Five Years of Declining Annual Consumption of Grid-Supplied Electricity in Eastern Australia: Causes and Consequences

For decades, consumption of grid-supplied electricity increased in line with a growing economy. In the five years since 2009, however, annual consumption in eastern Australia declined by 7 percent, even while the Australian economy grew by 13 percent. Declining consumption was not forecast by the planning authority nor by market participants. The authors review reasons for declining consumption, the failure of planning authorities to forecast this structural change, and ongoing consequences. Fuel switching from oil and gas offers one means of partly arresting the rapidly declining use of electricity grid infrastructure.

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I. Introduction

Since the oil crises of the 1970s, global economies have been able to reduce their energy intensity (the use of energy per unit of economic output) (BP Energy Outlook 2035, 2014). In Australia, energy intensity has steadily declined since the 1990s (Energy in Australia, 2014). Nevertheless until recently, absolute energy

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consumption across all sectors of the Australian economy continued to grow (Energy in Australia, 2014). In the decade preceding the 2008 global financial crisis (GFC), grid-supplied electricity consumption in eastern Australia grew at an average rate of approximately 2 percent per year (Australian Energy Statistics, 2014).

However, consumption of grid-supplied electricity in developed economies globally is now undergoing unprecedented and rapid change. In Australia and elsewhere (Today in Energy, 2013; UK Department of Energy & Climate Change, 2014; PLATTS, 2013), electricity markets are experiencing sustained declining consumption. This presents challenges to industry incumbents, market operators, regulators, and governments. In this article, we describe how in the Australian financial year (FY) ending Jun. 30, 2009 (FY 2008-09), electricity supplied by the eastern Australian grid (known as the National Electricity Market, or NEM) reached an all-time high of 195.0 TWh. Then, over the following five years while the Australian economy grew by approximately 13 percent, annual electricity consumption in eastern Australia declined by 7 percent to reach 181.2 TWh in FY 2013-14. This ongoing multi-year decline was not anticipated by market participants nor by the planning authority, the Australian Energy Market Operator (AEMO). In part, this was because for many decades Australian electricity consumption generally increased from year to year in line with the growing Australian economy. The lower-than-average growth in annual electricity consumption in FY 2008-09 followed by declining consumption in FY 2009-10 was initially credited to temporary factors such as the GFC. In August 2011 following the post-GFC recovery of the Australian economy, AEMO forecast that annual electricity consumption would reach 215 TWh by FY 2013-14 and 248 TWh by FY 2020-21. Experience shows that the forecast for FY 2013-14 was high by approximately 18 percent. Rather than the consumption decline of FY 2008-09 and 2009-10 being a temporary aberration, it presaged a fundamental shift in the Australian electricity market.

Consequences of declining annual consumption and forecasting failures include overbuilding of electricity infrastructure and declining use of this infrastructure.

It is now clear that annual consumption of grid-supplied electricity in Australia no longer tracks economic growth. In June 2014 AEMO forecast that in a ''medium scenario'' annual consumption will not exceed the level seen in FY 2008-09 until sometime beyond 2035. In this article, we review some of the reasons for this structural change including: energy efficiency programs, consumer response to dramatically rising retail electricity prices, the widespread deployment of rooftop solar photovoltaic (PV) systems, specific facility closures in the larger-industrial sector, and other factors. We describe some consequences of declining annual consumption and forecasting failures. These include overbuilding of electricity infrastructure and declining use of this infrastructure. Furthermore, overbuilding and declining consumption has driven some industry incumbents to support reversal of energy efficiency, renewable energy, and climate change mitigation programs. We present a scenario illustrating to what extent the annual consumption of grid-supplied electricity could continue to decline over the next 10 years. Finally we describe opportunities to increase electricity consumption while decreasing the use of oil and gas.

II. Eastern Australia's Electricity Supply System

The eastern Australian electricity transmission grid serves approximately 21 million people (90 percent of Australians)

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in Queensland, New South Wales, the Australian Capital Territory, Victoria, Tasmania, and South Australia. It is one of the longest transmission grids in the world stretching across 5,000 kilometers. Electricity transmission interconnections – with limited capacity – connect Queensland with New South Wales, New South Wales with Victoria, Victoria with Tasmania (via a subsea connection), and Victoria with South Australia. Western Australia and the Northern Territory have no physical connections to and remain separate from the eastern Australian system. (This article describes activities in eastern Australia only.) Population and electricity consumption is generally concentrated around the capital city of each eastern Australian state or territory. Regional areas in between are much more lightly populated.

Eastern Australia's electricity generation and transmission system has been one of the most reliable in the world with performance generally exceeding the 99.998 percent availability target (corresponding to un-served energy of 0.002 percent or approximately 10 minutes per year) (Australian Energy Regulator, 2013). Maximum (instantaneous) demand for electricity is the critical parameter that determines the required size of electricity-supply infrastructure. In all eastern Australian states with the exception of the southern island state of Tasmania, maximum demand occurs in late afternoon and early evening during summer heat waves that drive the use of air-conditioners. As a result, the electricity supply system is sized to meet maximum demand that may occur only for a few hours per year, if at all.

The National Electricity Market has operated across the eastern Australian states since 1998, with Tasmania joining in 2005. Australian Energy Market Commission describes the operation of the NEM as follows (National Electricity Market, 2014):

Eastern Australia's electricity generation and transmission system has been one of the most reliable in the world.

> The Australian Energy Market Operator (AEMO) operates the NEM. The NEM is an energy-only gross pool with mandatory participation. Generators sell all of their electricity through the NEM where supply and demand are matched instantaneously. From the generators' offers, the market determines the combination of generation to meet demand in the most cost-efficient way. AEMO then issues dispatch instructions to these generators. The market determines a spot price every half-hour for each of the five regions of the NEM. AEMO settles the financial transactions for all of the electricity traded on the NEM on the basis of these spot prices. Generators and retailers often protect themselves from movements in the spot price by entering into hedge contracts.

Annual electricity consumption in eastern Australia can be divided into three sectors. AEMO provides data describing the ''larger-industrial'' sector (22 percent of total consumption) based on direct meter readings (National Electricity Forecast Report, 2014). The subsequent division of the ''residential'' sector (28 percent of consumption) versus the remaining ''smaller-industrial-and-commercial'' sector (SI&C, 50 percent of total consumption) must be estimated (Saddler, 2013). The wholesale sales value (turnover) of grid-supplied electricity in eastern Australia has ranged from $A 6 to 12 billion in recent years with electricity production in the range of 180 to 195 terawatt-hours (TWh).

Traditionally, NEM electricity was generated from brown and black coal (27 GW of generation capacity now installed), gas (12 GW), and hydroelectricity (8 GW). The average age of Australia's coal power station fleet is over 30 years with some 50-year-old facilities still in service (Stock, 2014). Over the last decade, more than three GW of wind generation was installed. Total larger-scale generation

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capacity in the NEM now stands at approximately 50 GW. Furthermore over the last six years, more than 3.4 GW of small-scale rooftop solar photovoltaic (PV) has been installed in eastern Australia (''Renewable energy target, small-scale installations by postcode''), mostly on over 1 million homes and more recently by 15,000 businesses with commercial building roof space (Clean Energy Council, 2014). Rooftop PV electricity generation reduces the demand for grid-supplied electricity and is forecast to triple over the next 10 years (National Electricity Forecast Report, 2014). Recent wind and solar deployment has been driven at least in part by the Renewable Energy Target legislation of 2009.

Australia legislated a carbon price of $A 23/tonne CO_2-equivalent starting July 2012. This applied to electricity generation and some other sectors of the economy. However, any effect of the carbon price on electricity sector emissions was short-lived when the carbon price was repealed in July 2014 following a change of government.

III. History of Annual Electricity Consumption in Eastern Australia – Actual and Forecasts

Until recent years, eastern Australian retail electricity prices ranked amongst the lowest in the OECD group of nations (Section IV.B). For many decades, the consumption of grid-supplied electricity increased nearly each year, in step with the growing Australian population and economy. From July 1, 1998, to June 30, 2009, consumption increased at an average rate of 3.9 percent/yr (Australian Energy Regulator, 2013). In the industrial sector, Australian governments historically supported the development of electricity-intensive industries

Any effect of the carbon price on electricity sector emissions was short-lived when the carbon price was repealed in July 2014 following a change of government.

such as aluminum smelting. In the residential and commercial building sectors, given the historical low cost of energy and benign climate, energy efficiency was not an important design feature of Australian buildings or equipment. Concepts such as roof and wall insulation were mostly optional. Low-cost electricity competed with low-cost gas to heat water and living spaces. Consumers were incentivized by very low prices to use electricity at ''off-peak'' times (nighttime and weekends) to smooth demands on baseload coal-fired generators. In recent years, increasing numbers of Australian homes were fitted with air-conditioners and other high-energy-consuming items such as halogen downlights and plasma televisions. Modern mass-produced homes featured little in the way of passive-energy design principles, tending to dispense with traditional window-shading eaves and to favor single-glazed windows and dark-colored heat-absorbing external roofing materials.

Due to all of the above factors, Australia's energy consumption (electricity and other energy sources) per unit of production has been higher than the OECD average (ABS, 2012). The onset of the GFC occurred in September 2008; however, in 2008 and the following years, the Australian population and economy continued to grow. Annual consumption of grid-supplied electricity also continued to grow until it reached an all-time high of 195.0 TWh in FY 2008-09 (**Table 1**).

Lower-than-forecast annual consumption of grid-supplied electricity in FY 2008-09 and then declining consumption in FY 2009-10 was initially thought to be temporary and credited to factors such as the Global Financial Crisis. In August 2011, the relevant planning authority AEMO forecast that consumption would continue to grow at the rate of 2.3 percent/yr through to 2021, in line with projections for a continuously growing Australian economy (AEMO, 2011). With

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Table 1: Annual Consumption of Grid-Supplied Electricity in Eastern Australia

Australian Financial Year (FY) Ending 30 June		Annual Grid-Supplied Electricity (TWh) (National Electricity Forecast Report, 2014)	% Change vs. Previous Year	Note
FY 2005-06	The final years of continuously growing annual consumption	189.6	–	
FY 2006-07		192.5	+1.5%	
FY 2007-08		193.7	+0.6%	
FY 2008-09		195.0	+0.7%	The onset of the Global Financial Crisis, and all-time high for annual grid-supplied electricity in eastern Australia.
FY 2009-10	Period of continuously declining annual consumption	194.9	−0.1%	AEMO continues to forecast continual growth.
FY 2010-11		192.8	−1.0%	
FY 2011-12		189.1	−1.9%	
FY 2012-13		184.6	−2.4%	
FY 2013-14		181.2	−1.8%	Annual consumption now 13.8 TWh less than the all-time high, an overall decline of 7%.

that basis, consumption was forecast to reach 215 TWh by FY 2013-14 and 248 TWh by FY 2020-21.

This annual electricity consumption forecast and related ''maximum'' demand forecasts (Section V) indicated that 1 to 2 GW of new generation capacity and associated electricity supply infrastructure would need to be built each year. However, AEMO's forecast would prove to be inaccurate. After reaching an all-time high of 195.0 TWh in FY 2008-09, consumption declined each year over the following five years to reach 181.2 TWh in FY 2013-14: a decline of 7 percent overall and an average decline rate of 1.4 percent/yr (Table 1). This occurred despite the Australian economy growing by 13 percent over that time. This decline was not forecast by AEMO, in part because for many decades Australian electricity consumption generally increased from year to year in line with the growing Australian economy. AEMO's 2011 forecast of continuous growth resulted in the forecast for FY 2013-14 being high by 14 percent (25 TWh).

In June 2014, four years after the onset of declining annual electricity consumption and for the first time, AEMO forecast a brief interruption to continuous growth. In its ''medium scenario,'' AEMO forecast that consumption in FY 2014-15 would decline to 175.7 TWh (**Figure 1**). However for the years after that, AEMO forecasts that consumption will continuously rise, albeit at a slower rate than presented in earlier forecasts (National Electricity Forecast Report, 2014). Nevertheless, in its June 2014 forecast, AEMO does not see annual consumption reaching the all-time high of FY 2008-09 until after 2035.

It is now clear that the annual consumption of grid-supplied electricity in eastern Australia no longer tracks economic growth. From FY 2005-06 to FY 2013-14 while the Australian population and gross domestic product (GDP) grew, the consumption of grid-supplied electricity declined (**Figure 2**).

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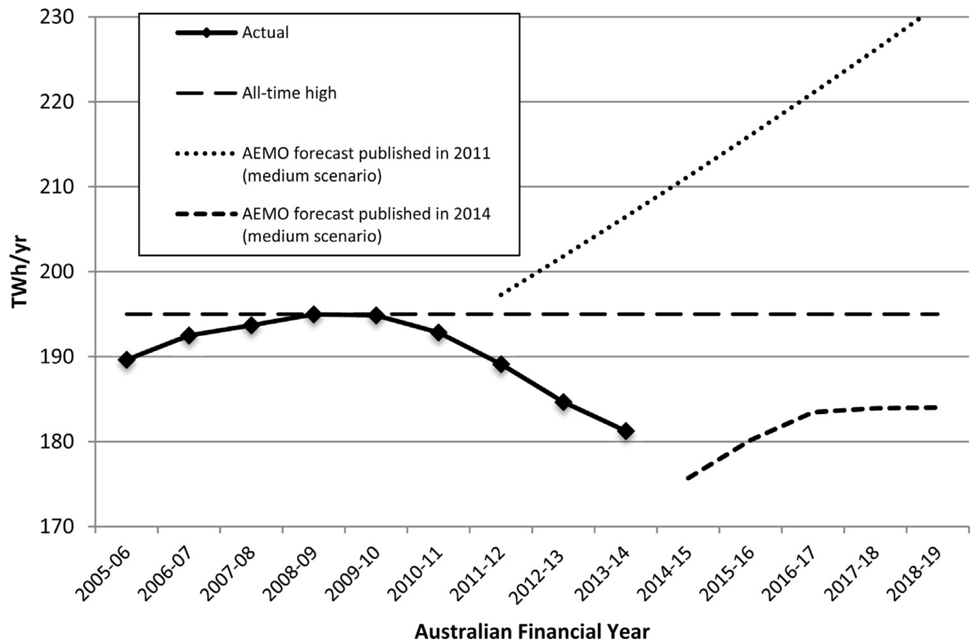

Figure 1: Annual Consumption of Grid-Supplied Electricity in Eastern Australia, Compared with Forecasts (National Electricity Forecast Report, 2014; AEMO, 2011)

IV. Reasons Why Annual Consumption Stopped Growing and Started Declining

This section examines why eastern Australia's annual consumption of grid-supplied electricity failed to grow at historical rates and instead declined in each of the last five financial years. Saddler (2013) investigated why, from FY 2005-06 to FY 2012-13, annual consumption for grid-supplied electricity fell short of a typical historical 2.5 percent/yr growth rate. By FY 2012-13, consumption fell short of the historical trend by 36.9 TWh/yr (~20 percent, equivalent to the output of 5 GW

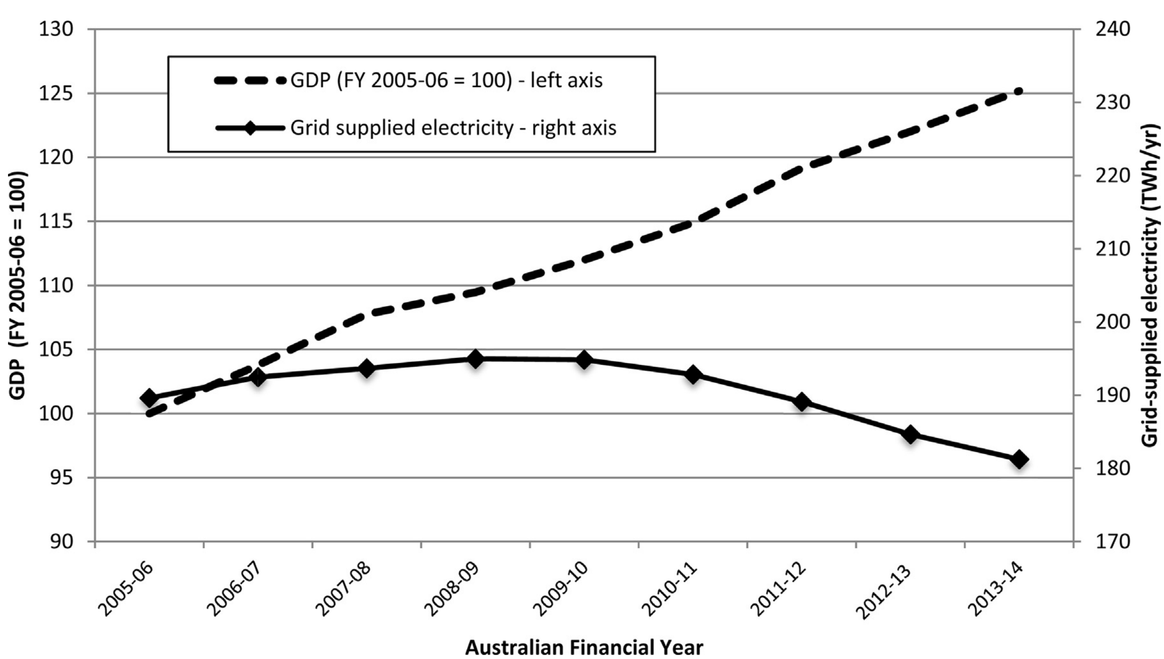

Figure 2: Australian GDP Growth Compared With Consumption of Grid-Supplied Electricity in Eastern Australia

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Table 2: Major Reasons Why Consumption Stopped Growing and Started Declining

Sector Impacted	Factor or Program	Impact in FY 2012-13 vs. an Historical Growth Trend TWh/yr	Program Subtotal	Sector Subtotal
Residential	Energy efficiency programs	7.9		
	Appliance upgrades (residential)		6.0	
	Other measures (insulation, building standards, state energy efficiency programs		1.9	
	Other consumer price response to dramatically rising retail electricity prices	5.2		
	Widespread deployment of rooftop solar PV	2.7		
	Water heating fuel-switch programs	1.2		
				17.0
Larger-industrial	Reduced growth of larger-industrial energy users vs. rate of growth seen in the past	5.0		
	Industrial facility closures	3.6		
	Embedded generation (other than solar PV)	1.5		
				10.1
Smaller-industrial & commercial (SI&C)	Energy efficiency programs and embedded generation (other than solar PV)	4.8		4.8
Various or uncertain	Other economic impacts and residual (including the Australian government Energy Efficiency Opportunities program that targeted large industry)	5.0		5.0
Total				36.9

Derived from Saddler (2013).

of generation). Saddler highlighted the limitations of available data sources but nevertheless identified factors or programs that led to declining consumption (**Table 2**). The single-largest factor driving consumption decline was the ''Equipment Energy Efficiency (E3) Program'' (Energy Rating) responsible for 9.4 TWh/yr of consumption decline across the residential and SI&C sectors. The second-largest factor was consumer response to dramatically rising retail electricity prices (5.2 TWh/yr). Saddler found that greatest consumption decline occurred in the residential sector, followed by the larger-industrial sector and then the SI&C sector. Consumption decline in the combined residential and SI&C sectors was first observed in FY 2008-09, whereas decline in the larger-industrial sector was not observed until two years later. Extremes of weather affect electricity consumption; however, the weather of recent years was insufficiently extreme to significantly impact year-to-year annual electricity consumption (Saddler, 2013).

A. Residential energy efficiency and hot water fuel-switching programs

In the residential sector, Saddler (2013) ranked the following energy efficiency programs in order of their impact:

1. Ongoing replacement of inefficient electrical appliances by implementation of energy

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efficiency standards and labeling programs, with some standards for refrigerators/freezers and electric water heaters commencing in 1999 (6.0 TWh/yr),

2. Energy efficiency regulations for new building construction, with some wall-cavity insulation standards commencing in some states in 1991 and national implementation in 2006 (1.9 TWh/yr),

3. State- and territory-based schemes such as the Victorian Energy Efficiency Target, the New South Wales Energy Savings Scheme, and the South Australian Residential Energy Efficiency Scheme, all commencing in 2009 (0.6 TWh/yr), and

4. The Home Insulation Program active from 2009 to 2011 (0.4 TWh/yr).

In Australia, replacing resistive-electric water heaters with heat-pump-electric or rooftop-solar-with-electric-or-gas-boost has been supported by Australian government programs since 2001. There was a strong increase in replacements between 2008 and 2010, and by 2013 water heater replacement programs had reduced annual electricity consumption by 1.2 TWh/yr, compared with a FY 2005-06 baseline (Saddler, 2013).

B. Rising retail electricity prices

Residential consumers reduced their electricity use because of dramatically rising retail electricity prices (Saddler, 2013). Prior to 2008, the retail price of electricity in Australia was low compared with other OECD nations and tended to rise in line with the Consumer Price Index (CPI). However, since 2008, retail electricity prices have risen dramatically and have nearly doubled in just six years (a 7 percent/yr annual growth rate) (ABS, 2014) (**Figure 3**). Today, Australian retail electricity prices rank toward the upper end of prices found in OECD nations (Mountain, 2012). As an example of current retail prices for residents in New South Wales, flat-rate electricity is available at \$A 0.25/kWh with a daily supply charge of \$A 0.80/day (includes 10 percent Goods and Services Tax). Alternatively, a time-of-use tariff is available at a cost of \$A 0.51/kWh during peak periods, \$A 0.20 during shoulder periods, and \$A 0.11/kWh at other times (Energy Made Easy).

Figure 4 breaks the price of electricity available to households in New South Wales (as an example) into components and compares the growth of these components between the financial years 2007-08 and 2012-13 (Australian Government – Productivity Commission, 2013). Overall, the total electricity cost more than doubled over five years. More than half of the costs are attributed to network costs that also increased by more than a factor of two over five years. Governments and regulatory authorities are focusing on ways to limit future retail electricity prices rises (Australian Government Department of Industry, 2014). According to the Australian Energy Market Commission, residential electricity price increases are

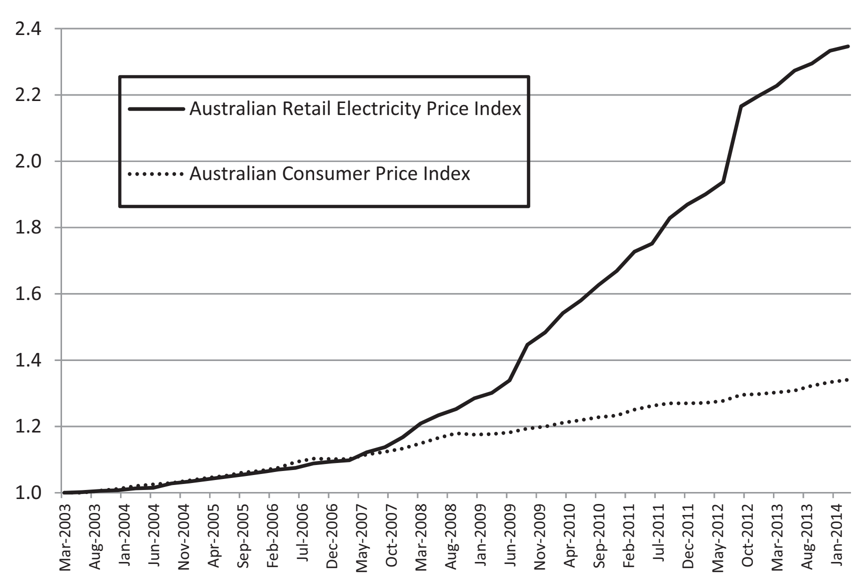

Figure 3: Australian Retail Electricity Price Compared With CPI (ABS, 2014)

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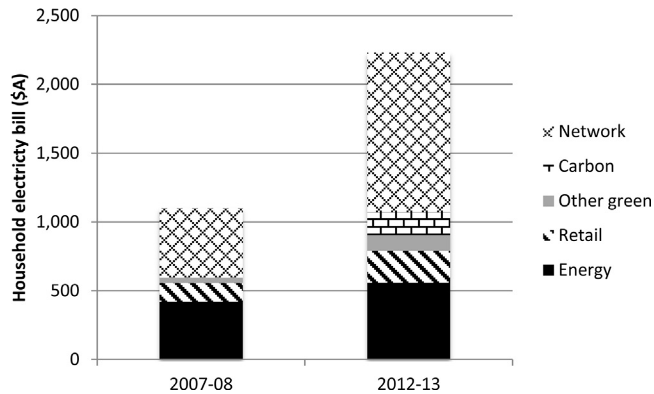

Figure 4: New South Wales Household Electricity Bill Components (Australian Government – Productivity Commission, 2013)

expected to moderate over the period 2014 to 2016 (Australian Energy Market Commission, 2013).

C. Widespread deployment of rooftop solar PV

In another response to rising electricity prices and other stimuli, homeowners and businesses reduced their consumption of grid-supplied electricity by installing rooftop PV systems. (Note that in our analysis as well as in the management of the NEM generally, rooftop solar PV is considered to be ''behind the meter'' and acts to reduce the consumption of metered grid-supplied electricity.) Starting from a negligible base, PV systems with generation capacity of more than 3.4 GW (''Renewable energy target, small-scale installations by postcode'') have been installed on over 1 million eastern Australian homes as homeowners invested more than $8 billion. Initially, this boom in residential solar systems was catalyzed by government-legislated incentives including rebates, renewable energy certificates, and feed-in tariffs. These incentives have been scaled back over time as the cost of solar PV systems has declined and competing business sectors voiced concerns.

More recently as electricity costs have increased and financing arrangements for rooftop PV have emerged, electricity-consuming businesses with suitable commercial roof-space are finding it economically attractive to install larger-scale rooftop systems. Some 15,000 Australian businesses had installed rooftop PV by mid-2014 (Clean Energy Council, 2014). For FY 2013-14, AEMO estimated that small-scale solar PV generated approximately 4 TWh of electricity in eastern Australia (National Electricity Forecast Report, 2014), an increase of 36 percent over the previous year. This is an amount of energy equivalent to approximately 2 percent of total electricity supplied.

As shown in **Figure 5**, in 2014 AEMO forecast that the amount of PV-generated electricity could more than double over the next five years to approximately 10 TWh/yr, or approximately 4 percent of total

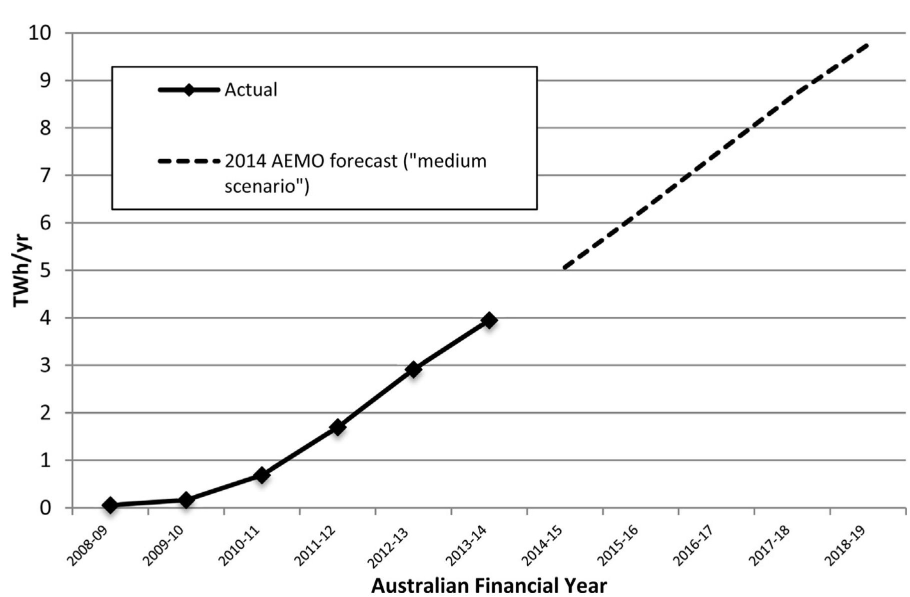

Figure 5: Electricity Generated by Rooftop Solar PV in Eastern Australia (National Electricity Forecast Report, 2014)

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electricity supplied. As described in Section V.A, solar PV is also shifting the time-of-day when summer maximum demand occurs (Australian Energy Market Operator, 2014; NEFR, 2014).

D. Annual electricity consumption decline in the industrial sector

In the industrial sector, the closures of or reduced operations at three facilities in New South Wales between October 2011 and September 2012 reduced annual consumption of electricity by 3.6 TWh/yr:

- Kurri Kurri aluminum smelter (~2 TWh/yr)
- Clyde oil refinery
- Port Kembla steelworks (part-closure).

Beyond those specific facilities, Saddler (2013) found no evidence of declining electricity consumption due to reduced or restructured economic activity in the industrial sector. There was, however, failure of industrial electricity consumption to grow at the rates seen in past decades. This failure-to-grow explains 5.0 TWh/yr of the difference between actual consumption and an historical rate of consumption growth.

E. Declining annual consumption analyzed by half-hourly intervals

This section illustrates year-to-year changes in grid-supplied electricity consumption by

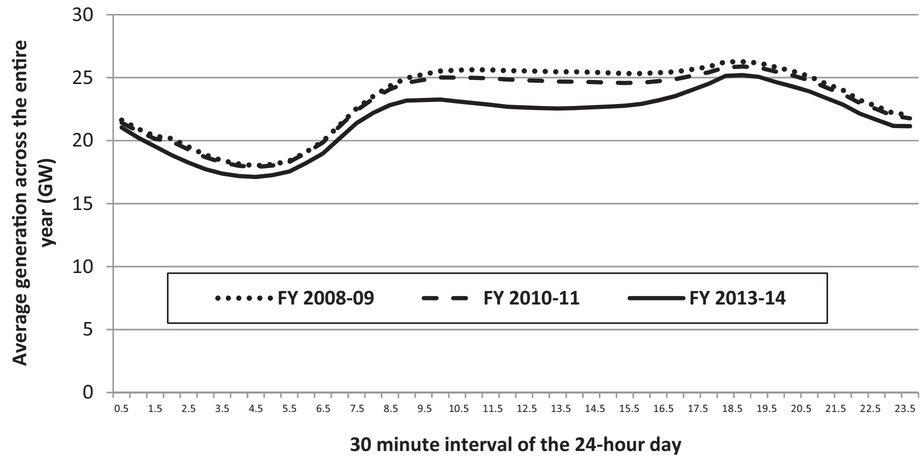

Figure 6: Comparing Annual Consumption of Grid-Supplied Electricity by 30 Minute Periods of the 24-Hour Day

comparing averaged consumption over the 48 half-hourly periods of the 24-hour day for different financial years. **Figure 6** shows consumption data for FY 2008-09, the year with the all-time highest consumption. It then shows how much consumption had declined by FY 2010-11 and by the most recent FY 2013-14.

Based on the data in Figure 6, **Figure 7** shows, for each half-hourly period, the net decline in consumption that occurred between the financial years of 2008-09 and 2013-14. At a conceptual level and recalling that this consumption decline has happened at a time of ongoing population and economic growth in eastern Australia, we observe:

- Consumption has declined at all hours of the day (Area 1 in Figure 7). This reflects factors such as energy efficiency measures and behavioral change that apply during all hours of the day, large-scale industrial closures, and constantly loaded embedded generation.
- Consumption decline was greater at around 2 a.m. (see Area 2) than, for example, at 5 a.m. This probably illustrates phase-out and/or improved efficiency of resistive-electric ''off-peak water heaters'' that traditionally were activated in the states of Victoria and South Australia between 11 p.m. and 6 a.m. For this same reason, we would expect that 1 am results would be similar to 2 a.m. results. However this is not the case: consumption decline at 1 a.m. is only about half of the 2 a.m. result. As the necessary data are not readily available, further analysis of this time period is beyond the scope of this article. Furthermore, this article does not explore the extent to which consumers in Victoria might be taking advantage of 2.8 million recently deployed ''smart'' meters to reduce their electricity costs by shifting load from day or evening periods to off-peak nighttime hours (11 p.m. to 7 a.m. AEST).

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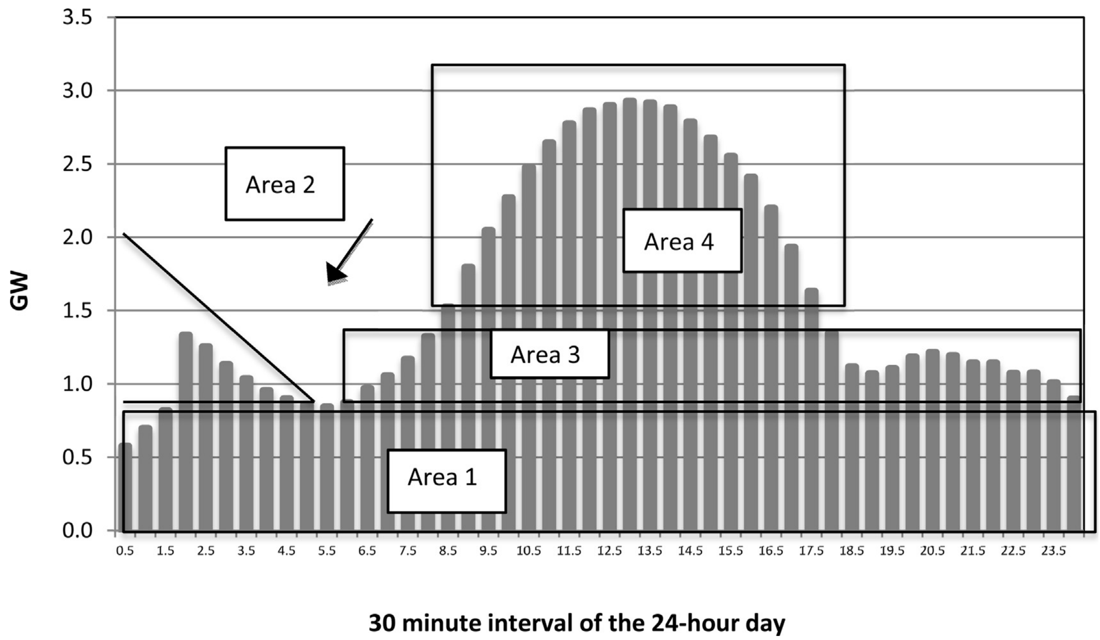

Figure 7: Consumption Decline Between FY 2008-09 and FY 2013-14

- Additional consumption decline occurred across all the ''waking hours'' from 6 a.m. to midnight (Area 3).
- Remaining consumption decline that occurred only during daylight hours (Area 4) may be credited to solar PV and/or other factors.

V. Maximum Demand – Actual and Forecasts

Forecast maximum (instantaneous) demand, which might occur only for a few hours in a given year, is a critical parameter that determines the size that electricity-supply infrastructure must be in order for consumers to be reliably served. Regardless of whether annual consumption of grid-supplied electricity is declining from year to year, if maximum demand cannot be expected to also decline, electricity supply infrastructure must be kept in readiness. This may mean that average utilization (or productivity) of the system falls. This section examines historical actual and forecast maximum demand for grid-supplied electricity at the NEM state level. Interconnections exist between the states (Section II), but because these have limited capacity, state-level maximum demand determines the level of electricity infrastructure required.

A. Maximum demand records set during heat waves prior to 2012

In all eastern states except Tasmania, historical record-high maximum demand occurred on weekday afternoons during summer heat waves, outside of weekends and holiday periods. This is because of the need for living-space cooling (refrigerant-type air conditioners and evaporative coolers). In 2011, 73 percent of dwellings in Australia had cooling, up from 59 percent in 2005 (AUSSTATS, 2011). Maximum demand in the cooler southern island state of Tasmania occurs in winter, reflecting the use of electricity for residential space heating. As shown in **Table 3**, no maximum demand records have been set in any state since 2011.

Since 2011, no new maximum-demand records have been set in any eastern Australian state despite increasing population, a growing economy, ongoing heat waves, and continued penetration of residential living-space cooling. The summer of 2012-13 was Australia's hottest on record. However, no new maximum demand records were set. Details

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Table 3: Record-High Maximum (Instantaneous) Electricity Demand in Eastern Australian States

	Record-High Maximum Demand (GW)	Date of Record-High Maximum Demand (Season)	Day of the Week	Time of Day When Record-High Occurred	Capital City Maximum Temperature on the Day of Record-High Demand
Queensland	8.9	18 January 2010 (summer)	Monday	1:15 pm AEST[a]	Brisbane: 38.0 °C
New South Wales (including ACT)	14.7	1 February 2011 (summer)	Tuesday	4:00 pm AEST 3:00 pm ADST	Sydney: 33.6 °C
Victoria	10.6	29 January 2009 (summer)	Thursday	4:00 pm AEST 3:00 pm ADST	Melbourne: 42.7 °C
South Australia	3.4	31 January 2011 (summer)	Monday	5:00 pm AEST 4:00 pm ADST	Adelaide: 42.9 °C
Tasmania	1.8	21 July 2008 (winter)	Monday	–	–

[a] AEST – Australian Eastern Standard Time; ADST – Australian Daylight Savings Time (does not apply in Queensland).

of certain heat waves that occurred in 2013 and 2014 are listed in **Table 4**. (Maximum electricity demand is most likely to occur in late January and early February when businesses and schools return to full activity following the summer holiday period.)

One reason why no new records have been set since 2011 is because the deployment of rooftop solar PV has reduced maximum demand for grid-supplied electricity during mid-day hours. Solar PV has also shifted the time-of-day at which maximum demand might occur until later in the day. For example in January 2011, South Australia – the state with the greatest per-capita penetration of rooftop PV – experienced record-high maximum demand at 5:00 p.m. AEST, whereas in January 2014 maximum demand for that summer did not occur until 6:30 p.m. AEST (Australian Energy Market Operator, 2014; NEFR, 2014).

B. Forecasts for maximum demand significantly reduced

In 2014, AEMO updated its maximum demand forecasts (National Electricity Forecast Report, 2014). As described above, maximum demand in most states depends upon summer weather conditions and air conditioner use. Therefore, in order to model a range of weather conditions, AEMO produces probabilistic forecasts. In AEMO's ''medium scenario'' and considering weather conditions that represent a 10 percent probability of exceedance (10 percent POE), AEMO forecasts that maximum demand will not exceed previous record highs within the next 10 years in Victoria, South Australia, or Tasmania. Minor exceedance is forecast to occur in New South Wales, but not until FY 2022-23 (**Table 5**). Only for Queensland does AEMO forecast that, within the next few years, future

Table 4: Periods of High Temperatures in Eastern Australian States Since Electricity Demand Records Were Set

	Example Heat Waves Occurring Since 2011	Capital City Ambient Temperature Recorded During This Heat Wave
Queensland	Early January 2014	Brisbane (Archerfield): 43.5 °C (highest-ever recorded temperature)
New South Wales	Mid January 2013	Sydney: 45.8 °C (highest-ever recorded temperature)
Victoria	Mid January 2014	Melbourne: 42.0 °C
South Australia	Mid January 2014	Adelaide: 43.0 °C

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Table 5: AEMO Maximum Demand Forecast Published in 2014 (''Medium Scenario'', 10% POE)

	Year When Previous Record-High Maximum Demand is Forecast to be Exceeded	Forecast Maximum Demand for FY 2023-24 (GW and % of Previous Record-High)
Queensland	FY 2015-16	10.0 GW (113% of 2010 record-high)
New South Wales (including ACT)	FY 2022-23	14.9 GW (101% of 2011 record-high)
Victoria, South Australia, Tasmania	Previous record-high maximum demand is not forecast to be exceeded within AEMO's 10-year planning outlook period	Not applicable

maximum demand might exceed the previous record-high. This is because in Queensland, new large-scale gas production and liquefied natural gas (LNG) export facilities may opt to purchase approximately 9 TWh/yr of grid-supplied electricity in FY 2015-16 and beyond instead of generating their own electricity (LNG, 2014).

The maximum demand forecasts published by AEMO in 2014 are significantly lower than forecasts published as recently as 2011. **Figure 8** compares record-high maximum demand with these two forecasts using the forecasts for FY 2020-21 as a comparison year. Using Queensland as an example, AEMO's most recent forecast for maximum demand is now only 65 percent of the forecast published three years earlier.

Over their ten-year forecast outlook period, AEMO do not forecast that maximum demand in any state will decline significantly below past record highs (National Electricity Forecast Report, 2014). If annual consumption of grid-supplied electricity declines in coming years but maximum demand cannot also be expected to decline, supply-infrastructure must nevertheless be maintained. The utilization (or productivity) of the electricity supply system will therefore continue to fall, as described in Section 6.

VI. The Consequences of Declining Annual Consumption and of This Decline Not Being Forecast

This section describes certain consequences of declining annual consumption of grid-supplied electricity in eastern Australia, and also the consequences of this remarkable change not being reflected in official forecasts until

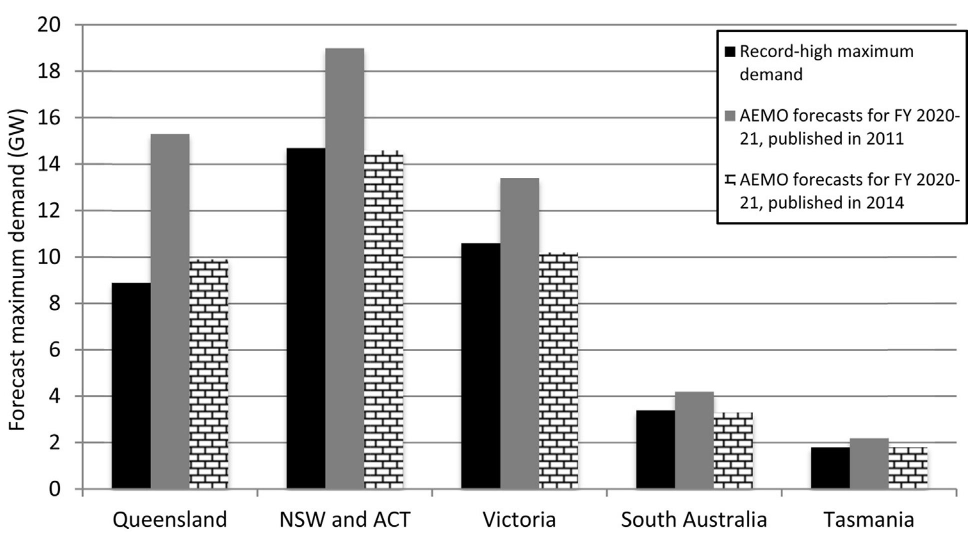

Figure 8: AEMO Forecasts for Maximum Demand for FY 2020-21 (''Medium Scenario'', 10% POE) (National Electricity Forecast Report, 2014; AEMO, 2011)

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four years after the decline began. These consequences include:

- Overinvestment in electricity generation and supply infrastructure,
- Declining wholesale electricity prices and sales value (turnover),
- Political pressure to scale back or terminate energy efficiency, renewable energy, and climate change mitigation policies and programs.

A. Overinvestment in electricity generation and supply infrastructure

As a consequence of the aggressive growth forecasts published in 2011 and earlier electricity supply infrastructure was built in eastern Australia with capacity exceeding what is likely be required for some time, if ever. In FY 2008-09, 195.0 TWh of electricity consumption in eastern Australia was supplied using generation capacity of approximately 45 GW. During the next four years, despite year-to-year declining consumption, 4.6 GW of new large-scale generation capacity came into service, raising total large-scale generation capacity to approximately 50 GW. This included 2.9 GW of new fossil-fueled generation capacity (mostly gas-fired) and also the installation of 1.7 GW of large-scale renewables-based generation (mostly wind energy) driven by the Renewable Energy Target legislation of 2009. Additional large-scale renewables-based generation capacity totaling 1.2 GW is committed to come on line between July 2014 and January 2016.

This growing ''capacity overhang,'' along with factors such as the carbon price that existed in Australia from July 2012 to July 2014, caused more than two GW of excess fossil-fueled generation capacity to be taken off line or to operate only seasonally over that period (''Generation Information''). In August 2014, AEMO highlighted that there was potentially 7.7 to 9.0 GW (15 to 18 percent) of excess generation capacity in the NEM (AEMO, 2014). Generation utilization has fallen from approximately 48 percent in FY 2008-09 to 41 percent in 2013-14 (**Figure 9**). In light of recent consumption forecasts, some planned infrastructure has now been deferred (Australian Energy Regulator, 2013).

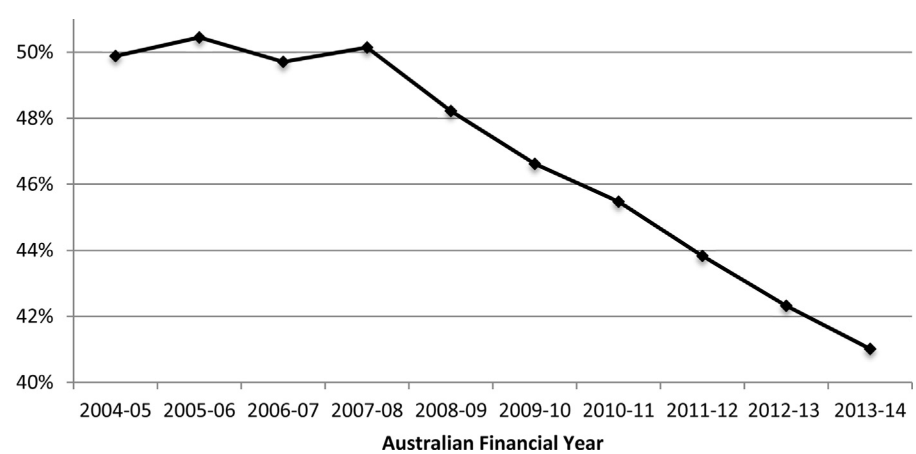

Figure 9: Electricity Generation Utilization in Eastern Australia (''Aggregated Price and Demand Data Files''; ''Generation capacity and peak demand'')

B. Declining volume-weighted wholesale electricity prices, price volatility and turnover

Over the last five years while consumption of grid-supplied electricity declined in eastern Australia, wholesale electricity prices also declined. This reflects the classic supply-demand relationship: where there is excess supply, the price tends to decline due to competition among suppliers. **Figure 10** shows nominal and real (2014 $A) volume-weighted wholesale electricity prices for the last 15 financial years. Note that these prices exclude the impact of the carbon price that applied during FY 2012-13 and FY 2013-14. Volume-weighted wholesale electricity prices peaked at $A 76/MWh (real) in FY 2006-07. At that time, severe drought conditions impacted hydroelectric generation and also cooling water supplies to some thermal generators.

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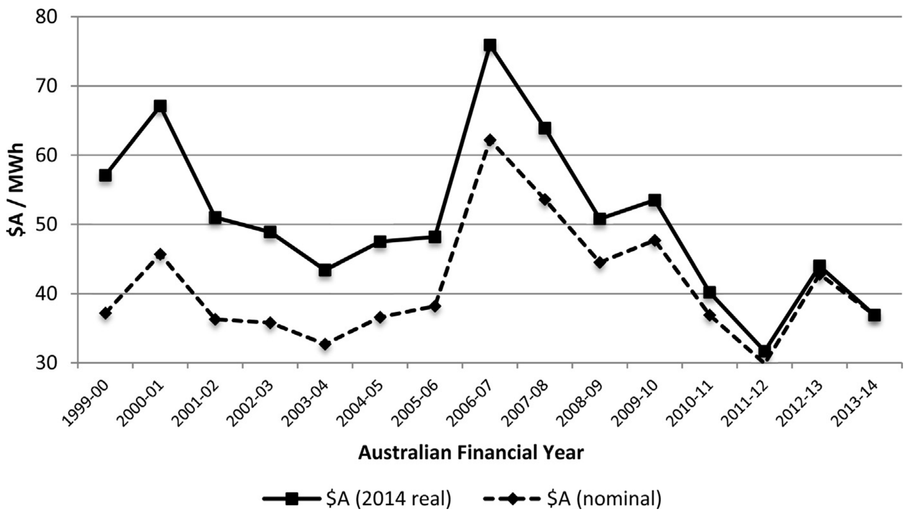

Figure 10: Volume-Weighted Wholesale Electricity Prices in Eastern Australia (Excludes Carbon Price)

In the seven years since FY 2006-07, rainfall increased, additional thermal and renewable generation capacity (including rooftop solar PV) came on line, certain market-power issues were addressed (AER, 2009), and consumption of grid-supplied electricity declined. By FY 2013-14, the volume-weighted wholesale electricity price had fallen by nearly half of the peak to $A 37/MWh. In real terms, wholesale prices over the last four years have been less than those seen over the period FY 1999-00 to FY 2009-10. The operation of the NEM allows wholesale prices to rise to levels above $10,000/MWh. These high price excursions occurred more frequently in the past than in recent years (Australian Energy Regulator, 2013).

Certain factors that may cause wholesale prices to decline further in the future include:

- Ongoing grid-supplied electricity consumption decline,
- The construction of additional low-operating-cost, renewables-based generation,
- Expansion of interstate electricity transmission connections (the expansion of the Heywood Interconnector between Victoria and South Australia is underway), and
- Developments in energy storage (Hearps et al., 2014).

However, if higher cost, inefficient, and/or carbon-intensive generation capacity is permanently removed from service, this could place upward pressure on wholesale prices, as might the following:

- Increasing gas prices – as liquefied natural gas (LNG) export facilities are commissioned in Queensland and for the first time eastern Australian gas prices become linked to world prices (Australian Government Department of Industry, 2014),
- Unplanned generation outages,
- Extreme weather conditions, and
- A return to increasing electricity consumption.

Figure 11 illustrates how wholesale electricity price volatility in eastern Australia has significantly declined in the last three financial years. Volatility, calculated as the log10 of the standard deviation of wholesale prices for the financial year, has declined because of factors such as:

- The presence of excess generation capacity,

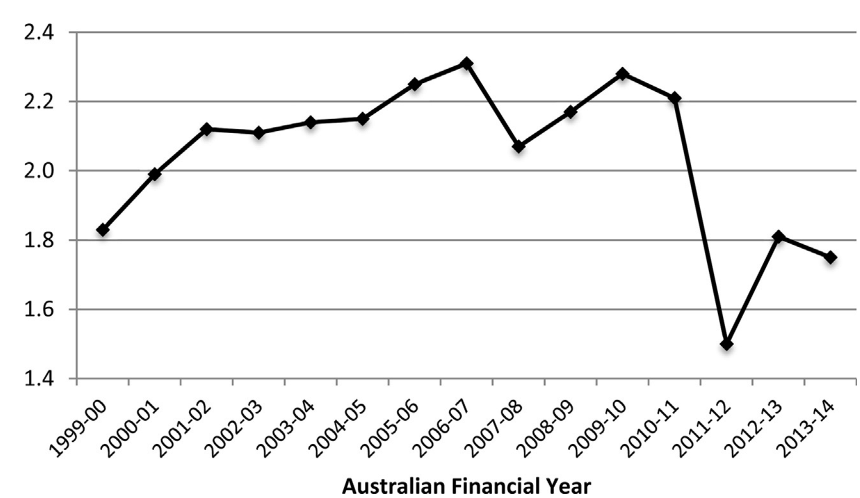

Figure 11: Wholesale Electricity Price Volatility

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• The availability of responsive hydroelectricity,

• Rooftop solar PV reducing the consumption of grid-supplied electricity during former maximum demand periods,

• Energy efficiency measures likewise dampening consumption at critical times, and

• General electricity consumption decline.

The consequences of declining volatility include reduced wholesale sales value for generators (turnover, discussed below) and reduced incentives for energy storage or demand response measures. Figure 11 shows that increased wind energy deployment (a variable renewable energy resource) has not increased price volatility.

Figure 12 shows wholesale electricity sales value (turnover) in eastern Australia since FY 2006-07 in real 2014 dollars. (Turnover has been corrected to remove the impact of the carbon price which caused turnover to increase by approximately $A 3.5 billion in FY 2012-13 and in FY 2013-14.) Turnover peaked in FY 2006-07 at approximately $A 15 billion and then fell to 45 percent of that value in the most recent financial year. Reasons for this decline are inferred in the discussion (above) about wholesale prices.

C. Reduced or terminated efficiency, renewable energy, and carbon-reduction programs

Declining annual consumption of grid-supplied electricity has been cited by some industry stakeholders as a reason to reduce or terminate various energy efficiency, renewable energy, and carbon-reduction programs. Other factors contributed to the reduced status of these programs, such as the declining cost of solar PV systems making them affordable with reduced subsidies. **Table 6** lists various programs and compares past apex and recent status.

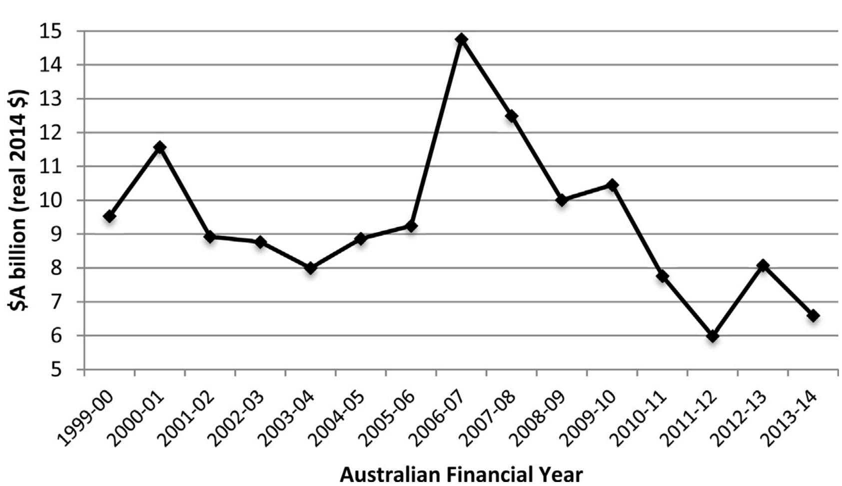

Figure 12: Wholesale Electricity Turnover, Corrected to Remove Carbon Price

VII. Declining Electricity-Generation Carbon Emissions in Eastern Australia

As shown in **Figure 13**, over the five years from FY 2008-09 to FY 2013-14, annual carbon emissions from electricity generation in eastern Australia declined by 16 percent or approximately 31 million tonnes/yr (CO_2 equivalent) (AEMO, 2013). This is a result of:

• The 7 percent decline in annual consumption of grid-supplied electricity;

• Gas-fired generation replacing coal over the period October 2009 to April 2011 (CEDEX, 2014), driven by the construction of new gas-fired generation prior to this time;

• The installation of additional wind generation, driven by the Renewable Energy Target legislation of 2009, and

• Greater use of existing hydroelectricity facilities, enabled by increased rainfall, and then motivated by the possibility that the carbon price (in place only between July 2012 and July 2014) might be short-lived. (The carbon price enhanced profits from renewable electricity generation by increasing market pool prices.)

In the future, carbon emissions from electricity generation in eastern Australia may increase as the use of coal increases because:

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Table 6: Comparing Apex and Recent Reduced Status of Programs

Program	Jurisdiction	Past Apex Status	Recent Status
Renewable energy target	Australia-wide	As at 2013, bi-partisan political party commitment to 41,000 GWh/yr of new renewable electricity production by 2020.	Under review in 2014. Target date may be extended and/or the required amount of renewables-based electricity reduced.
Carbon price	Australia-wide	$A 23.00/tonne CO_2-equivalent in July 2012 increased to $A 24.14/tonne in July 2013. Applied to electricity generation, gas supply, and other industry.	Repealed in July 2014.
Rooftop PV rebates	Australia-wide	Rebate for 1 kW or larger PV system raised from $A 4,000 to $A 8,000 in 2007. Ended in 2009 and replaced with certificate scheme.	Small-scale technology renewable energy certificates valued at approximately $2,000 may apply for a 3 kW PV system. This rebate is under review in 2014 and may be reduced or terminated.
Rooftop PV net feed-in tariff (state example)	Victoria	Net feed-in tariff of $0.60/kWh commenced in 2009 and remains in place for those eligible homes until 2024.	Net feed-in tariff reduced to a minimum of $0.08/kWh effective in 2014.
Rooftop PV gross feed-in tariff (state example)	New South Wales	Gross feed-in tariff of $0.60/kWh applied in 2009.	For new PV installations, net feed-in tariff set at $0.053/kWh for FY 2014-15.
Victorian Energy Efficiency Target (VEET)	Victoria	Commenced in 2009. Selected energy-saving products offered to residents at reduced cost.	Scheme was to be closed at the end of 2015.
Energy Efficiency Opportunities (EEO)	Australia-wide	Commenced in 2006. Required industry using more than 0.5 PJ of energy per year to identify and assess energy efficiency opportunities, with actual implementation being voluntary.	Closed 29 June 2014.

- The carbon price was repealed in July 2014, removing a price disadvantage for coal-fired generation relative to lower-emission alternatives and making energy efficiency improvements less attractive,
- Gas prices have increased and are increasing, which means that it is likely that the role of gas in electricity generation will decline (Simshauser, 2014), and
- The high hydroelectricity output of recent years is unsustainable, because it involved depleting water storage volumes in order to capture higher profits under the now-repealed carbon price.

Carbon emissions might also increase if electricity consumption increases (Section IX).

VIII. How Low Might Annual Consumption Go, over the Next 10 Years?

In 2014, AEMO published ''high,'' ''medium,'' and ''low'' scenario forecasts for grid-supplied electricity consumption (National Electricity Forecast Report, 2014) (**Figure 14**). In AEMO's ''low scenario,''

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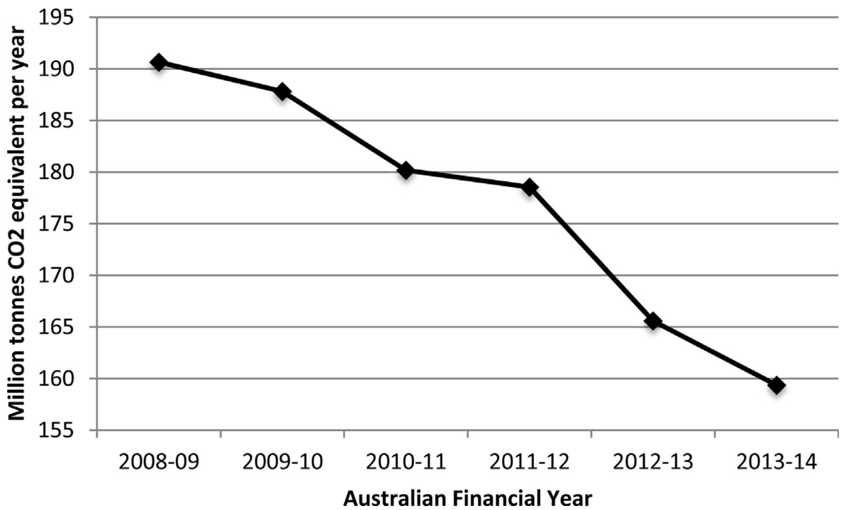

Figure 13: Electricity Sector Greenhouse Gas Emissions in Eastern Australia (AEMO, 2013)

consumption declines to ~154 TWh in FY 2023-24 as aluminum smelters close and other less-significant decline occurs in other sectors of the economy. We present an ''even-lower scenario'' where consumption declines to 139 TWh in FY 2023-24, a 29 percent decline overall (56 TWh) versus the FY 2008-09 all-time high of 195 TWh (Figure 14). This ''even-lower scenario'' involves:

- Further closures of aluminum smelters, bringing forward by 10 years AEMO's ''low scenario'' larger-industrial forecasts for 2033-34. (Note that the Point Henry, Victoria aluminum smelter which formerly consumed up to 3 TWh/yr of electricity (National Electricity Forecast Report, 2014) closed in July 2014.)
- Ongoing residential sector electricity consumption decline of 1 percent/yr (less than the 3 percent/yr rate of decline seen over the period FY 2007-08 to FY 2013-14).
- SI&C sector consumption decline of 2 percent/yr, given that there has been limited consumption decline in the SI&C sector to date. As mentioned in Section IV.C, the increasing deployment of rooftop PV in the commercial sector may have a significant impact in this sector. Impediments to reducing electricity use in the SI&C sector include:
  - businesses not ranking electricity reduction as a priority for the investment of money and management attention,
  - split incentives due to separation of ownership and occupation, and
  - attractive electricity sales contracts on offer to some businesses above a certain size.

Though not specifically reflected in our ''even-lower scenario,'' grid-supplied

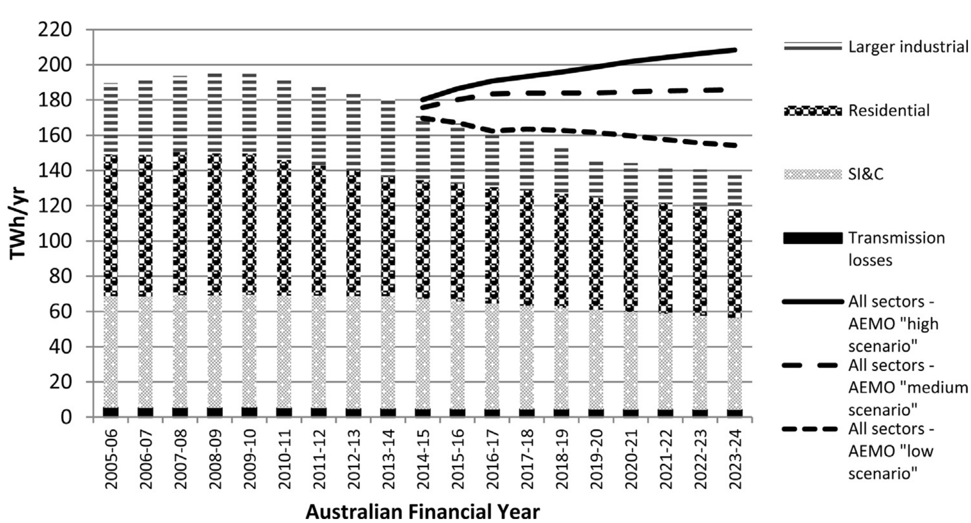

Figure 14: Historical and Future Projections of Annual Electricity Consumption (National Electricity Forecast Report, 2014)

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electricity consumption in the residential and SI&C sectors might further decline if homeowners, businesses, or some of the numerous regional Australian communities located at the fringe of the grid find it attractive to supply the bulk of their own electrical energy needs and even to disconnect from the main grid (Szatow and Moyse, 2014). Already 6 percent of Australia's electricity supply is sourced from beyond the two largest grids (Industry, 2011). In fringe-of-the-grid areas in Queensland, average customer density is as low as four customers per kilometer of electricity transmission line (Australian Government – Productivity Commission, 2013; Parkinson, 2014). Scenarios have been modeled where one-third of consumers disconnect from the grid (CSIRO, 2013). A potential future feedback response known as "the death spiral" (Simshauser, 2014) describes the situation where electricity consumers leave the main supply grid, the costs of maintaining and operating the grid are spread over fewer and fewer customers, and then these remaining customers see greater and greater economic benefit to join those who have already disconnected.

This "even-lower scenario" is intended to stimulate consideration of alternatives and is not intended as a definitive forecast. It ignores the potential for electricity consumption to *increase* because of fuel switching from oil and gas to high-efficiency electric devices (Section IX) or because of the establishment of new electricity-intensive industries.

IX. Opportunities to Switch from Oil and Gas, Using Modern Electric Devices

In contrast to Section VIII, this section describes opportunities in

buildings and transport to switch from fossil fuel devices to high-efficiency electrical devices and thereby increase the use of electricity supply and grid infrastructure. (Note that if conversion of eastern Australia's electricity supply-system from coal generation to renewables is delayed, switching from oil and gas to electricity in buildings and transport may not reduce carbon emissions.)

A. Buildings: switching from fossil gas to efficient electrical heating devices

According to AEMO, during 2012 in eastern Australia approximately 487 PJ (135 TWh) of fossil gas was used in the industrial and buildings sectors (excludes gas used for electricity generation) (Gas Statement of Opportunities, 2013). As gas prices rise, modern electric appliances such as high coefficient-of-performance air-source heat pumps and induction cooktops are replacing gas-fueled appliances in Australia (Moyse et al., 2014). The economic benefit of replacing gas-fueled appliances with electric depends upon the efficiency and purchase cost of the appliances, the current and projected prices of gas and electricity at peak and off-peak times, the potential to avoid fixed gas-connection charges if gas use is completely eliminated at a home or business, and the opportunity for self-generation of electricity. Other important factors for appliance purchasers are esthetics, comfort, familiarity, and the possibility of multiple uses (e.g. reverse-cycle heat pump air-conditioners can also be used for heating).

Installing and using modern electric appliances may require one-third or less energy input than legacy gas appliances, either because electric appliances can use renewable heat (i.e. heat pumps), may be more efficient (e.g. induction cook tops or furnaces) or because upgrading eliminates old, inefficient, or poorly maintained legacy equipment (Moyse et al., 2014). Were half of the energy services provided by fossil gas in the

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eastern Australian industrial and buildings sectors instead provided by modern electrical appliances powered from the grid, annual electricity consumption would increase by approximately 20 TWh/yr. Fuel-switching on this scale would more than fully reverse the 13.8 TWh/yr decline in electricity consumption that occurred from FY 2008-09 to FY 2013-14.

B. Transport: switching from fossil fuels to plug-in electric vehicles

In 2012, fossil fuel-powered Australian passenger vehicles traveled approximately 167 billion kilometers/yr (Survey of Motor Vehicle Use, 2013). To date, plug-in electric vehicle use has been insignificant in Australia. Were around half of that historical travel to be done with plug-in electric vehicles, the consumption of grid-supplied electricity would increase by approximately 10 TWh/yr (Sharma et al., 2012).

X. How Maximum Electricity Demand can be Reduced in Eastern Australia

As described in Section V, no new maximum demand records have been set in any eastern Australian state since February 2011. However, maximum demand forecasts depend on forecasts of future climate, weather conditions, the use of air-conditioners and other equipment at times of maximum demand, demand-side participation, and other factors. The Australian population, economy, living standards, and comfort and health expectations continue to grow. Global warming is driving extreme weather events and new record-high temperatures in Australian capital cities. In future,

plug-in electric-vehicle charging may present a new challenge for electricity-supply infrastructure (de Hoog et al., 2013). Therefore despite five years of declining annual electricity consumption, it is not yet possible for AEMO to forecast that maximum demand in any eastern state will stay below levels seen in the past (National Electricity Forecast Report, 2014). Nevertheless, below we describe several factors that may work to reduce maximum demand.

Industrial closures (such as aluminum smelting) may reduce electricity consumption at all times, including at times of potential maximum demand. (However in the past, aluminum smelters and other industry have been incentivized and able to reduce demand at critical times.) Continuous upgrading of air-conditioners, refrigerators, televisions, computers, and lighting will continue to drive down electricity use during times when maximum demand might occur. Homeowners will continue to deploy building envelope upgrades (e.g. insulation and window treatments) not only for economic and/or energy-saving reasons but also to improve comfort and health. (During the February 2009 heat wave, Melbourne temperature reached an all-time high of 47.2 °C which contributed to 374 heat-related deaths (Victorian Government Department of Health, 2012).).

Options for time-shifting and demand-side participation are becoming more widely available in eastern Australia. In Victoria, 2.8 million smart meters have been recently deployed. Some consumers can opt to time-shift load to "off-peak" times (11 p.m. to 7 a.m.) in order to reduce their electricity costs. AEMO forecasts greater use of industrial demand-side participation in years to come (National Electricity Forecast Report, 2014). Some eastern Australian electricity suppliers are trialing Demand Reduction Enablement Devices (DREDs), alternate tariffs, and other methods to reduce peak demand. Greater deployment of west-facing rooftop solar PV will further reduce maximum

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demand, shift the time of its occurrence to later in the day, and benefit homeowners by helping to supply their early-evening electricity needs. Battery storage may become a method by which homeowners and businesses increase the value of solar PV self-generation and reduce demand at critical times. Electricity tariffs in eastern Australia have, to date, only broadly addressed maximum demand management, if at all. However, governments, regulatory authorities, and businesses now see tariff reform as key to reining in expenditure on electricity-supply infrastructure (Australian Government Department of Industry, 2014).

XI. Conclusion

For decades in Australia, the consumption of grid-supplied electricity grew in line with population and economic growth. Each year, billions of dollars would be invested in new electricity generation, transmission, and distribution capacity to ensure reliable supply. However in 2009, eastern Australia entered a new world where the annual consumption of grid-supplied electricity declined even while population and economic activity continued to grow. Consumers saw retail electricity prices become nearly the highest among OECD nations. Energy savings were then readily achieved because eastern Australia was starting from a very energy-intensive and inefficient base. The electricity-supply system, designed to accommodate forecast growth, became underutilized. Wholesale electricity prices and turnover fell. With the support of industry incumbents, new state and federal governments used this time of consumer-electricity-price

concern to wind-back climate change mitigation programs. Now, as eastern Australia's gas prices become linked to world parity (for reasons unrelated to electricity), challenging years lie ahead for Australian energy consumers, suppliers, regulators, and policymakers. Future electricity consumption will be sensitive to a wide range of factors, many of which can be influenced by government policies, technology change, community attitudes, and electricity pricing.■

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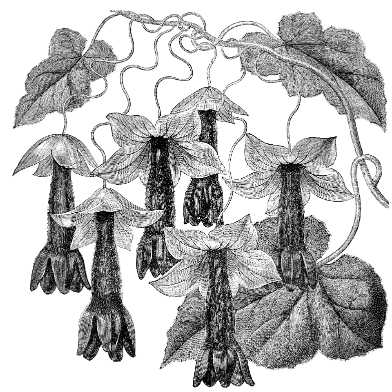

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