National Energy Emissions Audit Report

Double issue August/September 2020

Providing a comprehensive, up-to-date indication of trends in Australia's energy combustion emissions

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Key points

- **The impact of renewables displacing fossil fuels in the NEM had a greater impact on national energy emissions than the pandemic.** Over the 12 months to the end of July 2020, emissions (excluding emissions from LNG production in Queensland), fell by nearly 14 Mt CO_2-e, equivalent to 4.6%. Of which 1.6% was caused by the sharp fall in consumption of aviation fuel and petrol from March onward. A larger share, 2.5%, was caused by the displacement of coal generation in the NEM by wind and solar.
- The effect of the pandemic to the end of June has been to reduce annual transport emissions by just over 5%, with the most severe drop in April 2020, however consumption and emissions are now increasing back towards their pre-pandemic levels.
- **A record high share of renewables means a record low share for fossil fuel generation, which was 73.5%.** Black coal generation also reached a record low level of 49.5%, making September the fourth successive month in which, for the first time ever in the history of electricity supply in Australia, black coal generation supplied less than 50% of all electricity supplied to consumers.
- Renewable generation in September reached its highest ever share of total sent out NEM generation at 31.5%. In South Australia total renewable generations as a share of electricity consumed in the state was 75%.
- Total annual gas generation in the NEM was just 7.7%, slightly above the record low level, reached about a year and a half ago.
- The NEM is not built for high penetration renewables and the impact of imposed limits on maximum output of wind and solar, especially in north west Victoria and south west NSW, is about 1% of total NEM generation per year.
- The growth in rooftop solar is now causing daily minima to move from just after midnight to just after midday in regions with a high penetration of rooftop solar.
- On Tuesday 22 September in South Australia, grid demand fell to a minimum level of 380 MW and wind and solar were supplying over 90% of all generation.
- **Project Energy Connect, the proposed interconnector between SA and NSW, is crucially important** and without it further growth of renewable generation could be severely constrained. It is still waiting for final approval from the Australian Energy Regulator.
- **Under the 2020 Integrated System Plan (ISP), none of the five scenarios includes any new coal, gas, or hydro** (as distinct from pumped storage) power stations.
- Under all five scenarios, total annual gas generations falls rapidly, from over 8% of total NEM generation in 2020, to under 2% by 2025, or earlier, and remains not far above that level for the remainder of the projection period.

- **Gas makes electricity more expensive.** Because of the relatively high cost of gas, both now and under all foreseeable futures, any policy which forces up the volume of gas generation can only force electricity prices up also.
- The absence of a national climate and energy policy framework has resulted in businesses and governments pursuing their own interests, and all too often, working at cross-purposes.

INTRODUCTION

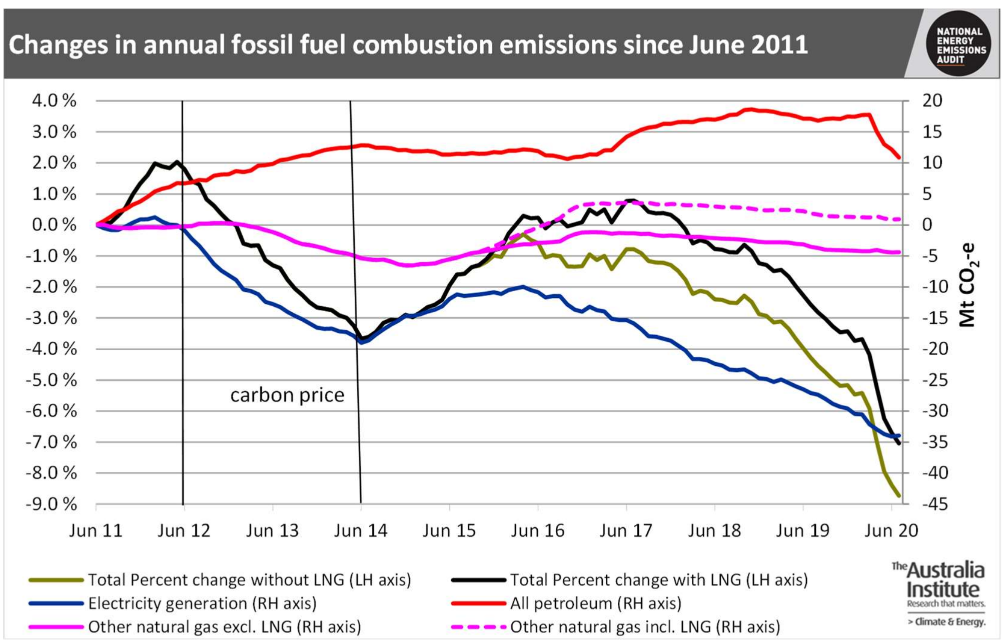
Welcome to this double *NEEA Report* issue, covering changes in energy emissions during the months of August and September 2020. Monthly data on electricity is up to the end of September, data on gas is updated to the end of August, and data related to petroleum fuels to the end of June. Data presented includes greenhouse gas emissions arising from: the generation of electricity in the National Electricity Market (NEM), the consumption of natural gas in eastern Australia (the area covered by the NEM), and the consumption of petroleum fuels throughout Australia.

After presenting an overview of energy consumption and fossil fuel emissions as at the end of the 2019-20 financial year, this issue looks at two separate, though closely related topics. The first is AEMO's 2020 Integrated System Plan (ISP), full results from which were published at the end of July. After a very summary overview, the discussion then focuses in more detail at what the ISP says about the future of gas generation in the NEM. The second topic is how the growth in generation from small ("rooftop") solar installations is transforming the balance of supply and demand in the NEM, and the challenges this presents for maintaining secure system operation.

HOW HAS THE ECONOMIC SLOWDOWN AFFECTED ENERGY CONSUMPTION AND EMISSIONS?

Figure 1 shows how moving annual totals of energy emissions reported by the NEEA – from NEM electricity generation, natural gas consumed in eastern Australia, and petroleum products consumed throughout Australia –have changed over the past nine years. Over the 12 months to the end of July 2020, emissions, excluding emissions arising from LNG production in Queensland, fell by nearly 14 Mt CO_2-e, equivalent to 4.6%. Of this total, 1.6% was caused by the sharp fall in consumption of aviation fuel and petrol from March onward. A larger share, 2.5%, was caused by the displacement of coal generation in the NEM by wind and solar, with no obvious change in total consumption of electricity. There was also a modest reduction in consumption of natural gas by consumers other than electricity generators; it is not possible to say whether or not this has been caused by the pandemic.

Figure 1



Figures 2 and 3 are updates of graphs first published in the June 2020 Report. They show, respectively, consumption, in energy units, and emissions, both expressed as monthly average daily values, for the period since January 2018. Gas consumption excludes all gas used to generate electricity but includes gas used by the oil and gas industry, mainly to produce LNG for export. Recall that data for petroleum products cover the whole of Australia, but data for electricity and gas excludes Western Australia and the Northern Territory. This means that about 30 per cent of national "other gas" consumption is excluded, and about 17 per cent of national electricity consumption.

The data clearly show the effect of the pandemic on consumption of petroleum fuels. They also confirm, as discussed in previous Reports, that there has been no major effect on consumption of either electricity or gas. Note that data available for use in NEEA Reports do not allow consumption by consumer category or industry. However, press reports in recent weeks appear to have confirmed the suggestion in previous NEEA Reports that lockdowns and working from home are likely to have caused a decrease in electricity and gas consumption in the service sectors of the economy and an increase in residential consumption.

Figure 2

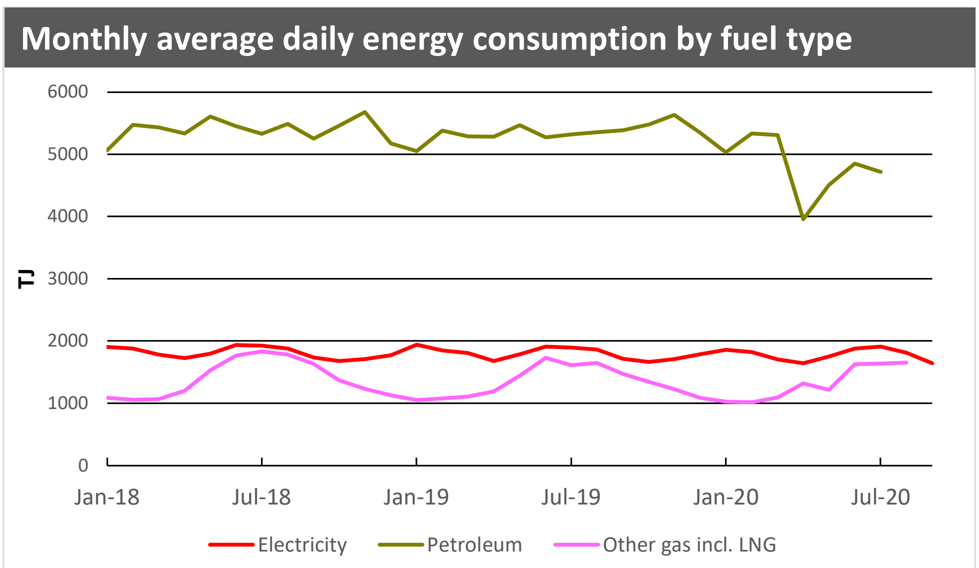


Figure 4 updates, to the end of July, monthly emissions data for the petroleum fuels most affected by the pandemic, which are fuels used for domestic aviation and for road transport by passenger and light commercial vehicles. International aviation has also been severely affected, but emissions from this source are not accounted as part of Australia's national greenhouse gas inventory under UN Framework Convention rules. The graph shows that the impact on road transport fuel consumption was most severe in April, and that consumption and emissions are now increasing back towards their pre-pandemic levels. If it is assumed that, if the pandemic had not occurred, road transport and aviation fuel consumption would have been the same in 2020 as in 2019 over the months of March to June, then the effect of the pandemic to the end of June has been to reduce annual transport emissions by just over 5%.

Figure 3

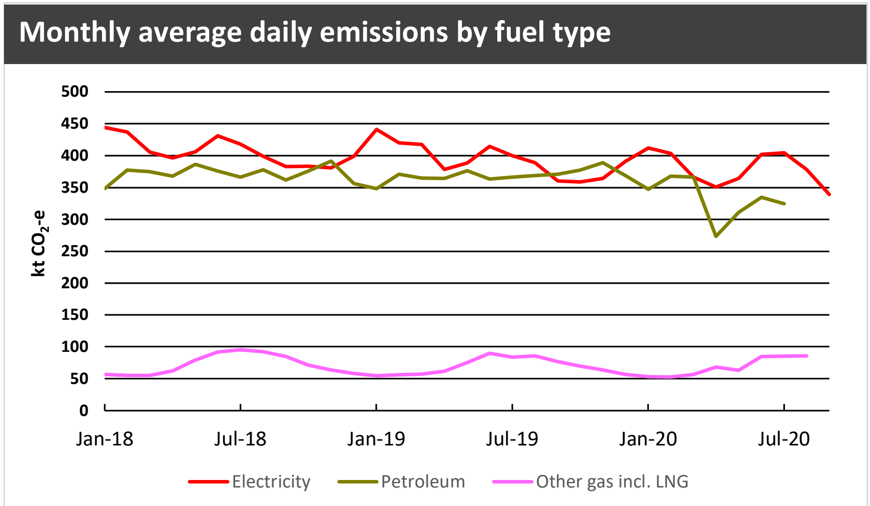
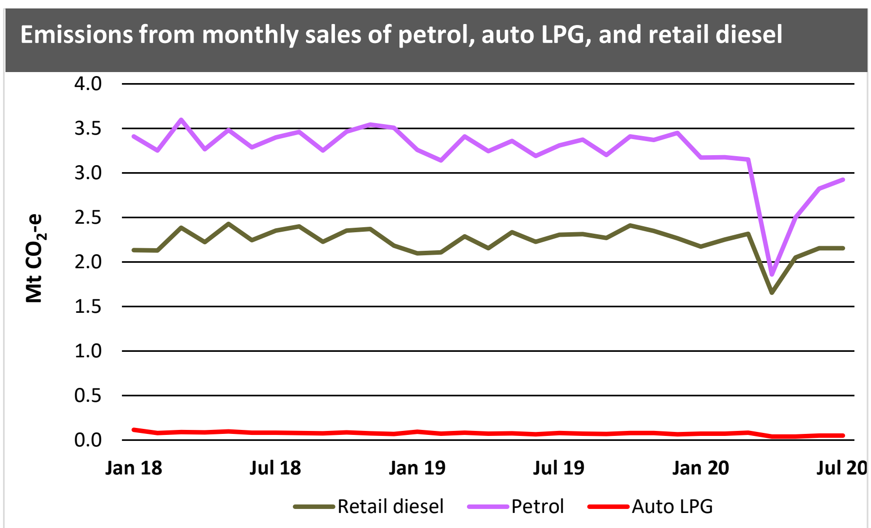


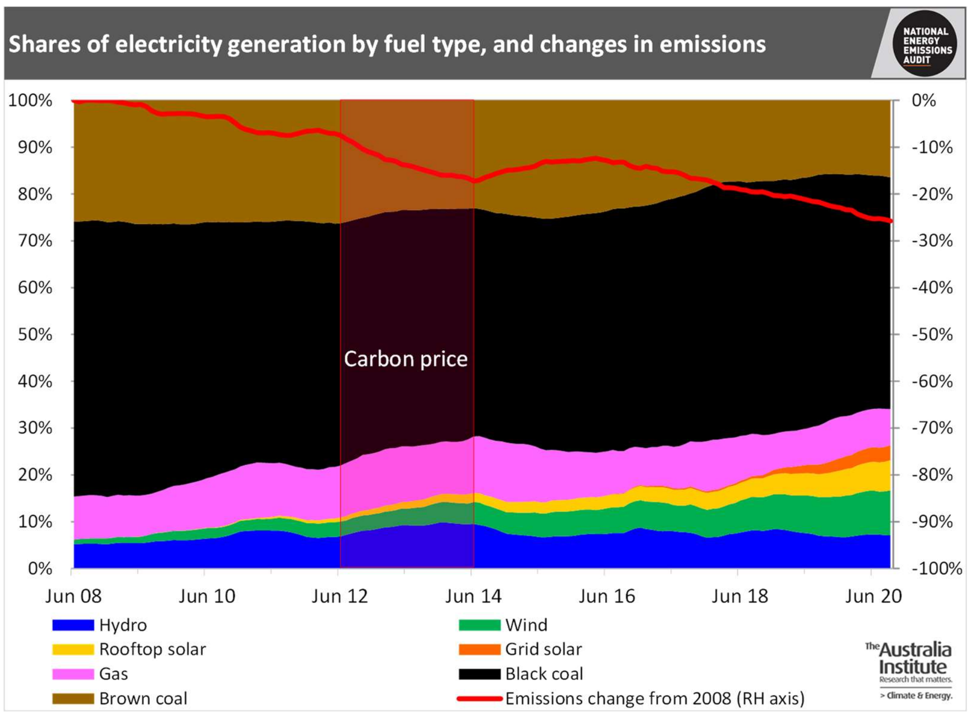
Figure 4



ELECTRICITY GENERATION IN THE NEM TO SEPTEMBER 2020

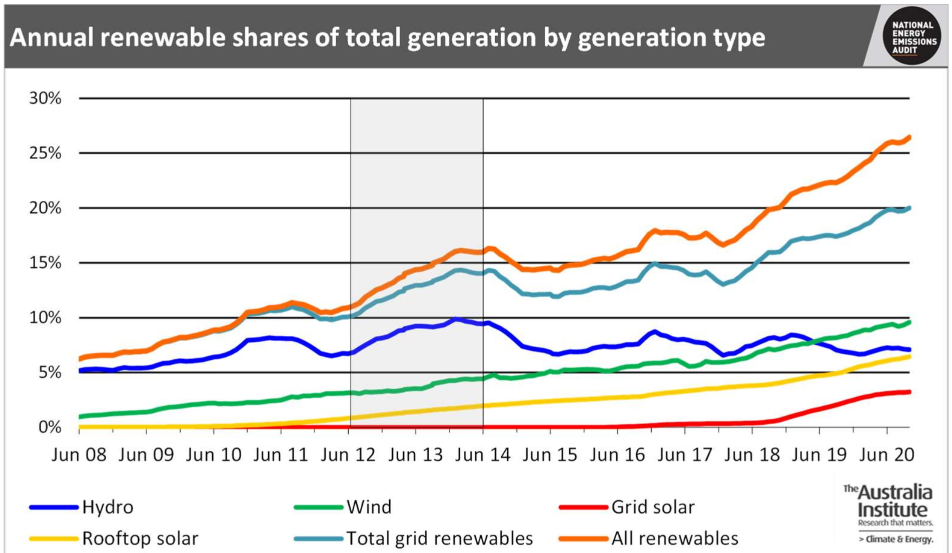
Figure 5 shows how the mix of generation types in the NEM, including both grid scale generation and small (rooftop) solar, has changed over the past twelve and a quarter years, expressed as shares of moving annual total generation. Total renewable generation in the year to September was about 26.5% of all generation, with grid scale generation contributing almost exactly 20% and small solar the '. "New" or variable generation, i.e. excluding hydro and also the vary small contribution from bagasse (sugar cane biofuel), totalled 19.4%. The growing shares of the various sources of renewable generation are shown more clearly in Figure 6, together with the totals just mentioned.

Figure 5



The shares of total annual renewable generation, including small solar, in the individual states are Queensland 15%, New South Wales 18.5% (made up of 2.8% from Snowy Hydro, 10% from grid scale wind and solar, and 5.5% from small solar), Victoria 25%, South Australia 57% and Tasmania 99%. It is relevant to note that over the year total generation and total consumption in Victoria, South Australia and Tasmania are almost exactly in balance – Victoria is a small net exporter to New South Wales and a small net importer from South Australia and Victoria. However, New South Wales is a large net importer of electricity from Queensland – net imports accounted for 8% of total consumption in the year to September.

Figure 6



A record high share of renewables means a record low share for fossil fuel generation, which was 73.5%. Black coal generation also reached a record low level of 49.5%, making September the fourth successive month in which, for the first time ever in the history of electricity supply in Australia, black coal generation supplied less than 50% of all electricity supplied to consumers. Annual brown coal generation was 16.4%, which was slightly higher than the lowest ever annual level of 15.7% seen eleven months ago. Similarly, total annual gas generation at 7.7% was just slightly above the record low level, reached about a year and a half ago.

Longer days, higher solar elevation and windy spring weather in southern Australia usually cause a sharp increase in renewable generation in August and September. During October and November growth in solar generation continues to increase, while milder weather typically means that the minimum levels of annual consumption are almost always seen during these months. This combination means that the share of renewable generations will almost certainly continue to grow, and fossil fuel generation can be expected to fall further.

The effects of more wind and sun can be seen very clearly in Figure 7, which shows that in September total wind generation set a new monthly record level in both absolute and relative terms: 2,700 MW average and 13% of all electricity supplied, including small solar. However, the highest ever trading interval level of wind generation occurred in August, in the middle of the evening peak, at 7.00 pm on Saturday 22 August, when wind supply across the NEM averaged just under 5,000 MW and supplied 17.5% of total consumption. Maximum shares, as opposed to maximum generation, in each of the mainland states occurred in the early afternoon, when grid demand was lower, because of the contribution of rooftop solar.

Figure 8 charts the same data as Figure 7, but stacks the generation from each type to give an overall total. It also shows renewable generation as a share of total generation, rather than in absolute terms. Figure 9 presents the same data as moving annual totals.

It can be seen that renewable generation in September reached its highest ever share of total sent out NEM generation – the precise figure is 31.5%. In South Australia the September share of renewable generation was much higher, at 67.6%. An appreciable proportion of generation during the month was exported to Victoria, which means that total renewable generations as a share of electricity consumed in the state was much higher, at 75%. The corresponding renewable share of consumption in Victoria, after adjusting for imports from South Australia and exports to Tasmania and New South Wales, was just over 30%, almost identical with the NEM-wide figure. The shares in New South Wales and Queensland were both over20%.

Figure 7

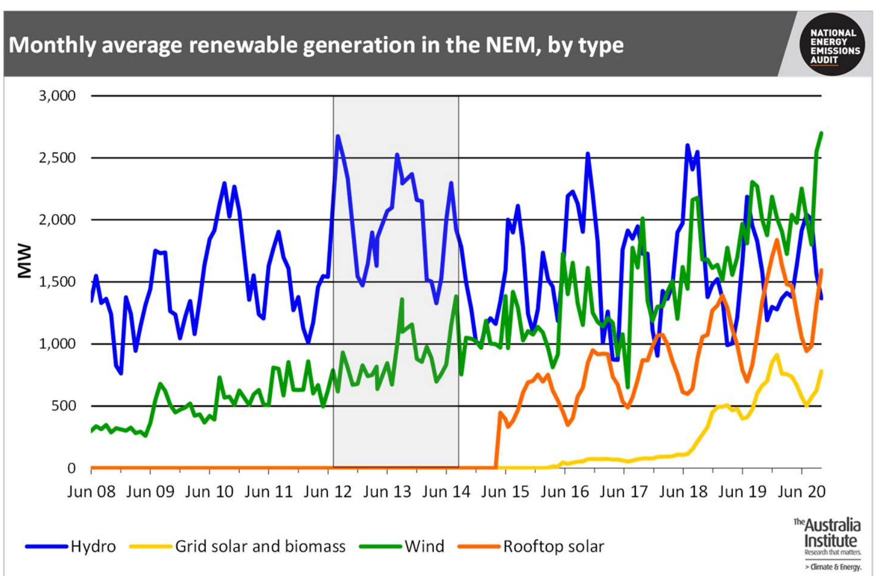


Figure 8

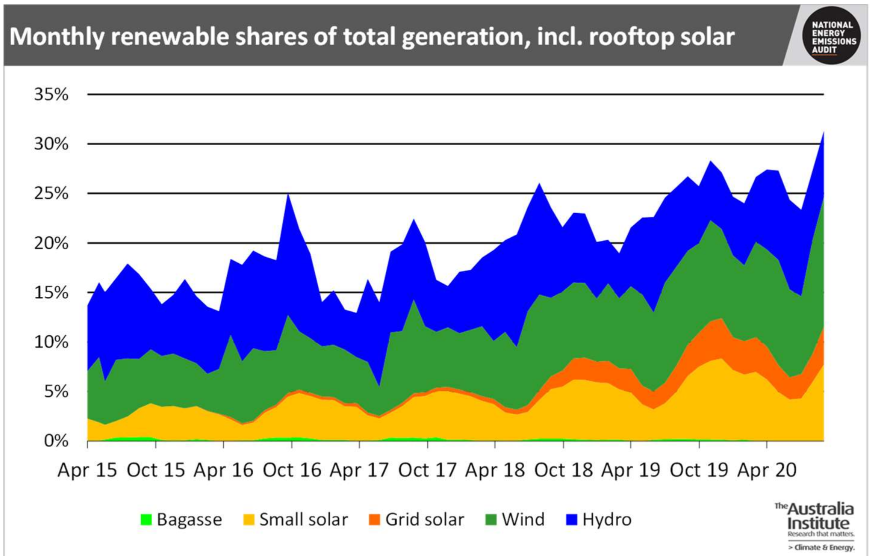
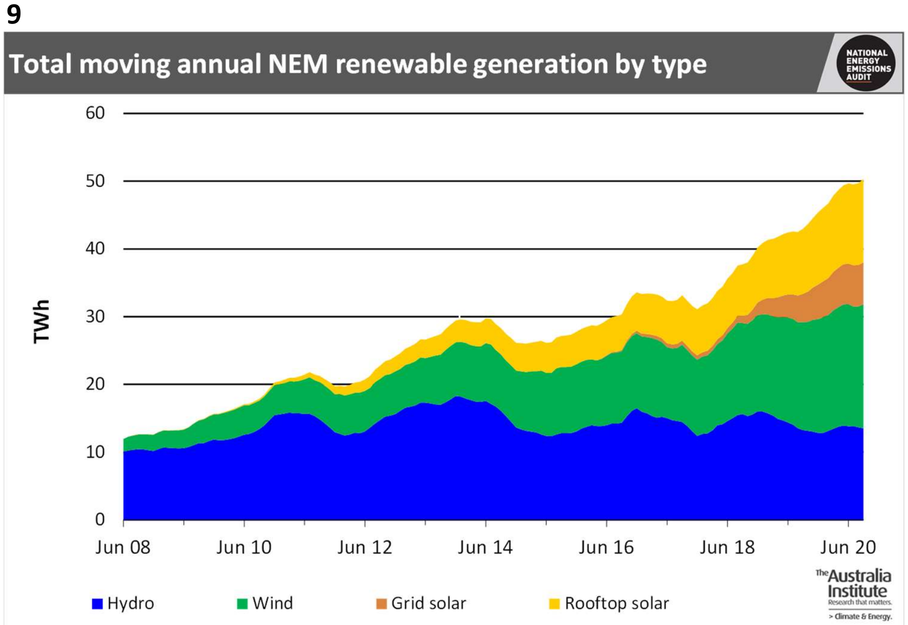


Figure 9



Figures 10 and 11 are updates of the capacity of grid scale wind and solar farms and small (rooftop) solar respectively. At the end of July 2020, the wind capacity connected and supplying was just under 7.2 GW, grid connected solar capacity was 3.6 GW, and small solar capacity was 9.4 GW. Figure 10 clearly shows the widely reported slowdown in new wind and solar farm connections over the past year, but it does not show the additional impact of imposed limits on maximum output set well below total capacity. We have made a rough estimate of the potential generation foregone over the past year and a half from a small number of the most severely affected projects in north west Victoria and south west New South Wales. The total comes out at about

1% of total NEM generation per year. In other words, without these delays, total renewable generation would have been about 27.5% rather than 26.5%.

There are a number of different factors contributing to this slowdown, and most have received extensive commentary and discussion both in specialist industry publications and more widely. Overall, however, there can be no doubt that the fundamental cause is a refusal of both major parties at the national policy level to accept and acknowledge the reality, the speed and the scale of the electricity system transition now occurring. The transition is being driven as much by business decisions as by policy settings, but in the absence of high level acceptance and an overarching policy framework, parties pursuing their own interests inevitably, and all too often, find themselves working at cross-purposes, which is exactly what is now happening with the roll out of grid scale solar and wind generation.

Figure 10

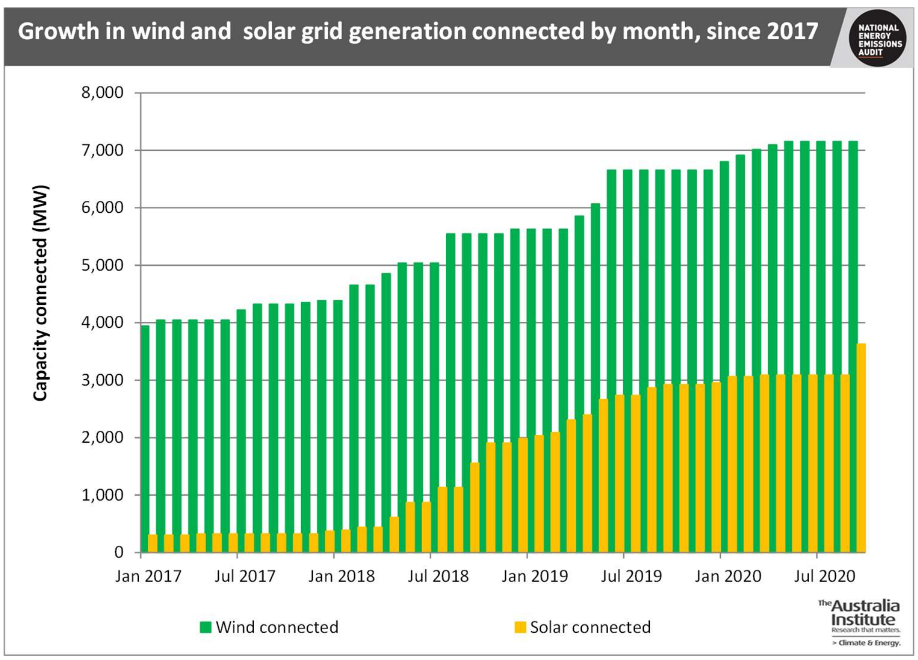
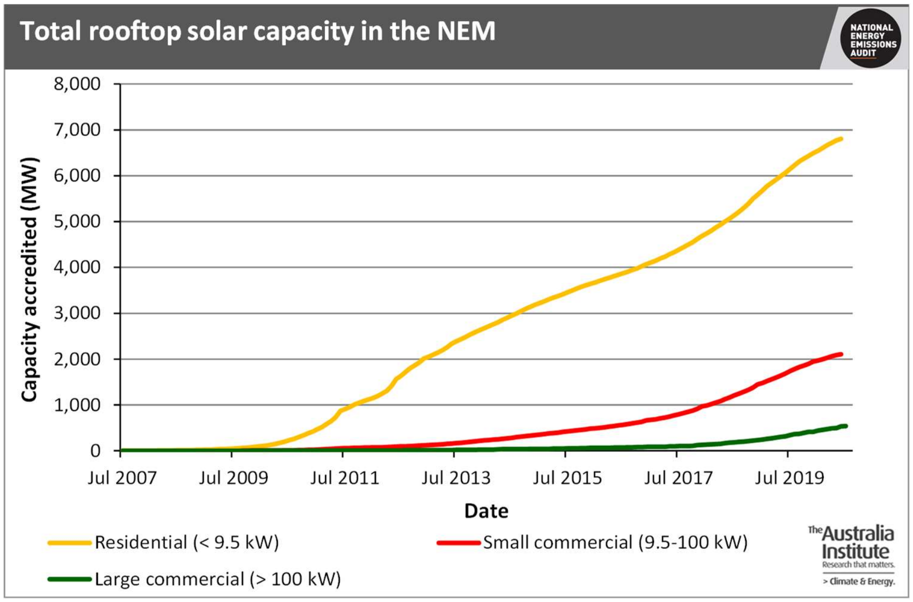


Figure 11



Fortunately, as Figure 11 shows that has not so far happened to small scale solar, or at least not to the same extent, but the industry is well aware that it is not immune from the damaging consequences of policy conflict and confusion.

THE IMPACT OF ROOFTOP SOLAR ON DEMAND FOR ELECTRICITY IN THE NEM

One of the most remarked upon effects of the growth in rooftop solar capacity is depression of grid demand in the middle of the day. Before solar arrived, the electricity supply industry designed and operated its systems on the basis of daily demand which fell to a minimum at some time between midnight and sunrise. Demand then rose to a short breakfast time peak, fell a little to a moderately high but stable level during the middle hours of the day, before rising to its daily peak, usually just after sunset, then fell steadily to the next daily minimum a few hours after midnight. The daily minimum almost always occurred during the hours after midnight, and the annual minimum always did.

The growth in rooftop solar is now causing daily minima to move from just after midnight to just after midday in regions with a high penetration of rooftop solar. Figures 12 to 15 plot annual minimum and annual maximum trading interval (30 minute) demand of grid supply of electricity in each of the four mainland NEM regions (states) since 2014-15. This is a clear and simple way of showing how each state is being affected year by year.

Figure 12

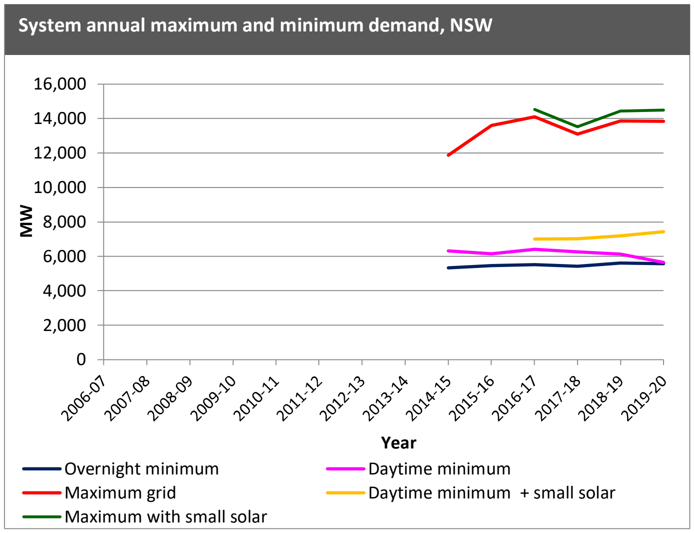


Figure 13

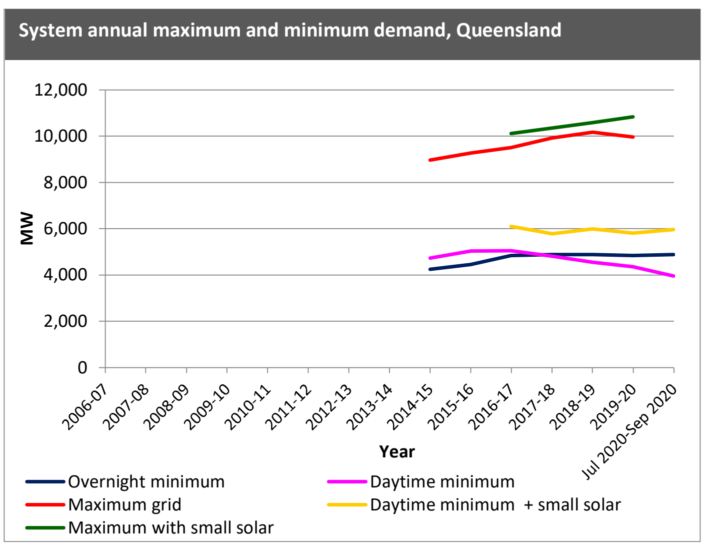


Figure 14

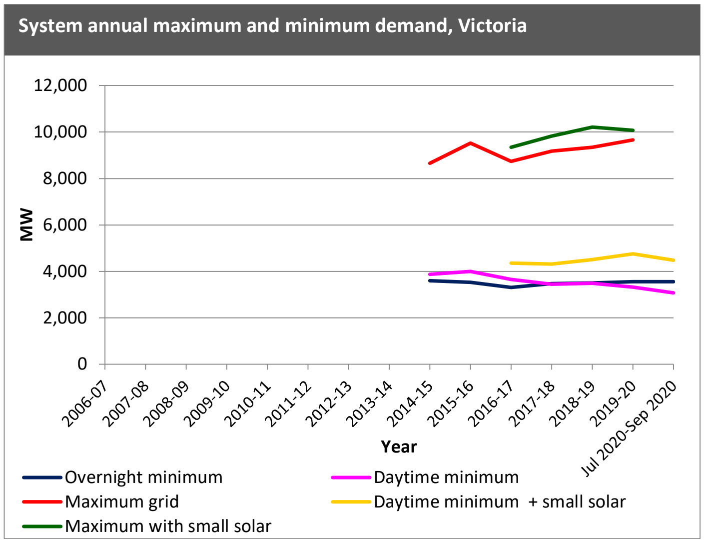
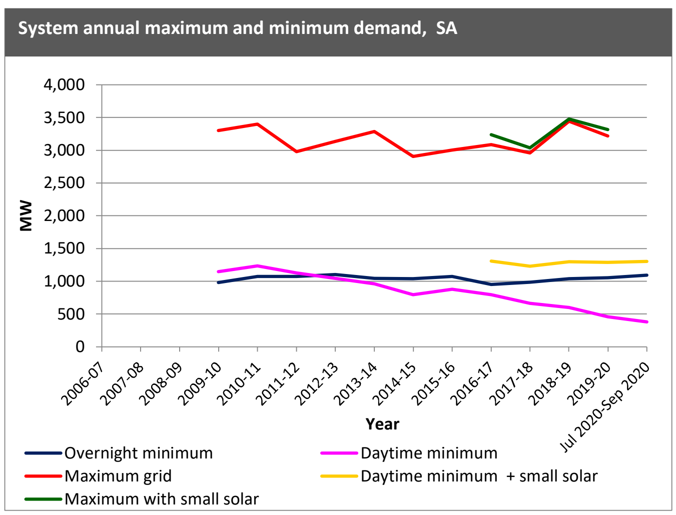


Figure 15



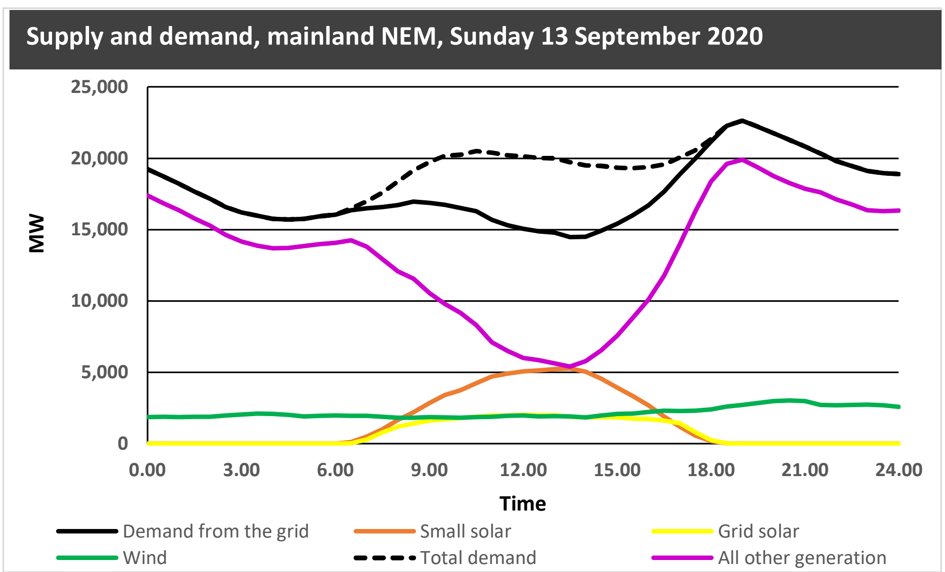
The day on which the most recent minimum grid demand level was reached in South Australia, as shown in Figure 1, was Sunday 13 September. This was also the day in which grid demand in the mainland NEM as a whole reached its lowest ever level. (In each of the other three mainland states, the minimum on that day was just a few MW above the minimum for the month.)

Figure 16 shows supply and demand in the mainland NEM, expressed in terms of average 30 minute (trading interval) values. Figure 17 shows the corresponding data for South Australia only. Both graphs clearly show the so-called ‘duck curve” shape of the gap between total electricity consumption and demand for electricity supplied through the grid. They also show the minimum level of demand for electricity supplied from the grid in the middle of the day, and the subsequent very steep increase in the requirement for electricity supplied by grid generators, as supply from rooftop solar declines during the afternoon.

In the mainland NEM, the minimum level of grid demand was just under 14,600 MW, in the early afternoon, at which time wind and solar were supplying 46% of total generation. If hydro is included, all renewable generation was supplying 48% of generation. Over the whole day, wind and solar supplied 23% of total demand for electricity, including demand supplied from rooftop solar. This is not particularly high values; the highest daily share for wind and solar in the mainland NEM during September was 29%, reached on Tuesday 22 September.

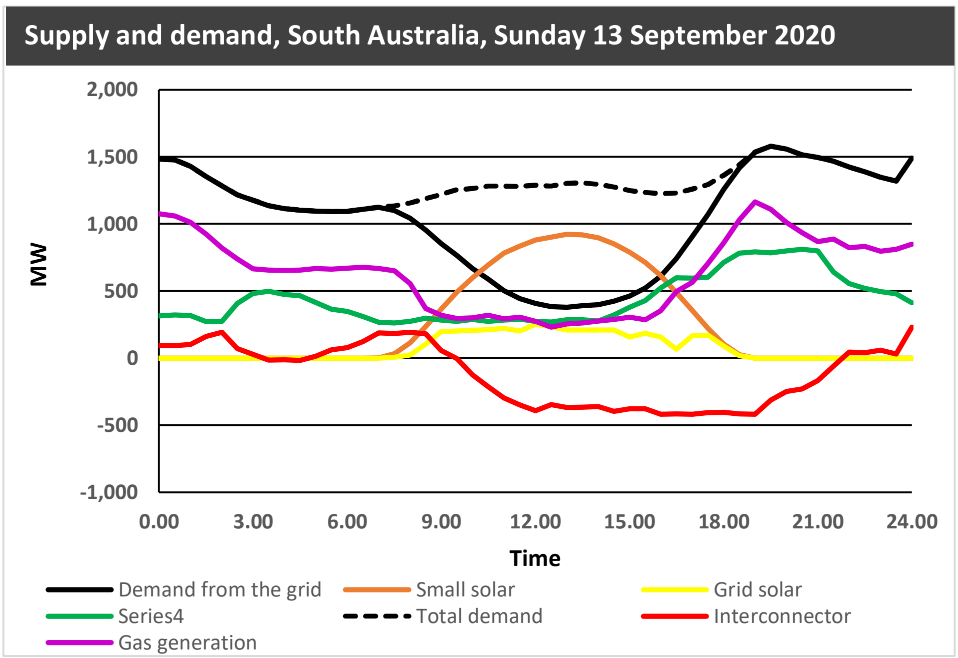
In South Australia, at the same time, grid demand fell to a minimum level of 380 MW. At this time, wind and solar were supplying over 90% of all generation in the state. Expressed relative to total state demand for electricity, wind and solar were contributing over 100% of the total for more than five hours, with excess generation being exported to Victoria. Over the whole day, wind and solar supplied 59% of total demand, and 55% of total generation.

Figure 16



Without the ability to export through the interconnector, AEMO would have been forced to severely curtail wind and solar generation in South Australia on 13 September, because the current system configuration in the state requires a small amount of synchronous generation at all times. On this day one of the four gas fuelled steam driven machines at Torrens Island B station and one machine at the Pelican Point combined cycle gas station operated through the minimum demand period. The requirement for synchronous generation at all times will be eased when the synchronous condensers being installed by ElectraNet, the state transmission business, are commissioned. What this experience also demonstrates is the crucial importance of Project Energy Connect, the proposed interconnector between South Australia and New South Wales, without which further growth of renewable generation would be severely constrained. The project, which is universally agreed to be essential for Australia's continuing transition towards a low emissions electricity supply system, is still waiting final approval from the Australian Energy Regulator, working through the cumbersome and protracted approval process required under the National Electricity Rules.

Figure 16



Finally, it is almost certain that the records renewable shares described here will be on a windy day in either October or November. These are typically the months when daily demand for electricity is at its lowest annual level, while the level of solar generation is steadily increasing.

SOME OBSERVATIONS ON AEMO'S 2020 INTEGRATED SYSTEM PLAN, WITH PARTICULAR REFERENCE TO FIRMING REQUIREMENTS AND CAPABILITY

At the end of July AEMO released the final version of its 2020 Integrated System Plan (ISP). It is based around five scenarios, each of which is based on a plausible combination of economic and social factors. Each combination yields a particular mix of demand for electricity and supply from wind and solar generation, based on the relative costs of generation from each source, i.e. continued functioning of the National Electricity Market as it operates today. Demand and renewable generation then determine the utilisation of legacy coal, gas and hydro generation capacity. None of the five scenarios includes any new coal, gas, or hydro (as distinct from pumped storage) power stations.

It is important to emphasise than none of these scenarios is a forecast or projection and neither are they the output of a model, other than the simple constraint that supply must match demand at all times and at all locations. The objective of the sophisticated modelling used by AEMO in developing the ISP is to determine the mix and timing of new investment in transmission, firming capability (storage etc.) and other grid infrastructure that will be required, under each scenario, to provide a secure and reliable supply of electricity at least cost to consumers.

Under four of the five scenarios demand is assumed to increase at an average rate of between about 0.4% and 0.6% per annum over the period from 2020 to 2042 (one scenario has much slower demand growth). There is relatively modest growth in use of electric vehicles. Rates of consumer switching from gas to electric technologies for low temperature heat supply (space heating and hot water) are also fairly modest. There is no closure of major industrial loads (meaning aluminium smelters). However, shares of variable or non-dispatchable generation, i.e. wind and solar generation, increase strongly. Under what is called the Central scenario, the variable generation share of total generation (excluding generation output from storage, to avoid double counting) reaches 70% in 2042, up from just under 18% in 2020. The share of coal generation falls from 67% in 2020 to about 25% in 2042.

Under the scenario with the largest fall in emissions, called Step Change, variable generation reaches 103% by 2042. The percentage is above 100% because some energy generated is lost in storage cycling. Under this scenario, coal generation is 2.5% in 2042 and gas generation is 1.6%. Nearly 11% of electrical energy supplied to consumers comes from storage, including both pumped hydro and batteries, including behind the meter batteries linked to rooftop solar.

The reason for focussing on this aspect of the ISP is that the variability of wind and solar generation is the argument conservatives have been using for years to support the retention and, in extreme cases expansion, of coal generation. The many fallacies of this argument have been previously examined in the *NEEA Report*. More recently, a strong push for increased supply of natural gas, including, if necessary, public funding of gas pipelines, has been based on arguments that more gas generation will be required to support variable renewable generation. The ISP supports the argument that gas generators "will continue to play a critically important role in the NEM" (p. 53). However, the results do not support the argument that a greater volume of gas will be required. On the contrary, under all five scenarios, total annual gas generations falls rapidly, from over 8% of total NEM generation in 2020, to under 2% by 2025, or earlier, and remains not far above that level for the remainder of the projection period. It is mainly the cost of gas which makes gas generation, which will always be crucially important, only a small source of generation in volume terms. Obviously, unless either additional gas production diverted to LNG exports, or existing production sources collapse, no new gas production will be needed for electricity generation under any of the ISP scenarios. What is more, because of the relatively high cost of gas, both now and under all foreseeable futures, any policy which forces up the volume of gas generation can only force electricity prices up also.

The total annual volume of gas generation is so small because only small quantities of electricity are required to be supplied by gas generators each year. The major "critically important role" of gas generation in the NEM occurs when the weather in south eastern Australia is both cloudy and still for several successive days, causing both solar and wind generation to fall to low levels. AEMO terms such periods V[ariable] R[enewable] E[nergy] 'droughts'; they occur in winter, typically on only a few occasions each year. During 2020, from May to late August, there were two such periods: one during the first week of June and another during the second week of July. The other use of gas generation occurs on some individual days, when renewable generation is at low levels and demand is at high levels, for a few hours in the early evening.

Shorter periods of low wind generation are more frequent and solar generation is of course zero for precisely half the hours in every year. Under all the ISP scenarios, the increasing need for firming functionality for these periods is mostly met by a mix of batteries and pumped hydro, including the existing pumped hydro stations in New South Wales and Queensland. Installation of new pumped hydro and battery capacity is projected to be important under all scenarios. Under all ISP scenarios Snowy 2.0 is defined not as new investment specified as least cost options by the modelling, but as a committed project which will definitely be commissioned in 2025. Under all but the rapid transition Step Change scenario, however, Snowy 2.0 is not much used until the early 2030s, some years after it is assumed to be commissioned. Throughout the intervening period, coal fired generation will be the marginal source of electricity for pumping. This means that the modest use of Snowy 2.0 to provide firming support for variable renewable generation will cause more greenhouse gas emissions than would making greater use of idle gas generators. Of course it is not possible to be certain about alternative outcomes without a complete modelling run with changed scenario specifications. However, it seems almost certain that, even under a rapid transition to a low emission future for the NEM, the least cost path would not see Snowy 2.0, or alternative pumped storage options, commissioned until the early 2030s, at the earliest.

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.