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NATIONAL ENERGY EMISSIONS AUDIT

National Energy Emissions Audit - Electricity Update

January 2018

Providing a comprehensive, up-to-date indication of key electricity trends in Australia

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Introduction

Welcome to the January 2018 issue of the *NEEA Electricity Update*, the companion publication to the *National Energy Emissions Audit Report*. The *Electricity Update* presents data on electricity demand, electricity supply, and electricity generation emissions in the National Electricity Market (NEM). This month's issue covers data to the end of December 2017.

Each issue of *Electricity Update* contains a more detailed discussion of one or two topical issues relating to the electricity system.

In this issue we look at the performance of hydro and wind generators in the NEM over the past ten years.

Key points

Electricity consumption per person and per dollar of GPD in the NEM has dropped and total consumption is down

Electricity consumption per capita fell by 2.1% and consumption per dollar of GDP fell by 2.6% for the period March 2016 – June 2017. Total electricity consumption has been stable for six months and is almost the same as it was over 18 months ago.

NEM electricity generation emissions fell again and average emissions intensity again sets a new low record

In the year to December, total annual emissions from electricity generation in the NEM fell for the sixth month in succession, and the average emissions intensity of NEM generation set a new record low. That said, the NEM remains one of the most emissions intense electricity supply systems in the world because of our high levels of consumption of brown coal in particular.

Household rooftop solar continues to grow, reaching a record of 6.2 TWh in the year to December 2017.

Rooftop solar has been installed by over 1.6 million households and is the most reliable source of steadily growing generation in the NEM (see Figure 3, red line). It has more than doubled since mid-2013.

Stable policy is essential for a smooth transition to lower emissions

Long term trends show the importance of consistent policy settings designed to achieve a smooth replacement of coal fired power stations by renewables. The ACT's wind auctions were the only driver of new wind farm construction for two and half years (see Figure 11).

Pumped hydro and Snowy 2.0

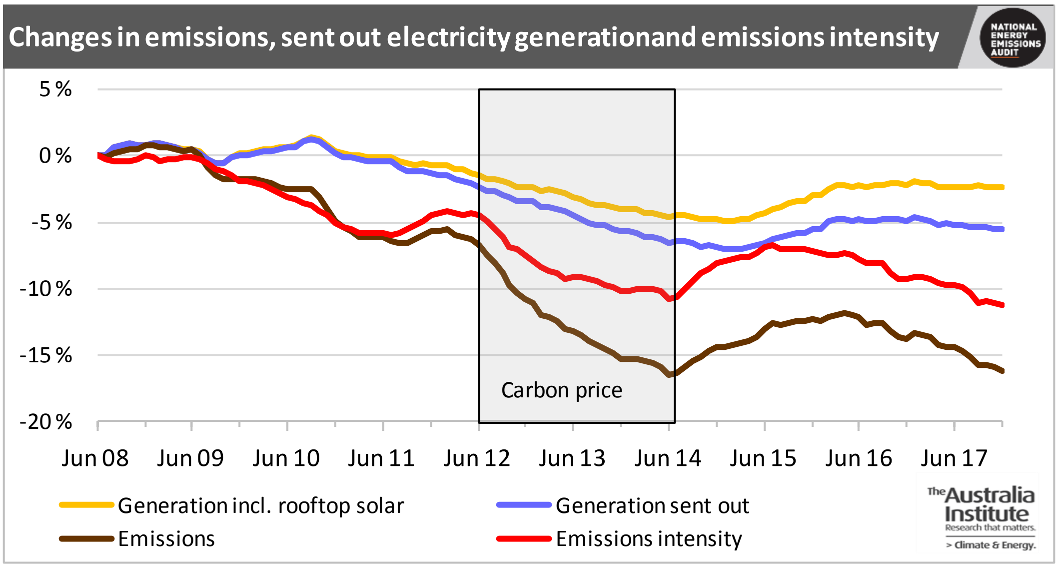
Discussion of the Prime Minister's Snowy 2.0 proposal has ignored the NEM's three existing pumped hydro schemes. The Tumut 3 played a crucial role during the NSW supply crisis in February 2017 and is a little-reported element of preparation for possible extreme peaks later this summer.

Queensland's Wivenhoe scheme, however, has been criticised for holding back supply, keeping prices high for the benefit of CS Energy's coal-fired generation. Pumped hydro can provide valuable services, but the size of the scheme, desired role in the NEM and incentives faced by operators need to be considered. The Snowy 2.0 proposal largely ignores these issues and is increasing uncertainty for other investors in storage and generation.

Generation, demand and emissions trends

The National Electricity Market (NEM) continues to make a gradual transition to distributed and lower emissions technologies. Steady growth in rooftop solar PV, contributed to net generation or 'generation sent out', being 5% lower than in June 2018 (see Figure 1 below).

Figure 1



Total demand for electricity In the NEM and WA in the year to December 2017 was again almost unchanged, for the sixth successive month. The overall consequence for the NEM is that annual consumption – termed operational demand by AEMO – has been almost constant for over a year and a half. During the period from March 2016 to June 2017, ABS data report population of the NEM states increasing by 2.1% and real GDP increasing by 2.6%. Hence, since total electricity consumption was constant, consumption per capita fell by 2.1% and consumption per dollar of GDP fell by 2.6%.

During December, total electricity supplied by generators to the NEM (in blue) and the total annual emissions from those generators (in brown) both fell, as shown in Figure 1. This continues the trend of the past two years.

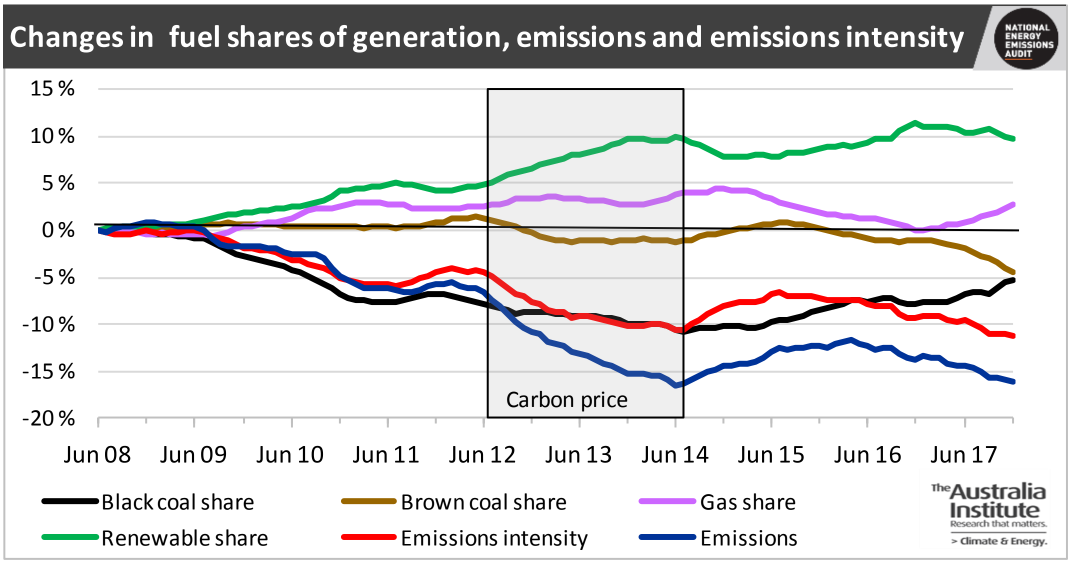
Electricity generation is the only significant source of Australia's greenhouse gas emissions to have fallen over the past two years (see *NEEA Reports* for September and December 2017). In order for Australia to meet our international climate responsibilities the bulk of emissions reductions need to come from the electricity sector. That is why NEEA and other Climate &

Energy Program reports provide such detail about changes to electricity emissions and the causes of those changes.[1]

In the December 2017 issue of *NEEA Electricity Update* we explained that emissions from electricity generation are the product of demand for electricity and the emissions intensity of electricity supplied. It was calculated that, up to the end of November 2017, reduction in demand for electricity from the grid contributed about one third of the total reduction in annual emissions from NEM generation since June 2008. The other two thirds were contributed by the lower average emissions intensity of electricity generation. It was pointed out that, in the year to November, the average emissions intensity of NEM electricity reached its lowest ever level, calculated by the NEEA to be 0.833 t CO_2-e/MWh sent out. (Different estimates of grid emissions intensity may vary slightly because the emissions intensity of individual generators often changes slightly from year to year, affected by such factors as coal quality and the operating cycle for the power station. However, all estimates will record similar trends over time, i.e. they will agree that emissions intensity is steadily falling.)

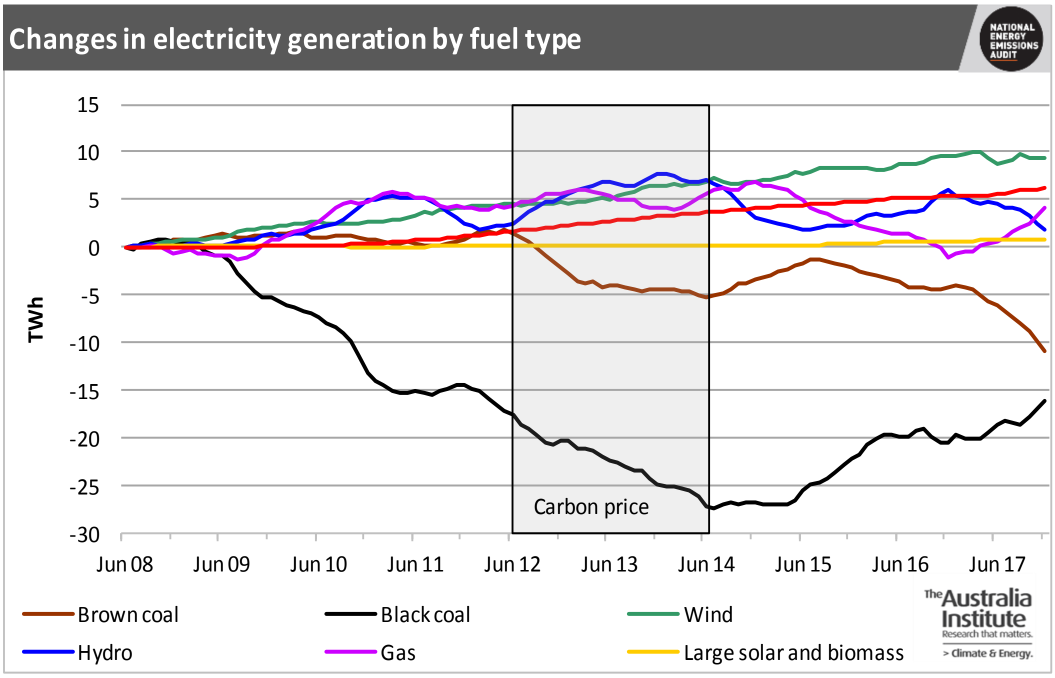
In the year to December 2017, average emissions intensity fell again, by 0.2%, to 0.831 t CO_2-e/MWh sent out. The changes in the mix of generation supplying the NEM, which have driven this fall in average emissions intensity, are shown in Figures 2 and 3.

Figure 2



[1] See also Campbell (2017) M*eeting Our Paris Commitment*, http://www.tai.org.au/sites/defualt/files/P439%20Meeting%20our%20Paris%20Commitment%20-%20TAI%20Climate%20and%20Energy%20Program%20-%20September%202017.pdf

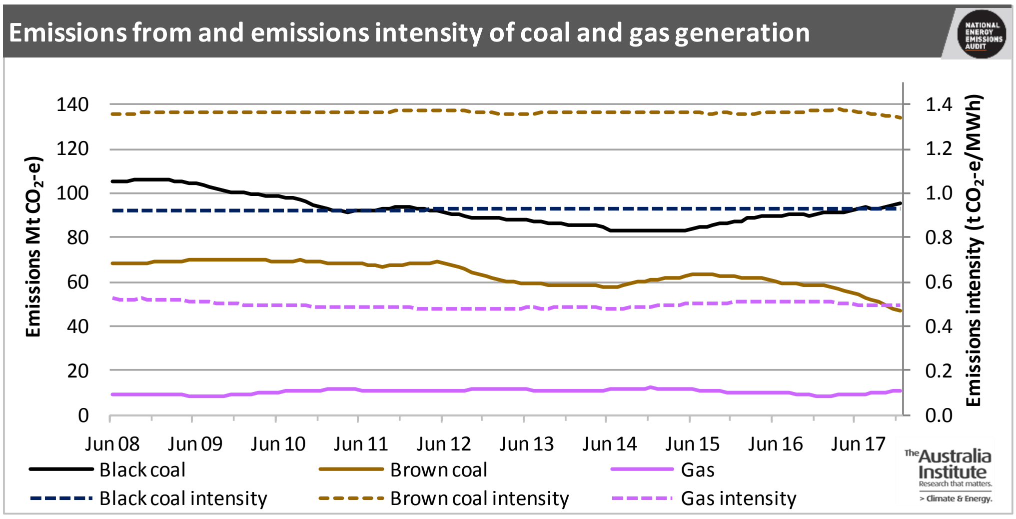
Figure 3



Figures 2 and 3 show that, for a few months after June 2016, both brown and black coal generation levelled off. However, gas generation continued to fall, while there was a sharp increase in renewable generation, meaning that the reduction in overall emissions intensity continued. Figure 3 shows that increased hydro output was the main contributor to higher renewable generation during this period, with a smaller increase in wind generation. Hydro output grew in all three states with major hydro capacity (Tasmania, Victoria and NSW). The reasons for this sudden output increase are discussed below, in the detailed special discussion of hydro and wind.

Figure 4 shows the fall in emissions intensity from March 2017 accelerated by the closure of Hazelwood power station, which was both the most emissions intensive power station in the country and one of the largest.

Figure 4



The removal of Hazelwood was offset by increased black coal generation, mostly in NSW, and increased gas generation, mostly in Victoria and South Australia. Both these generation sources have much lower emissions intensity than Hazelwood, as Figure 4 shows, and consequently overall emissions intensity fell steadily. Renewable generation fell, as the earlier increase in hydro generation was reversed and wind generation stayed roughly constant.

The other significant feature of this period, affecting the trend of overall emissions intensity, is the lack of growth in wind generation, which is also discussed in detail below.

State breakdown of demand

Figures 5 and 6 show, respectively, absolute and relative changes in demand for electricity supplied from the grid in each of the five state regions of the NEM and in the South West Interconnected system in Western Australia.

Figure 5

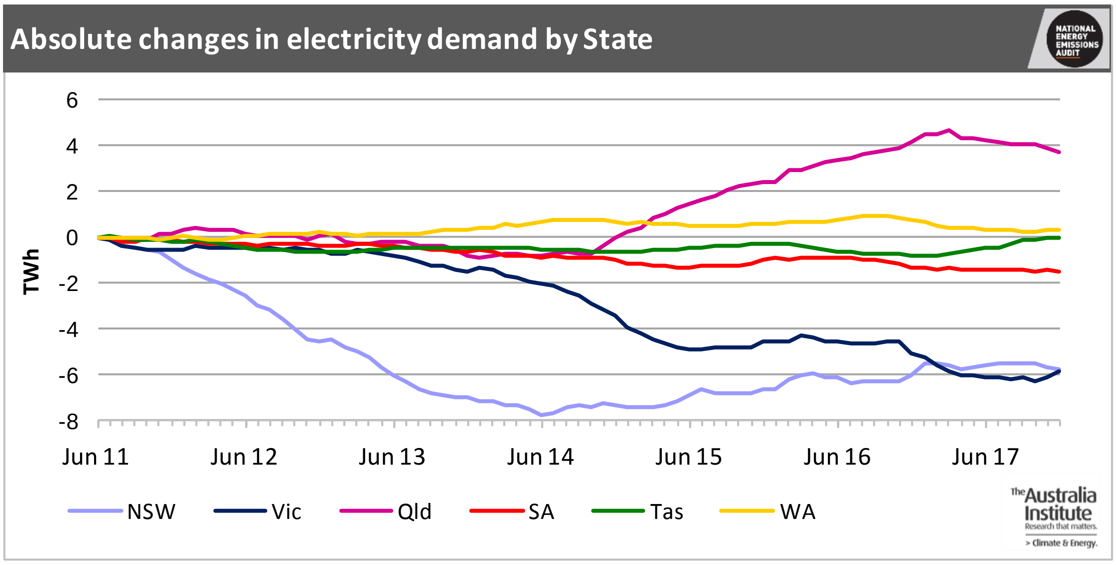
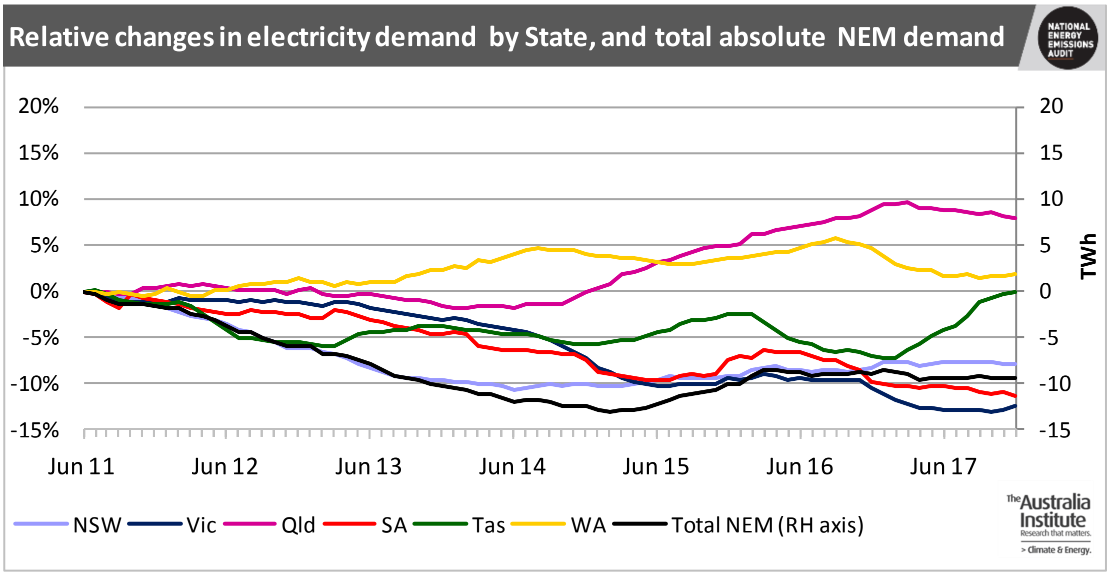


Figure 6



In December there was again no significant change from the trends established since the beginning of 2017. In the NEM annual demand is either constant or gradually falling in New South Wales, Queensland and South Australia. There has been a small uptick in Victoria, which has probably been caused by weather differences; in Melbourne October and November 2017 were both significantly warmer on average than the same months in 2016 (data for December was not yet available from the Bureau of Meteorology at the time of writing).

Demand in Tasmania has been growing strongly over the past year. In December the Australian Energy Regulator published the annual performance data submission from the Tasmanian network business, from which it can be deduced that the demand growth is coming from major industrial consumers. At least up to June, their consumption was recovering from the cutbacks imposed during the state's electricity supply crisis during the first half of 2016. Since then consumption has grown further, but now seems to be levelling off.

A closer look at hydro and wind generation

Figure 7 shows generation by each of the renewable technologies, expressed as shares of total NEM electricity supply (including rooftop solar), rather than as changes in absolute generation quantities, as in Figure 3.

Figure 7

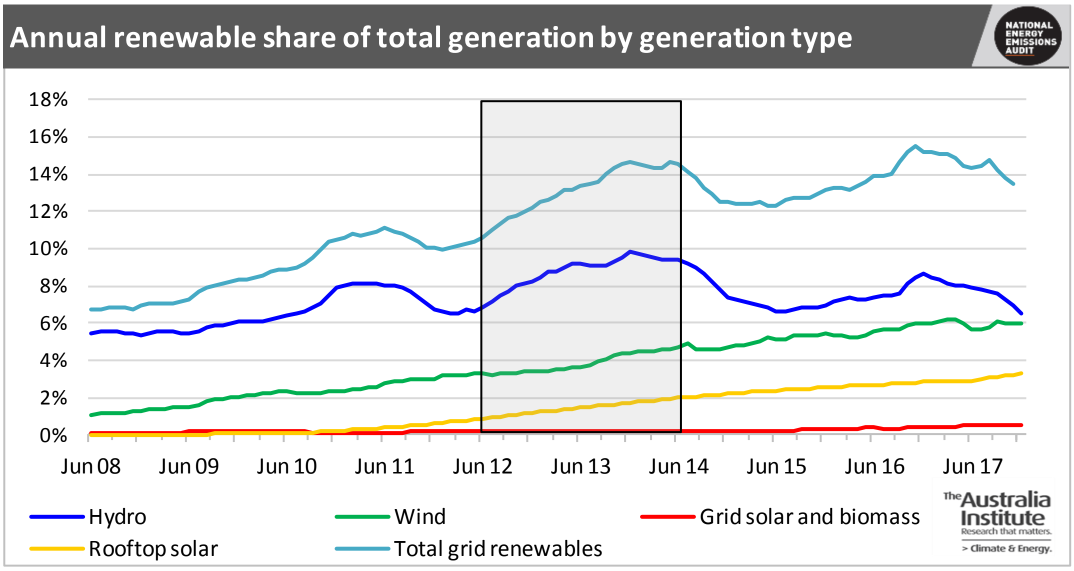
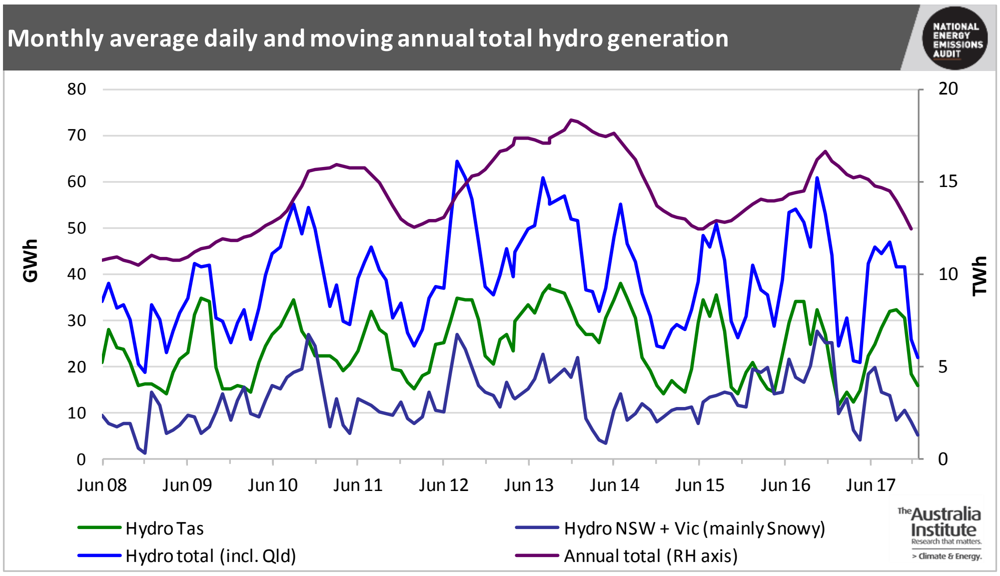


Figure 7 also show steady growth in rooftop solar, which has more than doubled since mid-2013 to 6.2 TWh per year.

Hydro

Figure 8 shows moving annual hydro generation in the NEM, as in Figure 7. It also shows average daily generation, by month, for the NEM as a whole and, separately, for Tasmania, and for New South Wales and Victoria combined.

Figure 8



NSW+Vic is mainly the Snowy scheme, but also includes the much smaller Kiewa scheme, in Victoria, and generators at a number of irrigation storage dams. In New South Wales these include Blowering and Hume, and in Victoria Eildon, Dartmouth and Hume. Some generation at Hume is allocated to the New South Wales NEM region and some to the Victoria region. A similar arrangement, on a larger scale, applies to the Snowy scheme. Output from the two large Murray power stations is part of the Victoria region, while output from the three Tumut power stations, plus Guthega, is part of the New South Wales region. The two transmission lines between the Murray and the Tumut power stations form the largest interconnector between New South Wales and Victoria.

The NEM total also includes output from the relatively small Barron and Kareeya hydro stations in Far North Queensland.

Normal generation in the Snowy scheme is somewhat constrained by its obligation to supply irrigation water to the Murray and Murrumbidgee Rivers, affecting when it can release water, and how much. This constraint would partly explain the rather erratic pattern of monthly output apparent in Figure 8. However, like all hydro schemes, Snowy output is also affected by precipitation and run-off. Bureau of Meteorology data indicate that winter 2017 was dryer than average and Snowy Hydro data show that Lake Eucumbene, the main water storage in the scheme, is at its lowest level since June 2014. The need to replenish storage would explain the reduced Snowy output over recent months, and the consequent fall in national hydro generation.

Turning to Tasmania, the most obvious point to note is that the Tasmanian system consistently generates significantly more electricity than all other Australian hydro generators combined, a fact which is sometimes not well appreciated. The second point is that Tasmanian hydro generation shows a much more consistent annual pattern than Snowy. This reflects a combination of several factors:

- the generally more consistent and strongly seasonal precipitation in the Tasmanian highlands,
- the fact that many of the Tasmanian generators are run of the river, meaning that they have little or no storage and have to run when the water is available, and
- the marked seasonal pattern of electricity consumption in Tasmania.

Finally, the plots of both Tasmanian and Snowy/mainland generation show the increased output during the carbon price period, from 1 July 2012 to 14 July 2014, and the subsequent "hangover" period of reduced generation. The graph shows that Snowy made a dramatic cut in output from January 2014, whereas Tasmanian Hydro kept going strongly right up to 14 July.

Pumped hydro

Recent discussion of pumped hydro in Australia has focused on the Snowy 2.0 project promoted by the Prime Minister. Meanwhile, very little attention has been given to the performance of existing pumped hydro schemes. There are three pumped storage hydro schemes currently in the NEM:

- Wivenhoe, in Queensland, is purely pumped storage, with generation capacity of 500 MW. It is owned by the Queensland Government's CS Energy.

- The Shoalhaven scheme, in New South Wales, combines pumped hydro with a water supply function. It has total generation capacity of 240 MW and is owned by Origin Energy.
- Tumut 3, at Talbingo, forms part of the Snowy scheme, jointly owned by the Commonwealth, Victorian and NSW Governments. It has six machines of 250 MW each (300 MW maximum for short periods), three of which are also pumps.

The Wivenhoe scheme has been criticised for not generating electricity during peak periods, particularly during the 2016-17 summer, despite a recent $13.5 million upgrade.[2] As the Wivenhoe scheme's owner, CS Energy also owns coal-fired generation assets, it has been alleged that Wivenhoe generation was curtailed to keep peak prices high. This allowed CS Energy to earn greater profits on these peak prices using its cheaper to run coal-fired generators.[3]

The Shoalhaven scheme includes two pumping and power stations, Bendeela and Kangaroo Valley. In addition to pumped hydro, it has some inflow of water to its upper level storages, meaning that it has some stand-alone hydro generation capacity. The scheme is also used to pump water from the Shoalhaven River catchment into the Sydney water supply catchments, to supplement water available to Sydney during drought. However, the high cost of electricity for pumping means it is only used by Sydney Water in extreme circumstances. Data from Sydney Water suggest that it has not been used to supply water since 2009.

By contrast with Wivenhoe, the Shoalhaven scheme is owned by Origin Energy, one of the "big three" so-called gentailers; it owns coal, combined cycle gas and open cycle gas power stations in four states and in 2015-16 a share of retail electricity sales of nearly 30%[4]. Operating data show that Origin consistently operates Shoalhaven as an internal physical hedge, pumping at times of low overnight prices, and generating during late afternoons and evenings on days when prices reach high levels. In other words, it is being used exactly as it was designed to be used, in a system (New South Wales) which currently has a combined share of wind and solar generation totalling less that 4% of total state consumption.

Perhaps most interestingly of all, however, this (relatively) high level of utilisation did not start until a year or two after completion of Origin's purchase of the scheme from the New South Wales government, and not long before the start of the NEM-wide increase in wholesale prices. How should this be interpreted? Does this mean that generation-only businesses

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[2] Bailey (2016) *Australia's largest hydro machines set for overhaul*, http://statements.qld.gov.au/Statement/2016/8/3/australias-largest-hydro-machines-set-for-overhaul

[3] Leitch (2017) *Wivenhoe pumped hydro: the big little plant that didn't*, http://reneweconomy.com.au/wivenhoe-pumped-hydro-big-little-plant-didnt-30606/

[4] Australian Energy Regulator (2017). *State of the Energy Market May 2017*. https://www.aer.gov.au/publications/state-of-the-energy-market-reports/state-of-the-energy-market-may-2017

cannot make money from the price arbitrage opportunities provided by pumped storage? Or were the arbitrage opportunities too few and too small until the big overall rise in wholesale prices? Serious consideration should be given to these questions before public investment in still larger scale pumped hydro.

Tumut 3 is the oldest pumped hydro scheme in Australia, as well as the largest. It has the advantage of a large upper storage reservoir, which means that it can store a lot of energy for use at crucial times. For example, during December it pumped at an average rate of 75 MW for the entire month, making Tumut 3 a little reported element of preparation for possible extreme peaks later this summer. Tumut 3 played an absolutely crucial role during the New South Wales supply crisis on 10 February last year; without extensive pumping during the preceding weeks, load shedding would have been far more likely.

The existing pumped hydro schemes show that it can provide a valuable service, but its role in the NEM needs to be carefully planned. This consideration has been almost entirely absent in discussion of the Snowy 2.0 scheme. Neither Wivenhoe nor the Shoalhaven scheme are mentioned in the Snowy 2.0 feasibility study.

The partial release of the Snowy 2.0 feasibility study in December estimates that the construction cost of the project will be between \$3.8 and \$4.5 billion, about twice the estimate used by the Prime Minister when he first announced the project in February 2017. It is also telling that while overall cost estimates were published, the chapters on 'Commercial', 'Business analysis and Modelling' and 'Cost Estimate' were omitted, preventing serious scrutiny of the economics of the proposal.

The overall cost estimates do not include the undoubtedly large additional cost of building new transmission lines needed for the proposed scheme to be fully accessible from the grid; these are identified in the feasibility study as a 500 kV line of about 200 km, from the Snowy to near Marulan in New South Wales, and a 330 kV line of about 400 km, from the Snowy to Melbourne. The feasibility study states that, from when a final decision to proceed is made, it will take seven years to complete.

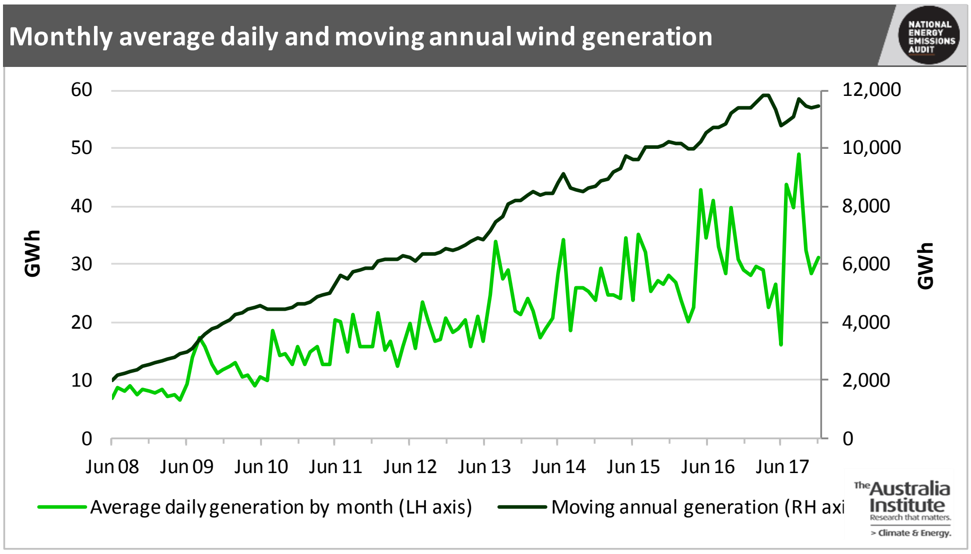
The existence of this enormous proposal can only have a chilling effect on the prospects for investment on other, smaller and faster to build pumped hydro and other storage projects across the NEM. As the government repeatedly states, further transition of the NEM towards higher shares of renewable generation will need complementary investments in energy storage. By discouraging such investment, and taking so long to build if it does proceed, Snowy 2.0 could therefore threaten and/or delay much new investment in renewable generation as well as energy storage.

Finally, relying on one big storage project rather than many, smaller, spatially dispersed pumped hydro and other types of storage projects, prevents a more gradual build-up of storage capacity, matching the need for system reliability. It also makes the supply vulnerable to catastrophic disruption. What would happen if, just when Snowy Hydro 2.0 was generating at its full 2,000 MW full capacity, a tornado took out the new 500 kV transmission line, as happened to three of the 275 kV lines in South Australia in 2016? Around the world, electricity supply systems are transitioning to a more modular and distributed structure, away from the 20th century model of radial supply of energy outwards from large, centralised generators. No less than the atavistic attachment to coal fired generation, Snowy 2.0 is a throwback to old and outdated modes of electricity supply.

Wind

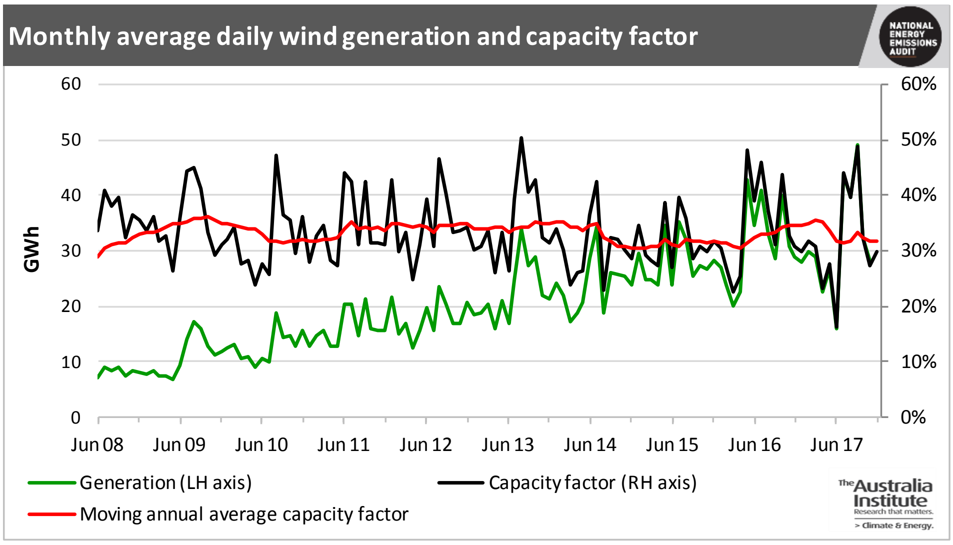
Figure 9 shows monthly and moving annual wind generation in the NEM. It can be seen that the current stagnation in growth of wind generation has mainly been caused by abnormally low generation during most of the period from January to June 2017.

Figure 9



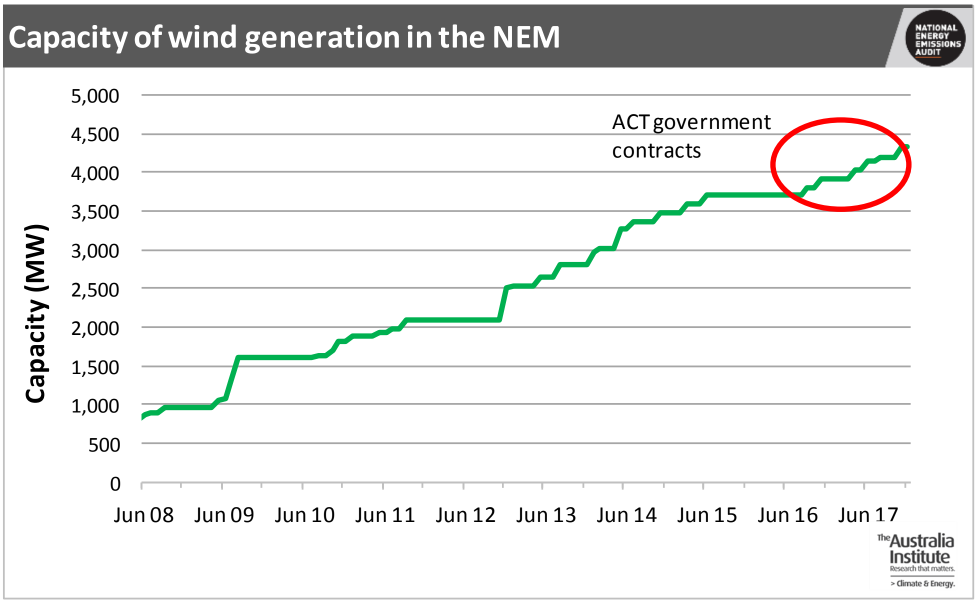
This can also be seen in Figure 10, which shows not only average daily generation by month but also the average overall capacity factor, both by month and as a moving annual average. When there is below average wind in a month, the capacity factor will fall below the long term average. It can be seen that June 2017 was, by a wide margin, the worst ever month for wind generation in Australia, and April was not a great deal better.

Figure 10



Capacity factor is the ratio of average power generation over a period, i.e. total MWh divided by hours, to the nameplate capacity of generation installed. Installed capacity increases as new wind farms are commissioned. The total installed wind generation capacity in each month was calculated from data in the NEEA model, based on the date at which each new wind farm started feeding into the grid, with some smoothing, to account for staged commissioning, which is a common practice in wind farm construction. The resultant trend is shown in Figure 11.

Figure 11



Capacity factor is a crucial determinant of the economics of wind generation. Unlike thermal generators, for which fuel can account for large part of the total supply cost, almost all the costs of wind generation are unrelated to output, meaning that the higher the output, the lower the costs.

Capacity factor in any given month depends primarily on how windy the weather was during the month. It can be seen that month to month variation in generation, and hence capacity factor, is very large. Over the longer term, however, the average annual capacity factor has not varied greatly. The long term capacity factor is mainly determined by two elements: the quality of the wind resource at the site, and the technical performance of the wind generators in converting energy in the wind to electricity. Technical performance is affected by the characteristic of individual wind turbines and also by the layout of all turbines at a site.

It can be seen in Figure 10 that average national capacity factor has been relatively constant over the past ten years, with an average of 33.0% for the whole period since July 2007. The corresponding average for wind farms in South Australia is 33.7% and for those in New South Wales since mid 2009, when the first wind farm in the state was commissioned, the average capacity factor is 34.6%. The average for wind farms in Victoria is lower, at 30.3%. The best performing wind farm in Australia is Woolnorth, in Tasmania, which has a long term average capacity factor of just under 40%. Musselroe, also in Tasmania, and several others in each of the other three states have long term average capacity factors of between 36% and 39%. The worst performing wind farms, of which there are also several in each mainland state, have long term average capacity factors in the range 26% to 28%.

The lower factors in Victoria and South Australia are partly explained by the existence of constraints on the capacity of parts of the transmission network to which some of the wind farms are connected. These constraints mean that at times these wind farms have to curtail their output. Transmission constraints are one reason why wind farm developers are turning more to northern New South Wales and Queensland as locations for new projects. Locating new wind farms in these areas will also increase geographical, and hence weather, diversity across the total wind farm fleet, meaning that hour to hour and day to day variation in total wind generation in the NEM will be reduced.

In the early years of the RET (now the LRET), some analysts speculated that average capacity factor would decrease over time, as the locations with the best wind resources were exploited first. The data show that this has not occurred. The explanation almost certainly lies with two main causes. Firstly, the assessment of wind resources has improved and extended in area assessed. Secondly, wind generation technology has steadily improved, notably through the use of larger and higher turbines.

Finally, apart from low wind, the other reason for the lack of growth in annual wind generation over the past year has been the slow growth of new capacity. This is the delayed impact of the complete cessation of new investment under the Large Renewable Energy Target (LRET) between 2014 and 2016, caused by the overt hostility of the Abbott Government to renewable electricity generation, particularly wind, and the LRET. The effect of this investment freeze is clearly seen in Figure 11. For over a year, from mid 2016 to mid 2017, the average annual increase in capacity installed fell below 10%, or 200 MW on an absolute basis, for the first time since the early 2000s. For two and a half years, between the commissioning of the Taralga and Bald Hills wind farms, in early 2015, and the commissioning of the first units of the White Rock wind farm (in the electorate of New England), during the closing months of 2017, the only new wind farms built were those commissioned by the ACT government, outside the LRET scheme. This highlights the fact that state and territory policy is very important, particularly when federal policy is creating uncertainty.

The chequered history over recent years of both hydro and wind generation in the NEM, as described here, shows the long lasting damage created by policy gyrations and uncertainty. A great deal of policy uncertainty remains, notwithstanding the resolution of the LRET. Indeed, as 2020, the year in which expansion of the LRET will be completed, approaches, uncertainty about subsequent policy will increase month by month.

Appendix: Notes on methodology

Data on annual consumption of electricity, and seasonal peak demand, are for each of the six states. All other data are for the states constituting the National Electricity Market (NEM) only, i.e. they exclude Western Australia. All data are reported as annual moving averages. This approach removes the impact of seasonal changes on the reported data. Annualised data reported in *NEEA Electricity Update* will show a month on month increase if the most recent monthly quantity is greater than the quantity in the corresponding month one year previously. Most data are presented in the form of time series graphs, starting in June 2011, i.e. with the year ending June 2011. Some graphs start in June 2008. These starting dates have been chosen to highlight important trends, while enhancing presentational clarity.

Defining the particular meaning of the various terms used to describe the operation of the electricity supply system will help in understanding the data discussed.

Demand, as defined for the purpose of system operation, includes all the electricity required to be supplied through the grid level dispatch process, operated by AEMO. This includes all the electricity delivered through the transmission grid to distribution network businesses, for subsequent delivery to consumers. It also includes energy losses in the transmission system and auxiliary loads, which are the quantities of electricity consumed by the power stations themselves, mostly in electric motors which power such equipment as pumps, fans, compressors and fuel conveyors. Auxiliary loads are very large: in 2011 they amounted to 6.3% of total electricity generated and currently about 5.6%. Most of this load is at coal fired power stations, where it can be as high as 10% of electricity generated at an old brown coal power station and 7% at a black coal fired power station. Auxiliary loads are much lower at gas fired power stations, and close to zero at hydro, wind and solar power stations. Both demand and generation, as shown in the *Electricity Update* graphs, are adjusted by subtracting estimates of auxiliary loads. Thus demand, as shown, is equal to electricity supplied to distribution networks (and a handful of very large users that are connected directly to the transmission grid) plus transmission losses.

Generation is similarly defined to include only electricity supplied by large generators connected to the transmission grid. It does not include electricity generated by rooftop PV installed by electricity consumers, irrespective of whether that electricity is used on-site ("behind the meter") by the consumer, or exported into the local distribution network. From the perspective of the supply system as a whole, the effect of this generation, usually termed either "embedded" or "distributed" generation, is to reduce the demand for grid supplied electricity below the level it would reach without such distributed generation. That effect can be clearly seen in the regular total generation graph; the gap between the red line – electricity sent out to the grid from large grid connected power stations – and the yellow line – that electricity plus estimated electricity generated by distributed solar systems – is the electricity supplied by those systems, which for the year ending September 2017 was about 5.9 TWh p.a., equivalent to 3.1% of the combined total.

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"Rising Electricity Prices Reveal True Cost of National Policy Inaction." Australian Energy Council, March 9, 2017. https://www.energycouncil.com.au/news/rising-electricity-prices-reveal-true-cost-of-national-policy-inaction/.