovins.[28]

Figure 21: The effect of major energy efficiency policies and programs on electricity demand



[28] Lovins, A B (1989) 'The negawatt revolution: Solving the CO_2 problem', *Green Energy Conference*, Canadian Council for Nuclear Responsibility, Montréal, 18-23

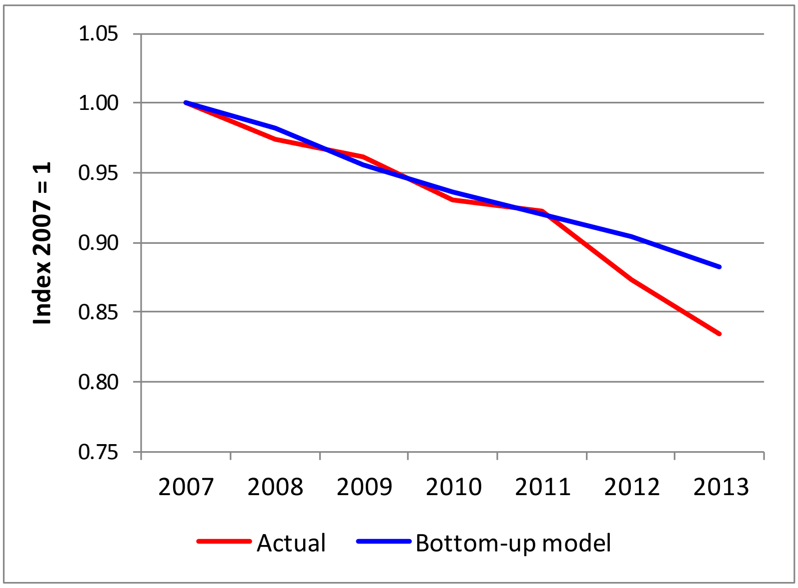
Figure 22: NEM Residential and commercial demand, plus embedded generation and savings from enhanced energy efficiency



In thinking about Figure 21 and Figure 22 it is important to recognise the difference between the estimates of electricity supplied by distributed generation and electricity consumption ended by the closure of specific industrial plants, on the one hand, and, on the other hand, estimates of consumption savings attributable to energy efficiency policies and programs. The former are explicitly measurable megawatt hours. The latter are modelled estimates, dependent on a large number of assumptions, including assumptions about the behaviour of millions of individual electricity consumers.

The modelled estimates for all years from 2010 onward depend on *ex ante* assumptions about input parameters. It is therefore reasonable to question the reliability of the results. Their reliability is confirmed by the fact that they are completely consistent with the results of *ex post* modelling of residential electricity consumption in a large metropolitan local government area in NSW. This modelling used very detailed data on the characteristics of the housing stock in the area, and applied the same assumptions about appliance, equipment and building efficiency trends as the *ex ante* national modelling. In this particular area, data provided by the local electricity network business showed that per dwelling electricity consumption was already decreasing prior to 2010. The decrease up to 2010 could be accurately replicated by the bottom up efficiency modelling. After 2010, the rate of decrease accelerated and could not be replicated by the modelling, as shown in Figure 24.

Figure 23: Trends in actual and modelled annual per household residential electricity consumption in a NSW metropolitan local government area



Source: pitt&sherry, *pers. comm.*.

An alternative approach to analysing why measured electricity consumption has been declining is to apply basic micro-economics, which postulates that changes in consumption of a commodity or service can be explained by the response of consumers to changes in the price of the particular commodity or service, by relative changes in the prices of substitute commodities and services, and by the incomes of consumers. That is the focus of the next section of this paper.

7 The impact of increasing electricity prices

This section examines whether trends in demand for electricity in recent years can be explained by the effect of higher real prices for electricity on demand, using values for the price elasticity of demand for electricity that are plausibly consistent with the extensive economic literature on the topic.

AEMO analyses the relationship between the historic trend in each NEM region (i.e. state) of total residential and commercial demand for electricity (starting in 2000) and key variables, including the price of electricity, the price of gas, gross state product or final demand and interest rates. The analysis, which uses quarterly demand data, also takes account of heating degree days and cooling degree days during each quarter. Using sophisticated econometric techniques the analysis was able to determine statistically significant long-run – i.e. exclusive of seasonal effects – relationships between electricity demand, the price of electricity and incomes. AEMO uses the relationships established by these analyses for each state (the results vary between states) to estimate future demand. AEMO forecasts Large Industrial Load separately, by assessing the probable future demand from each of the relatively small number of consuming organisations that constitute this category.

A fundamental feature of this type of analysis is that these relationships, specified by price and income elasticities, are assumed to be constant throughout the historical period (2000 to 2012) covered by the analysis and used to calibrate the model, and throughout the period into the future covered by forecasts. However, AEMO was only able to obtain statistically significant relationships that are constant over time by allowing the elasticities to vary widely between states. For example, price elasticity estimates for the four largest states ranged from -0.13 in Victoria to -0.21 in NSW, while income elasticity ranged from 0.23 in Queensland to 0.37 in NSW. Values for both price and income elasticities for Tasmania were well outside these ranges. No explanation is offered as to why the response of electricity consumers to changes in price and income should differ so widely between states.

The analysis in this paper uses the same consumption data series as AEMO – i.e. AEMO residential and commercial demand – as shown in Figure 21, less distribution losses. This constitutes the most accurate available series of annual electricity consumption figures for these consumers. The nature and extent of responses by major industrial consumers to electricity price changes will differ markedly from the response of smaller consumers, for a number of reasons.

- As shown in Figure 18, with the exception of the major closures previously discussed, major industrial electricity consumption has not in fact decreased significantly.

- Major industrial consumers typically buy electricity under long-term contracts at confidential prices.
- It is known that the prices they pay are much lower than those paid by smaller consumers, both because of the volume of their purchases and also because they generally do not use distribution networks and so do not incur distribution costs.
- Many large users qualify as Emissions Intensive Trade Exposed Industries and so, since mid-2012, have been exposed to much lower carbon costs than smaller consumers.
- Most large users have very few options to reduce electricity consumption in the short term, except by reducing their output.

The modelling was undertaken in three stages. All the modelling used 2006 as the starting point – that is, modelled demand was set to equal actual demand in 2006.

Stage 1

The first stage seeks to replicate the 'raw' AEMO figures for Total NEM demand, plus a backward extrapolation constructed by merging ESAA data with the AEMO data. It does this by modelling residential and commercial separately from Large Industry, and then adding the two modelled results together to give a modelled total demand. This is, in effect, a greatly simplified version of AEMO's modelling.

Residential and commercial demand is in turn modelled at the individual state level, to allow for differences between states in the timing and size of price changes and in income growth. The modelling parameters are:

- For prices, the Electricity Expenditure Class Index of the CPI for the relevant state capital city, divided by the applicable CPI to give an index of real price changes.[29]
- For income, Gross State Product.

State per capita figures are then multiplied by population in each year to give state totals aggregated back to the total NEM.

Large Industry is modelled at the NEM level using the national Producer Price Index values for electricity prices. The ABS does not compile the Producer Price Index at the state level.

The elasticity values used were adjusted by trial and error to find the combination that appeared, on visual inspection, to provide the best (or, more accurately, least bad) fit. The very small number of data points makes the use of statistical analysis pointless. The values used in Figure 24 are as follows.

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[29] Australian Bureau of Statistics (2013b) *Consumer Price Index, Australia, Sep 2013*. Cat. No. 6401.0 <http://www.abs.gov.au/ausstats/abs@.nsf/mf/6401.0>

For Residential and Commercial:

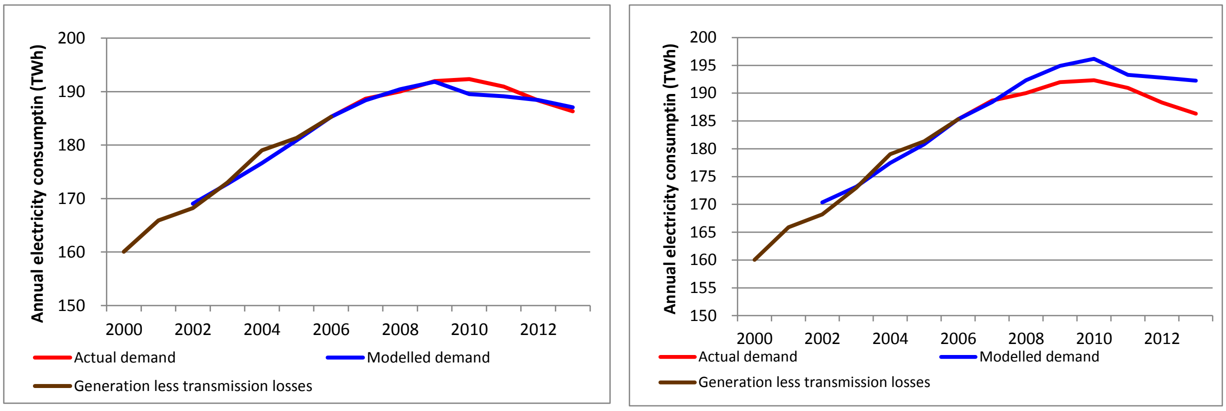
- Price elasticity = -0.25
- Income elasticity up to 2006 = 0.4
- Income elasticity from 2007 = 0.1

For Large Industry:

- Price elasticity = -0.1
- Income elasticity = 0

Modelling is undertaken with no lag in the response of demand to price changes and with a lag of one year. The results are shown in Figure 24. They show that for the period prior to 2006, when real prices were either declining or increasing only slowly, actual demand can be tracked closely in the model, using a relatively high income elasticity. When per capita demand starts to level off and then decline, it is impossible to reproduce the observed demand trends if the same income elasticity value is retained, even with absurdly high values for price elasticity. It is therefore necessary to postulate a fundamental change in the relationship between increasing consumer incomes and demand for electricity.

Figure 24: Best fit results of modelling total electricity demand with no lag between changes in prices and income and demand response (left) and a lag of one year (right)



It is important to recognise that the apparent close relationship between actual and modelled demand in the last few years is heavily dependent on the reduction in Major Industry consumption. As previously discussed, these closures were not primarily influenced by higher electricity prices. It would therefore be preferable to model residential and commercial demand by itself. This first modelling stage provides the assurance that a model in which demand growth is primarily driven by income elasticity can accurately reproduce the growth in demand experienced up to about 2006, i.e. during the period when actual data for residential and commercial demand are not available. This knowledge provides a sound basis for moving to the next stage of modelling.

Stage 2

The second stage seeks to replicate the 'raw' AEMO figures for residential and commercial NEM demand, for which values are available for the period 2006 to 2013 inclusive only. It would be preferable to model residential demand separately from commercial demand (and separately again from Large Industry). There are many reasons for thinking that each of these three categories of electricity consumers are driven by a quite widely differing array of factors, and so could be expected to show different responses in the current environment. This is borne out by the actual data.

The comprehensive electricity meter data collected by the ABS[30] covering NSW, Queensland and Tasmania and summarised in Table 4 show large reductions in average annual household electricity consumption in successive years from 2010. The ABS says similar data for the other states will be published before the end of 2013.

Table 4: Average per household annual electricity consumption by households without rooftop PV, 2010 to 2012

	2010	2011		2012	
	MWh per annum	**MWh per annum**	**per cent reduction**	**MWh per annum**	**per cent reduction**
NSW	6.82	6.42	6.9 per cent	6.04	6.1 per cent
Queensland	6.99	6.73	3.8 per cent	6.46	4.0 per cent
Tasmania	8.85	7.76	12.3 per cent	7.32	5.7 per cent

It appears that the declining trend continued in 2013. For example, Energex, which is the network provider in south-east Queensland, observes in its most recent Annual Report that, "The decline in total energy differs between the residential and non-residential sectors, with residential energy declining by 3.8 percent in the 2012-13 year. Non-residential energy grew by 1.1 percent in the same period[31]." Ergon Energy, which covers the rest of Queensland, reported that consumption per residential customer fell by five per cent in 2012-13,[32] which equates to almost the same reduction in total residential consumption as

[30] Australian Bureau of Statistics (2013c) *Household Energy Consumption Survey, Australia: Summary of Results, 2012*. Cat. No. 4670.0 <http://www.abs.gov.au/ausstats/abs@.nsf/mf/4670.0>

[31] Energex (2013) *Annual Report*, 2012-13 <https://www.energex.com.au/__data/assets/pdf_file/0003/167322/Annual-Report-2012-13.pdf>

[32] Ergon Energy (2013) *Annual Stakeholder Report 2012/13* <https://www.ergon.com.au/__data/assets/pdf_file/0011/167636/Ergon-Energy-Annual-Stakeholder-Report-2013.pdf>

experienced by Energex. The Community Energy Report published by Ausgrid,[33] the network business for eastern Sydney, the Central Coast and the Hunter region, reports a total decline of 3.6 per cent in residential consumption, equivalent to 4.3 per cent per residential customer. For both Ergon and Ausgrid, the decline in consumption by business customers was considerably less.

These reductions are so large that, combined with the major industrial closures, they account for the entire fall in total electrical energy supplied in the NEM between 2010 and 2012 and, almost certainly, in 2013 as well. It follows that electrical energy consumption from all other consumers, i.e. all commercial and industrial consumers except the large industrials, accounting for about half of total electricity consumption, is continuing to increase, albeit much more slowly than in earlier years. Since the majority of these consumers have experienced price increases not dissimilar from those seen by residential consumers, their responses to changes in prices, and perhaps also to changes in income, would seem to be different from the responses of residential consumers. It would therefore be highly desirable to analyse residential demand separately from commercial.

Unfortunately, however, there is no high quality multi-year time series of residential electricity consumption covering the whole of the NEM. The ESAA data provide the only such series but, as previously explained, these data display what look like inconsistencies in specification and also do not include a value for 2013. Nevertheless, they are also modelled.

Specifically, the two data series modelled are:

- AEMO residential and commercial demand, net of distribution losses, as previously described, running from 2006 to 2013.
- ESAA residential demand starting, for this exercise, in 2002 (in full it extends back many decades) and running to 2012.

The modelling parameters are:

- For prices, the Electricity Expenditure Class Index of the CPI for the relevant state capital city, divided by the applicable CPI to give an index of real price changes.
- For income, Gross State Product.
- For population size, state population for the AEMO data analysis and numbers of residential customers in each state for the ESAA analysis.

The elasticity values used were adjusted by trial and error to find the combination that appeared, on visual inspection, to provide the best (or, more accurately, least

[33] Ausgrid (2013) *Average household electricity consumption by LGA 2013*. <http://www.ausgrid.com.au/Common/About-us/Sharing-information/Data-to-share/Average-electricity-use.aspx>

bad) fit. The very small number of data points makes the use of statistical analysis pointless. The values used in Figure 24 and Figure 25 are as follows.

For the AEMO data analysis:

- Price elasticity up to 2006 = - 0.25
- Price elasticity from 2007 = - 0.3
- Income elasticity up to 2006 = 0.4
- Income elasticity from 2007 = 0.1

For the ESAA data analysis

- The same values as for the AEMO series with the exception of price elasticity from 2007 to 2012, which is set at - 0.35.

Figure 25: Modelled results for AEMO residential and commercial demand

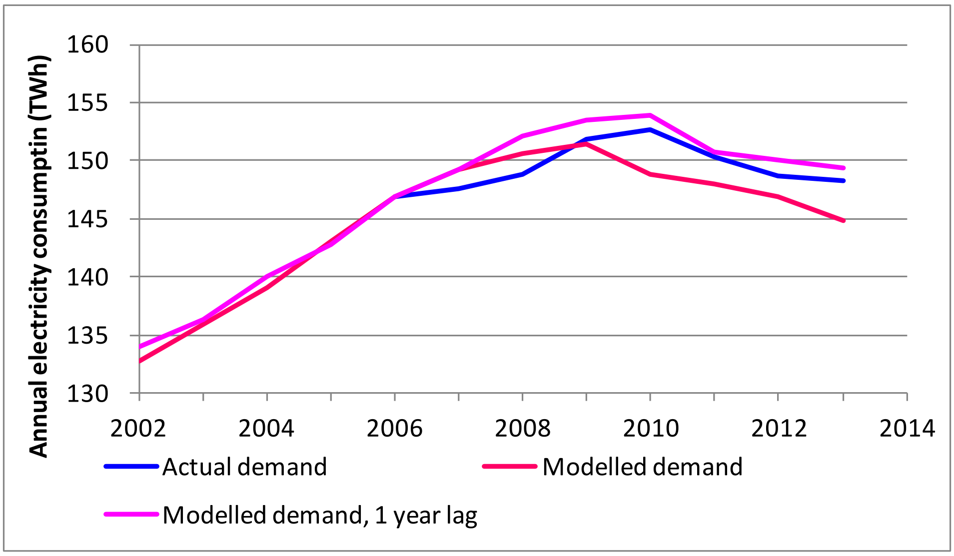
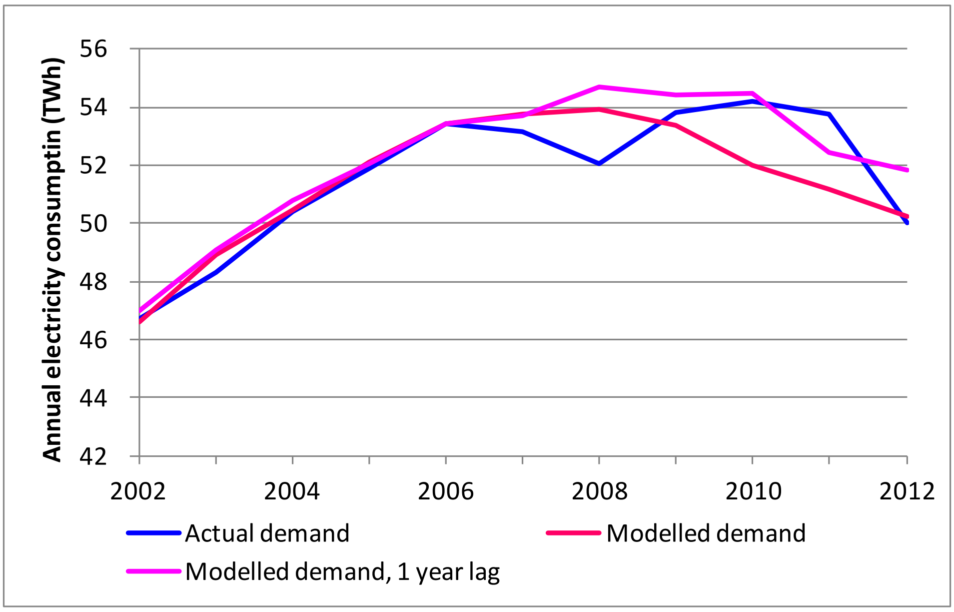


Figure 26: Modelled results for ESAA Residential demand



The results of this Stage 2 analysis show that the observed recent trends in electricity demand cannot be well explained, at a national level, as a simple response to changing prices. It requires the assumption of a dramatic change in income elasticity around 2007 – when electricity demand per capita, or per household, clearly started to fall. For the ESAA residential sector-only data, it also requires the assumption of a simultaneous increase in price elasticity. Separate analyses of the AEMO data have also been undertaken at the state level. They reveal that both elasticity values and response lags needed to give the best fit to observed demand trends vary between states and thus differ, in some cases quite considerably, from the values that give the best fit at the national level. This is not a promising basis for characterising the changes in electricity demand in simple economic terms alone.

Stage 3

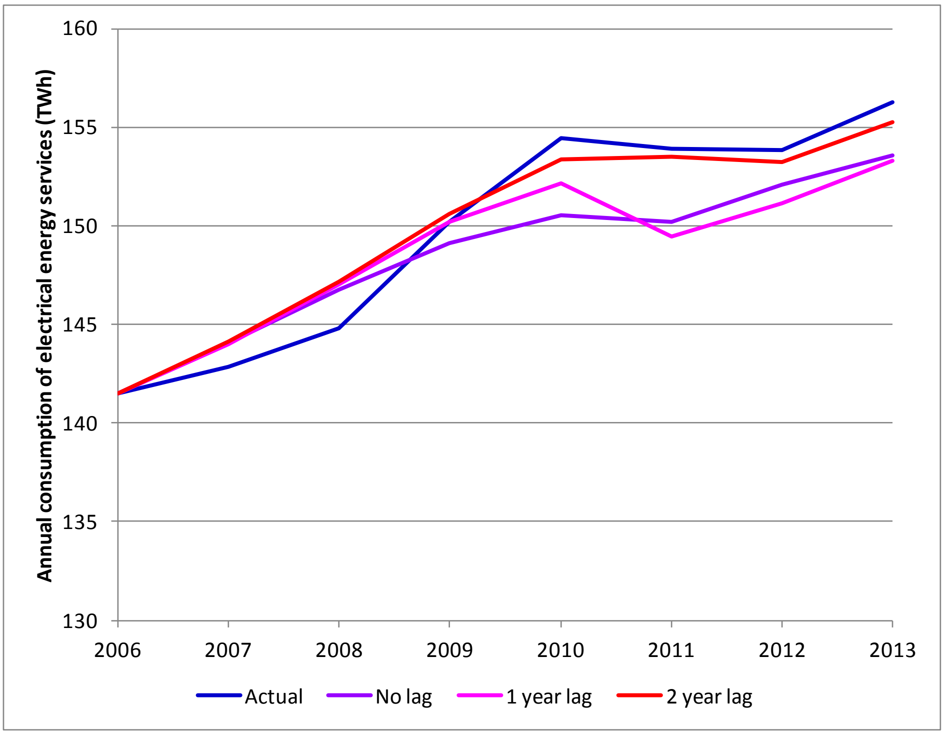
The final stage of the analysis seeks to model the total demand for electrical energy services by residential and commercial consumers, as shown in Figure 22 above. Because the estimates of savings for appliance and equipment services, which are the largest component of the various energy efficiency measures, are not available at the state level, this modelling can only be undertaken at the whole-of-NEM level. This means that it cannot allow for differences between states in the size and timing of electricity price changes. The analysis uses the CPI eight-capital-city weighted average real electricity price index. For income it uses real Gross Domestic Product minus Gross State Product for WA and the NT.

The analysis results shown in Figure 27 use a constant income elasticity value of 0.42. For price elasticity a very low value of -0.05 is used up to 2010, a higher value of -0.15 in 2011, and lower values of -0.10 and -0.05 respectively in 2012 and 2013. Model results have been computed with the responses to changes in both price and income occurring at the point when those changes happened, with a lag of one year and with a lag of two years. It can be seen that when the response to changes in both price and income are lagged by two years, the modelled results fit closely to actual demand.

Apart from the issue of the change in 2011, which will be discussed in the concluding section of this paper, it should be noted that these price elasticity values are lower than the majority of estimated values in the economic literature. However, most of these values are based on analysis of residential consumption, whereas residential demand accounts for only about 40 per cent of the demand for electricity being analysed, and 37 per cent of the total demand for electricity services shown in Figure 21. On balance, business consumers as a whole are likely to be somewhat less responsive to increased electricity prices, in part because they may be able to recover some of the cost increase in higher prices and in part because, since electricity is an input to production, they are likely to have fewer opportunities to reduce demand through simple behavioural changes.

Were separate, quality time series data for residential and commercial (excluding large industry) consumption available, more refined and accurate analysis would be possible. Unfortunately, as previously explained, such data are not available.

Figure 27: Modelled results for total residential and commercial electricity services



8 Conclusions

The major conclusions of this analysis of Australian electricity demand trends are as follows.

The rate of growth of total demand for electricity supplied by major generators – those generators participating in the wholesale market – in the NEM has been slowing since about 2006, and since 2009 annual demand has been decreasing each year. If demand is expressed on a per capita basis, both the slowdown in growth and the reversal to absolute decline are seen to have started a couple of years earlier.

About 3.6 TWh per annum of the absolute decline from the peak, equivalent to 1.8 per cent, has been caused by the increased output from rooftop PV and other types of distributed generation. As a decline from an extrapolation of the pre-2006 rate of growth, this generation is of course a much smaller proportion.

There is no evidence to support an argument that declining consumption has been caused by consistently milder seasonal weather in either summer or winter. While changes in weather clearly contribute to changes in demand from year to year, electricity consumption per capita has trended steadily down, irrespective of changes in weather. For example, in Victoria the summer of 2012-13 was the hottest for at least a decade, but summer electricity consumption was lower than in each of the two previous summers, when conditions were considerably milder. On the other hand, the relationship between seasonal peak demand and weather appears to have changed very much less, meaning that, with growing population, a gradual increase in annual peak demand can be expected to continue.

There is also no evidence to support an argument that demand for electricity has fallen because of a general 'collapse' in manufacturing output. Three large and widely publicised partial or complete closures of major electricity users, all in NSW, have caused a reduction in annual demand almost exactly equal to the increased output from distributed generation – that is, 3.6 TWh or 1.8 per cent. Apart from these three, total electricity consumption by the largest 100 non-electricity supply industry businesses reporting under NGERS increased by between four per cent and five per cent over the two years from 2009-10 to 2011-12. This pattern applies equally to businesses in the manufacturing sector and to businesses in the mining and services sectors of the economy. Moreover, sectoral value-added data from the National Accounts provide no evidence of any sudden downturn in manufacturing value added in the past few years. Sectors that have been declining for some years continued to decline, while those that have stayed roughly constant continue to do so. The only major manufacturing sector showing growth is machinery and equipment manufacturing, which is the least electricity-intensive (and energy-intensive) sector of manufacturing. This structural trend makes a small contribution to reduced economy-wide electricity consumption.

On the other hand, 'bottom up' modelling of the probable effect on electricity consumption of energy efficiency programs, mostly of a regulatory nature, suggests that electricity consumption in 2013 would have been about 13.5 TWh, or nearly eight per cent, higher, had pre-2006 electricity consumption trends continued. The largest contribution to this demand reduction comes from appliance and equipment Mandatory Equipment Performance Standards under the national Equipment Energy Efficiency Program.

When all these contributions to the supply of electrical energy services are added to the contribution of NEM generators to the supply of electricity, it is found that consumption of electrical energy services continued to grow at much the same rate as experienced for many years prior to 2006 for several more years. Specifically, consumption grows up to 2010 and then growth almost ceases.

A series of separate 'top down' analyses were undertaken of both residential electricity demand, as reported in the ESAA statistics and residential and commercial electricity demand, as reported by AEMO. All analyses used annual data and no attempt was made to account for state-by-state and year-by-year variations in the severity of summer and winter weather. As noted above, previous analysis had shown that the effect of such changes on total electrical energy consumption, as opposed to annual peak demand, is relatively small. It was found that no combinations of price and income elasticities or lags in the response to changes in prices and income were able to yield a convincing modelled description of the observed trends in electricity consumption.

The final stage in modelling was to apply the top down econometric analysis to the 'wedge' of reduced consumption of electrical energy services between an extrapolation of demand growth prevailing prior to 2006 and the bottom up modelling of the various embedded generation and energy efficiency contributions. It was found that modelled demand tracked closely with actual demand, with a price elasticity value of -0.05 up to 2010, a higher value of -0.15 in 2011, followed by a progressive decrease back to -0.05 in 2013 and an income elasticity value of 0.2 for the whole period.

The results of this analysis make it possible to calculate the contribution of the various components described above to the reduction of electricity demand in the NEM below the historic trend. The results for the NEM over the whole period since 2000 are shown in Figure 28 and values for each 'wedge' in 2013 are shown in Table 5. The various factors examined in this study are sufficient to explain effectively all of the change in demand for electricity since 2006. (The small residual is simply departure from the highly simplified assumed extrapolation of 2.5 per cent per annum historic growth.)

Figure 28: Contribution of the various factors to reduced demand for electricity in the NEM since 2006

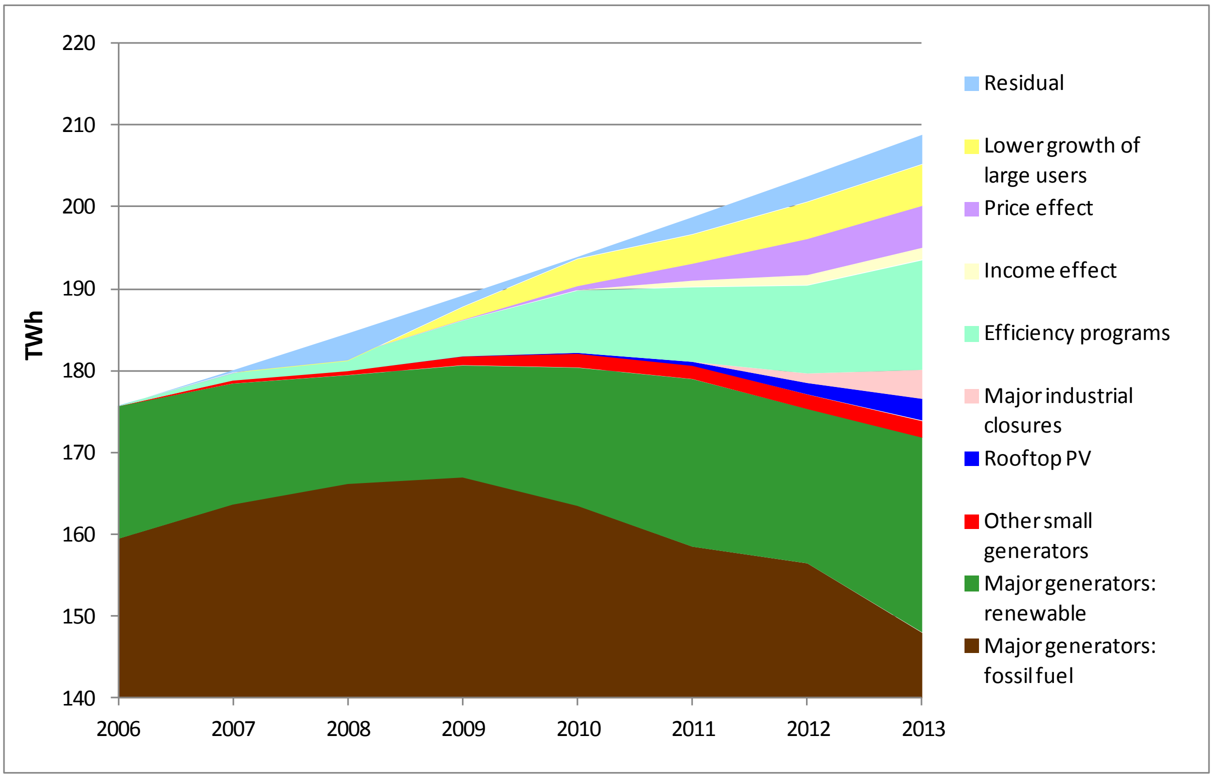


Table 5: Contribution of various factors to the observed reductions in growth of electricity demand in the NEM since 2006

	TWh	Share of "reduction"
Electricity supplied to consumers by major generators (equals "NEM demand" minus auxiliary loads minus transmission and distribution losses)	171.8	
Electricity supplied if growth had continued from 2004 at 2.5 per cent per annum	208.7	
"Reduction"	36.9	100 per cent
Made up of:		
Rooftop PV	2.7	7 per cent
Increase in other embedded generation	2.0	5 per cent
Major industrial closures	3.6	10 per cent
Energy efficiency programs	13.5	37 per cent
Income effect (if real GDP per capita had continued to grow after 2008 at 1.5 per cent per annum)	1.4	4 per cent
Recent price effect	5.2	14 per cent
Reduced growth of large users	5.0	14 per cent
Residual	3.6	10 per cent

The three largest factors contributing to the recent dramatic changes in demand for electricity are:

- the abrupt change in the trend of demand for electricity services after 2010, and the change in responsiveness of demand to price changes that is needed to achieve a good fit of modelled to actual demand,
- the impact of (mainly regulatory) energy efficiency programs, and
- structural change in the economy away from electricity intensive industries.

They will be discussed in turn.

Changing electricity consumer behaviour

It is surely not a coincidence that 2009-10 was the year in which the possible effect of a carbon price on electricity prices became a major national political issue, and in which increasing political attention was also paid to the rapid increases in electricity prices already occurring, mainly because of higher network costs.

Electricity prices remain a major preoccupation of political debate. The hypothesis is that the political attention paid to electricity prices led consumers to pay more attention than they had previously done to their expenditure on electricity. When they did, they responded by reducing their consumption, so as to limit what they were spending, and the outcome showed up strongly in the total electricity demand figures for 2010-11, and has continued to since then.

The elasticity, or sensitivity, of demand to changes in price is a key economic variable. If the quantity of a product sold is highly sensitive to changes in price then the demand for that product is referred to as elastic; whereas if the quantity of a product is relatively insensitive to changes in price then the demand is said to be inelastic.

The elasticity of demand for a product is related to a wide range of factors including the availability of substitutes, the proportion of income spent on the product, the cultural and habitual attributes of the product, awareness of the price of the product and the relative ease or difficulty of switching from a product. When calculating the price elasticity of demand, economists make the assumption of *ceterus paribus* (all other things remaining equal).

In attempting to estimate the price elasticity of demand for electricity in recent years it is difficult to argue that the assumption of *ceteris paribus* is helpful or appropriate. While large electricity price rises started around 2008 in most states, at first they received little public attention. From late 2009 onward, however, as price rises continued because of rapidly rising network costs, the degree of political and media attention paid to those price rises was unprecedented, due to the impending introduction of the carbon price. Similarly, the intention to increase the price of electricity, as a claimed consequence of the carbon price, meant that the impending increase in electricity prices in 2012 was one of the most anticipated price increases in Australian history.

As a result of the recent heightened, and at times hysterical, awareness of electricity prices it is highly likely that consumers have been more responsive to expected and actual electricity price changes than had previously been the case. Put simply, the price elasticity of demand for electricity is unlikely to have remained constant in recent times. Elasticity is a behavioural variable and it is difficult to argue that the attention paid to electricity prices over the past few years has not increased the perceived proportion of income spent on electricity, shifted individual attitudes towards wasting electricity and increased awareness of energy saving opportunities.

The price elasticity of demand exhibits volatility for a wide range of goods and services. Demand for prawns is far less sensitive to price at Christmas time just as demand for bottled water and petrol is less responsive to price ahead of expected disasters or strikes. Since the attention paid to electricity prices has shifted significantly, it is not surprising that it is necessary to measure changes in the elasticity of demand for electricity.

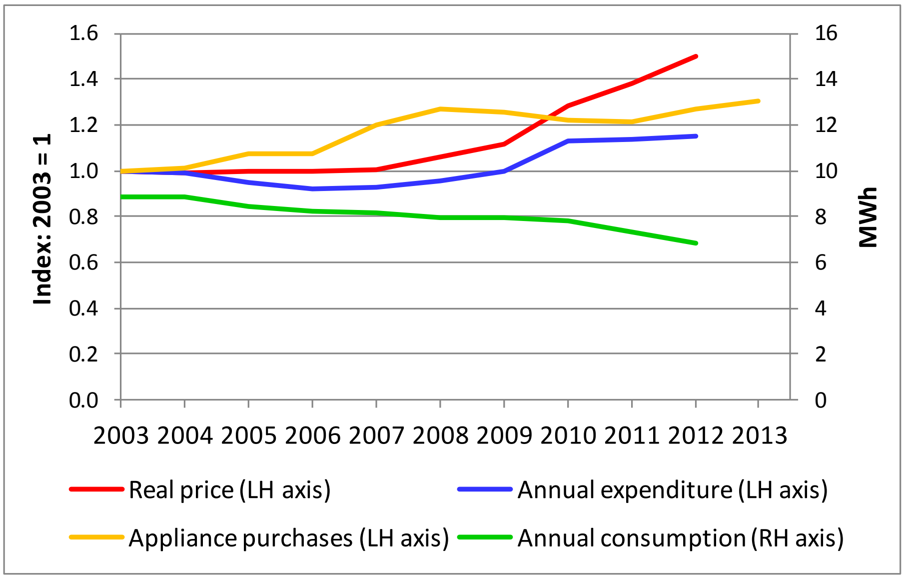
ABS data support this hypothesis. Figure 29 shows trends since 2002-03 in per capita residential electricity consumption in Australia and per capita household expenditure on electricity.

The striking feature of these trends is that total annual household expenditure on electricity and gas has almost ceased to increase since 2009-10, despite the continuing increase in electricity prices. That is of course consistent with the declining trend in per household demand for electricity. It is also, and importantly, not consistent with the obsessive emphasis placed in the public debate on the price per unit of electricity, rather than the cost to households of buying the quantities of electricity they require. One might, if being provocative, suggest that households know better and have more sense than the politicians they elect.

That said, it is possible that reduced household expenditure on electricity has been at the cost of personal comfort and amenity. If that is the case, then household electricity consumption could be expected to start growing again when price increases moderate or reverse. The same might also apply to business consumption, though it is relevant, as previously noted, that the fall in business consumption has been less than the fall in residential consumption.

Two other explanations for the reduction in household consumption are, however, possible. Each is also probably more applicable to business electricity consumption than the ‘freezing in the dark’ explanation.

Figure 29: Trends in real average residential electricity price, real average annual per household expenditure on electricity and on appliance purchases, and average annual per household electricity consumption, Australia



Sources: ABS[34, 35, 36]

The first hypothesis is that consumers, prompted by rising prices and the publicity they received, identified straightforward behavioural changes they could make, with little, or at least acceptable, loss of amenity. Well known examples include, in business, turning of lights and computers when not in use and turning down air conditioning when buildings are unoccupied and, in households, taking shorter showers, turning off lights, turning cooling thermostats up slightly in summer and heating thermostats down slightly in winter, and reducing the operating hours of swimming pool pumps. Changes in electricity consuming behaviour of this kind will certainly be more permanent, in the face of moderating electricity prices, than behavioural changes associated with loss of amenity, but they are not 'locked in' for the future.

The second hypothesis is that consumers responded to higher electricity prices by bringing forward replacement purchases of new and more efficient appliances and equipment. For households, the trend of expenditure on buying appliances shown in Figure 29 provides some support for this suggestion. In recent years, two up-ticks in purchases are apparent: one in the consumer credit boom period preceding the onset of the financial crisis and the other in the last two years. Above trend expenditure on new appliances would raise the uptake rate of new appliances above that assumed in the energy efficiency modelling described in

[34] Australian Bureau of Statistics (2013a) *op. cit.*
[35] Australian Bureau of Statistics (2013b) *op. cit*.
[36] Australian Bureau of Statistics (2013d) *Energy Account, Summary: Main findings* Cat. No. 4604.0 <http://www.abs.gov.au/AUSSTATS/abs@.nsf/DetailsPage/4604.02011-12?OpenDocument>

Section 6, and thereby increase the contribution of regulatory energy efficiency to reducing demand for electricity. Consumers might also choose an appliance model that was more efficient, and possibly more expensive, than required by the MEPS level, because of concerns about electricity costs. Business consumers of electricity could well make similar equipment purchase decisions. National Accounts figures are not inconsistent with this argument. Real private capital expenditure – that is, capital expenditure by business – fell for two successive years in 2008-09 and 2009-10, then rose by six per cent in 2010-11 and another 10 per cent in 2011-12, but fell by three per cent in 2012-13.

Electricity consumers will not go back to using older and less efficient equipment if electricity prices fall. Therefore changes in electricity consumption caused by the purchase and installation of new appliances and equipment will be more permanent than either of the other two types of behavioural change suggested as alternative explanations for the change in consumption of electricity services since 2010. Growth, or otherwise, of electricity consumption in the next few years will be affected by what mixture of these three responses to higher prices has been the most important. This is not an uncertainty that can be resolved by analysis of available data; it is an issue that can only be resolved by market research of both household and business consumers of electricity.

The data point to a difference between household and business consumers of electricity: households on average have made larger reductions in their consumption. Possible reasons for this difference are that:

- MEPS and other regulatory programs have had a bigger impact on residential appliances and equipment than on commercial equipment;
- residential consumers are more responsive to higher electricity prices than are business consumers
- businesses in general require shorter payback periods than households for any investment they make to increase energy efficiency; and
- other energy efficiency programs, e.g. subsidies, information, are more focussed on households than on business electricity consumers.

Energy efficiency programs

The major energy efficiency programs work by increasing the energy efficiency of new and replacement appliances, equipment and buildings. This means that the rate at which they can change energy efficiency depends on the rates of turnover of stock, much of it fairly long lived. Modelling of the impact of the appliance and equipment programs estimated as long ago as 2005 that the impact would be negligible until about 2006, but would grow very quickly thereafter.[37] The majority

[37] George Wilkenfeld and Associates (2009) *Prevention is Cheaper than Cure - Avoiding Carbon Emissions through Energy Efficiency*. <http://www.energyrating.gov.au/>

of the current consumption savings come from measures affecting refrigerators and freezers, air conditioners, motors and lighting, all of which have been in place for many years but also, according to the modelling, have considerable potential for further savings, even without increases in regulatory stringency. Regulation of the efficiency of computers, standby power and televisions is more recent and is likely to achieve much greater savings in the next few years than at present. Because of the long life and slow turnover of buildings, the impact of energy efficiency regulations in the Building Code of Australia is much slower still, with much of the potential still to come, even though the measures themselves date back to 2003 or beyond.

The modelling makes no allowance for possible increases in either the coverage of energy efficiency regulations or the stringency of performance standards applied to types of appliances and equipment already covered. There is therefore the potential for further increases in consumption reductions if this path is taken. Further increases could come from activities, whether through government-supported programs or otherwise, which accelerate the retirement and replacement of the stock of older and less efficient appliances, equipment and buildings. A further avenue for increase lies in the opportunity for increased uptake of equipment that performs well above the minimum regulated standard. The rapid uptake of LED lighting, driven by the technology's spectacular rate of performance improvement and cost reduction, is an obvious example of this process.

All in all, it seems likely that, provided existing programs are retained and receive the level of administrative support required to ensure wide compliance, their contribution to reducing electricity demand will continue to grow.

Long term change in the relationship between economic growth and electricity demand

Looking at the long-term trend in Figure 2, a change in the rate of growth of per capita electricity supply may have started as long ago as around 2000. This is most likely to be a manifestation of a long-term structural change to how Australian consumers as a whole, including businesses, households and all other types of electricity consumer, use electrical energy. If correct, it should affect thinking about possible future growth in electricity demand.

As observed in the opening section of this paper, consumption of electricity in Australia grew uninterrupted for more than a century, as it did in most other countries. This led many leaders of the electricity supply industry and, indeed business and political supporters of the industry, to believe that there was a direct, simple and unchanging relationship between economic growth and demand for electricity. This was expressed in economic terms as a constant income elasticity of demand for electricity. It was also the basis of the very successful industry growth model delivered by state electricity commissions between the end of World War 2 and the early 1980s. Although growing public, and eventual political, dissatisfaction with this industry model led to its break-up in the 1990s, growth inertia continued for some time, driven in part by new large industrial consumers, notably aluminium smelters, and in part the growth in size and electrification of dwellings.

As explained in Section 5, output from aluminium and other particularly electricity-intensive primary metal production activities stopped expanding about five years ago, after several decades of fairly steady growth. The consequent ‘missing’ electricity consumption is one of the ‘wedges’ in Figure 28. Less recognised by the electricity industry, though not by economists,[38] has been the implication of long term changes in economic structure, away from manufacturing and towards the much less electricity-intensive service sectors. This was hidden for many years because manufacturing itself shifted towards the more energy-intensive sectors, defined in Section 5 above – a shift that has now ended. As a share of total GDP, value added by the energy intensive sectors of manufacturing fell from 7.3 per cent in 1980-81 to 5.2 per cent in 2002-03, but from there more quickly to only 3.7 per cent in the next ten years. The major industrial closures are one particularly obvious component of this decline, and they may be followed by others within the next few years. More far-reaching changes, however, with long-term implications for electricity demand, are also in play.

In the household sector another type of structural change also appears to be at work. Over the past decades, residential electricity demand growth has been driven by the shift to near universal ownership of major appliance types: hot water systems, refrigerators, clothes washers, dishwashers, freezers, televisions and air conditioners. In colder areas the majority of dwellings are now heated throughout the main living areas – and most space heating uses gas rather than electricity. Computers and other electronic appliances are also now widely owned and are becoming smaller and more energy efficient. Again, therefore, the scope for continued strong growth in electricity consumption – ignoring, of course, the possible impact of electric vehicles – seems to be limited.

To conclude, this study is not and was never intended to be a basis for projecting possible future demand for electricity. Yet the findings point to a number of changes in the drivers of increased electricity consumption. The logical conclusion is that, although growth in consumption may resume in the next few years, it will

[38] Che, N and Pham, P (2012) *Economic analysis of end-use energy intensity in Australia*, Bureau of Resource and Energy Economics, Canberra <http://www.bree.gov.au/documents/publications/energy-intensity/Energy_intensity.pdf>

then continue at much lower annual rates than those that prevailed for more than a century up to about 2004.

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