Australian National University

Australian National University Institute for Climate, Energy & Disaster Solutions

Australian Energy Emissions Monitor

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Australian Energy Emissions Monitor

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Key Points

- When economic and social activity returns to pre-pandemic levels, as expected for 2022, Australia's energy combustion emissions will probably return to gradually decreasing at a rate of roughly 4 to 5 Mt CO2-e per year, as prevailed prior to March 2020. Decarbonisation will again be almost entirely driven by the transition of electricity generation in the NEM towards more supply from wind and solar generators.
- A factorisation analysis of the nearly 58 Mt CO_2-e decrease in emissions from NEM generation from June 2008 to Jan 2022 shows that 66% of the decrease is attributable to the change in generation mix (more renewables, less coal), 25% to the displacement of grid supplied electricity by rooftop solar, 5% to reduced auxiliary generation, as coal fired generation decreases, and 4% to an absolute reduction in total electricity consumption (Figure 6 & Table 1).
- In the year to January 2022, variable renewable (wind and solar) generation supplied just over 25% of all electricity generated in the NEM. If hydro is included, the renewable share increases to 33%.
- On a monthly basis, wind and solar generation across the NEM set a new record of just under 32% of total generation, equal to an average of 7,000 MW, in December 2021. Total renewable generation, including hydropower, reached almost 38%.
- The rate of increase in the capacity of both wind and solar generation supplying the NEM slowed during 2021.
- Plots of monthly electricity, gas and petroleum fuel consumption in New South Wales, Victoria and Queensland over the period from January 2018 to January 2022 confirm the previously reported large reduction in consumption of aviation fuel since the arrival of the pandemic in March 2020, and the small but sharp reductions in consumption of road transport fuel coinciding with major lockdowns. However, while there are a few changes in monthly consumption of electricity and gas, which appear atypical of previous trends, there is no evidence of a prolonged reduction in energy consumption, such as reportedly has been observed in some European countries.

Introduction to the February 2022 issue

Welcome to the second issue of the *Australian Energy Emissions Monitor*, which is a bi-monthly publication of the ANU Institute for Climate, Energy and Disaster Solutions, providing timely analysis of the most recent trends in energy related greenhouse gas emissions. The publication is intended as a service to Australia's energy community.

This issue includes a factorisation of reductions in emissions from electricity generation in the NEM since 2008, which shows that two thirds of the reductions are due to the change in the generation mix on the grid, mostly substituting coal fired power with wind and solar power, while one quarter of the emissions reductions are attributable to increased rooftop solar. Only 4% of emissions reductions are due to a fall in electricity use. This issue also includes a detailed examination of month by month consumption of electricity, gas and petroleum fuels, in New South Wales, Victoria, and Queensland over the past four years.

The aim of the *Monitor* is to estimate and report on Australia's energy combustion emissions as soon as reasonably possible after data sufficient to do so becomes publicly available. This timing has consistently been 6 to 8 weeks after the last day of the month to which the emissions estimates relate. Energy combustion remains by far the largest contributor to Australia's total greenhouse gas emissions (72% in 2020) and is the main opportunity to rapidly reduce emissions. Minimising the lag between when emissions occur and when they are reported allows faster and more complete understanding of how Australia's emissions are tracking, and what changes are needed to achieve faster emissions reductions.

The *Monitor* covers around 80% of Australia's energy combustion emissions, with data on the remaining 20% of energy related emissions not available within the window of a 6 to 8 week lag, and some not publicly available at all. A comparison and reconciliation will be provided in the first issue published after the annual National Greenhouse Gas Inventory Report (NGGI) has been released; this will probably be the June issue. More detailed information on which emissions are reported by the *Monitor* and which are not, and on data sources and methodology, are in the Appendix. The underlying data is provided in a separate online document alongside the report.

Hugh Saddler (author and analyst) and Frank Jotzo (Head of Energy, ICEDS)

Trends in energy consumption and emissions

The December issue of *Australian Energy Emissions Monitor* opened with two graphs which summarise trends in total energy combustion emissions, as calculated by the *Monitor*. That is repeated in this issue and our intention is that all subsequent issues will open with the same two summary graphs. Figure 1 shows total energy combustion emissions by major energy source and Figure 2 shows changes in energy combustion emissions, also by major energy source.

With petroleum and gas consumption data now available to the end of November 2021, it is fairly clear that the pandemic-induced fall in total energy combustion emissions has now ended. While the steady decline in electricity generation emissions will continue, over coming months it is likely that this decline will be more than offset by growth in emissions from consumption of petroleum fuels. On present trends, it seems most likely that total emissions will increase for a few months as petroleum emissions increase up to the level seen at the start of 2020, before the onset of the pandemic. A later section of this *Monitor* issue provides a more detailed examination of month by month consumption over the last few years of energy, and particularly of petroleum fuels.

As we have observed on many previous occasions, however well Australia is progressing with decarbonisation of electricity generation, the rates of emission reduction needed to achieve serious decarbonisation of the whole economy will be unachievable unless and until serious and credible policies to reduce petroleum fuel consumption are introduced.

Readers should note that the December 2021 *Monitor* issue provided an explanation of the apparent sharp increase in petroleum emissions during 2016-17.

Figure 1: Moving annual energy combustion emissions, 2011-21

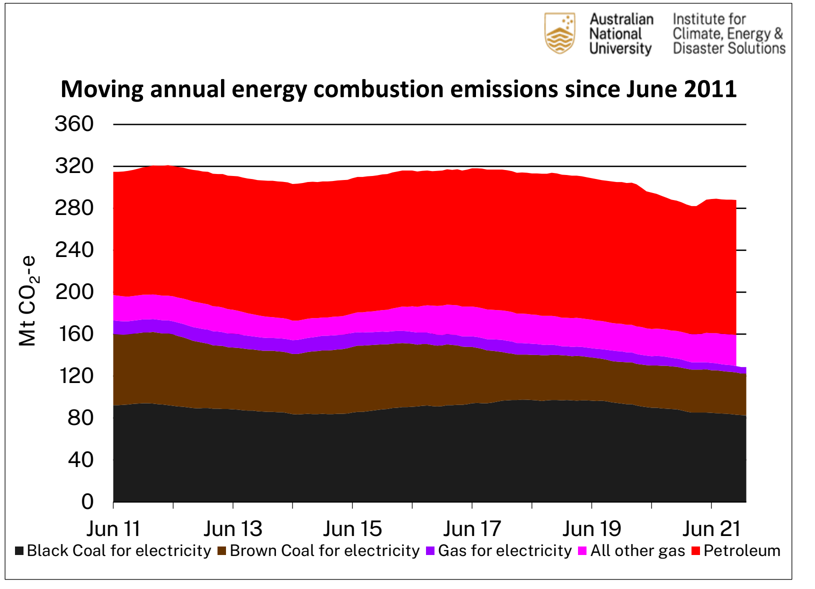
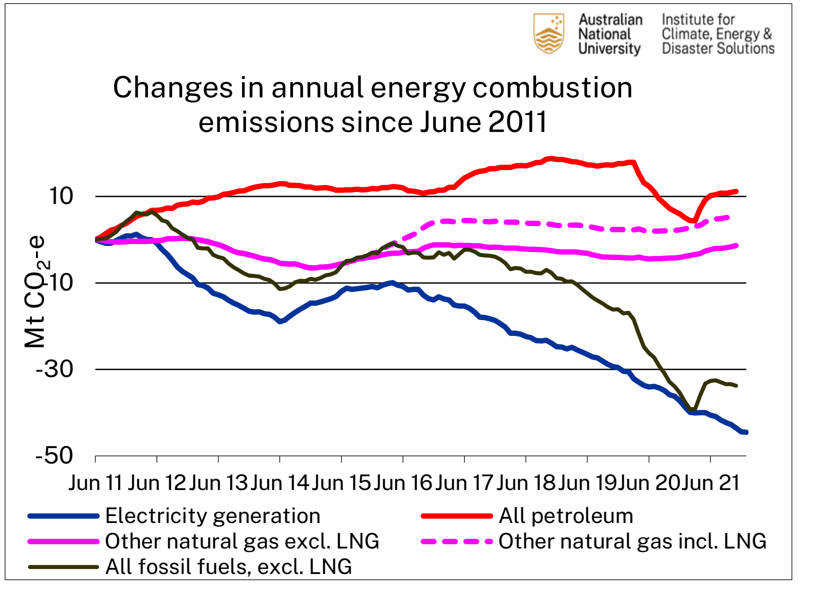


Figure 2: Changes in moving annual energy combustion emissions, 2011-21



Electricity generation, consumption and emissions in the NEM

Decarbonisation of Australia's energy consumption continues to depend entirely, as has always been the case, on decarbonisation of electricity generation and, in particular, decarbonisation of generation in the National Electricity Market (NEM). Our intention is therefore that, as with total energy combustion emissions, future issues of the *Monitor* will also include the three graphs included here.

Figure 3 shows absolute changes in sent out generation in the NEM by fuel type (for an explanation/definition of sent out generation, see the December 2021 issue of the *Monitor*). Figure 4 shows the same data, but expressed as shares of total sent out generation. In this graph electricity supplied by wind, grid solar and rooftop solar is shown as a combined single number, termed variable renewable generation.

In the year to January 2022, variable renewable generation, including rooftop solar, contributed 25.3% of sent out NEM generation, up from 24.5% in the year to November 2021, which is certainly an encouragingly fast rate of growth. The total renewable generation share, including hydro, was 33.2%.

Figure 3: Annual electricity generation in the NEM, 2008-21

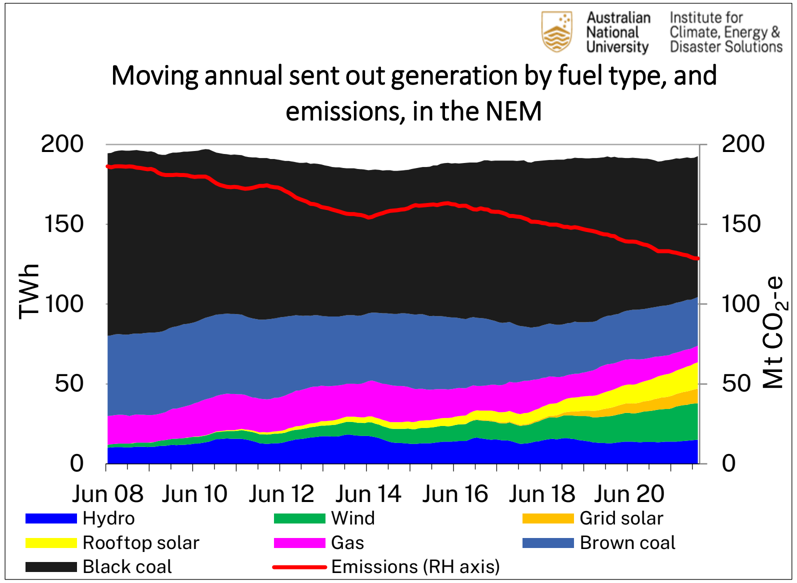


Figure 4: Changes in shares of sent out generation, 2008-21

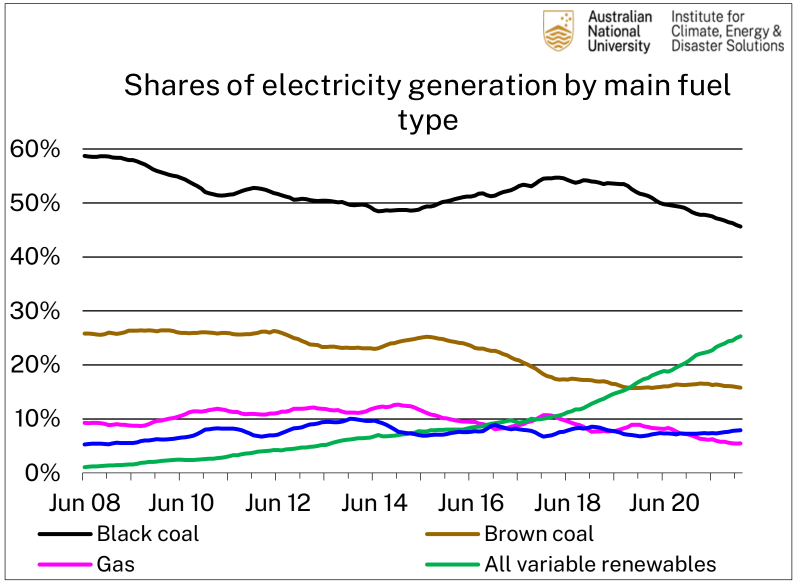


Figure 5: Relative changes in generation, emissions and emissions intensity, 2008-21

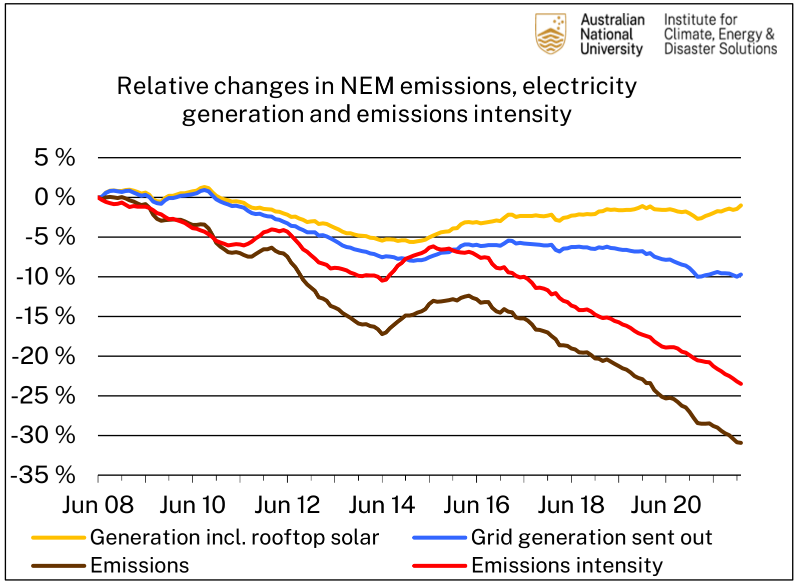


Figure 5 shows how the changes in the generation mix and in the total demand for electricity have combined to result in falls in both emissions and emissions intensity from electricity generation over the past thirteen years. The emissions intensity measure used is total emissions divided by the sum of total generation sent out by grid generators.

New readers of the *Monitor* should note that the December 2021 issue contains a more detailed description and explanation of the historic course of electricity demand and generation mix shown in Figures 3, 4 and 5.

Figure 6 shows the results of a new analysis which uses a more rigorous way of understanding the factors contributing to the decarbonisation of the grid since June 2008. Table 1 is another way of displaying the results of this analysis, by expressing all emission reductions as a percentage of total NEM emissions in the year ended June 2008, when NEM emissions were very close to their historic maximum level, as seen in Figure 4.

Figure 6: Factors contributing to NEM grid decarbonisation

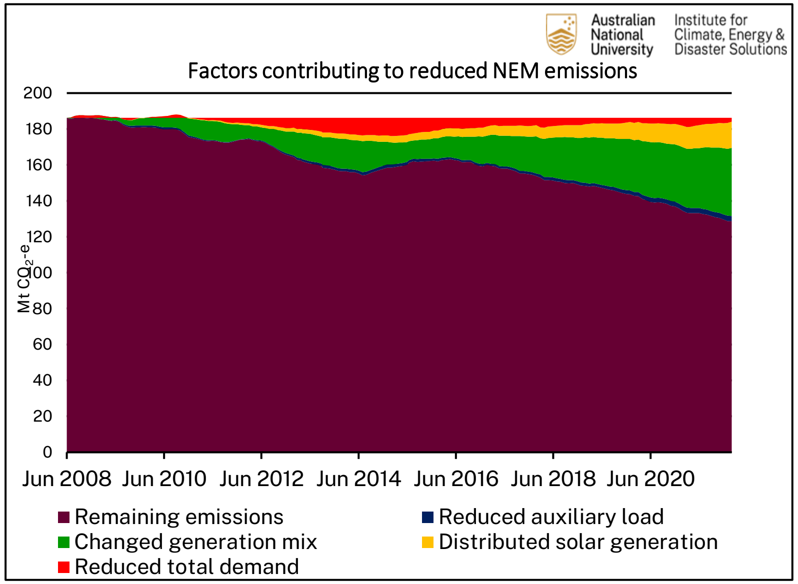


Table 1: Shares of 2008 emissions contributed to total reduction each year by each factor

Year ending	Reduced auxiliary load	Changed generation mix	Distributed solar generation	Reduced energy demand	Total emissions reduction from 2008
Jun 2008	0.0%	0.0%	0.0%	0.0%	0.0%
Jun 2009	0.2%	1.0%	0.0%	-0.3%	0.9%
Jun 2010	0.6%	3.3%	0.1%	-0.5%	3.5%
Jun 2011	0.2%	5.8%	0.3%	0.8%	7.0%
Jun 2012	0.2%	4.2%	0.8%	2.3%	7.5%
Jun 2013	0.7%	8.1%	1.3%	3.8%	13.9%
Jun 2014	0.9%	9.3%	1.7%	5.3%	17.2%
Jun 2015	0.8%	5.6%	2.1%	4.9%	13.4%
Jun 2016	0.6%	6.7%	2.4%	3.1%	12.8%
Jun 2017	0.7%	9.1%	3.0%	2.4%	15.2%
Jun 2018	0.9%	12.3%	3.5%	2.4%	19.0%
Jun 2019	1.0%	14.2%	4.3%	1.7%	21.3%
Jun 2020	1.3%	16.7%	5.6%	1.7%	25.3%
Jun 2021	1.5%	18.3%	6.8%	2.1%	28.8%
Jan 2022	1.6%	20.3%	7.9%	1.2%	30.9%

The four factors are as follows.

Auxiliary load is the electricity generated by a power station which is used to operate the power station, to power essential heavy equipment such as fans, pumps, conveyors and crushers, and therefore never leaves the power station. For a given generation capacity, a typical coal fired power station has a much higher auxiliary load (up to 10% of electricity generated for an older coal fired power station) than a gas fired power station, which in turn has a higher auxiliary loads than hydro, wind and solar power stations, for which auxiliary loads are very small. As the electricity supplied by coal fired power stations declines, less of the total electricity generated in the NEM is consumed by auxiliary loads, and therefore emissions are reduced.

Changed generation mix derives from the growing shares of zero emission wind and solar generation, meaning that the average emissions intensity of electricity generated in the whole NEM is gradually decreasing. The graph shows that the growth of wind and solar generation has made by far the largest contribution to NEM decarbonisation.

Distributed (rooftop) solar generation is another source of zero emissions electricity which directly displaces electricity supplied from the grid, most of which is currently supplied by coal and gas fuelled generators, with associated emissions.

Finally, if consumers demand less electricity, less electricity is required to be generated, meaning that emissions are reduced. The graph shows, just as Figure 5 also shows, that total demand for electricity decreased significantly over about three years from 2011 to 2014, since when it has very gradually increased again.

Parenthetically, regarding electricity generation and associated emissions in Western Australia and the Northern Territory, information is not included in the *Monitor* because detailed daily operational data relating to individual power stations is not available in the same way it is available for NEM generators. As a generalisation, the historic emissions intensity of electricity generation in WA is lower than in the NEM, because WA has a lower, though by no means zero, share of coal generation, and a much larger share of gas generation. Electricity generation in the NT is almost entirely reliant on gas. However, the growth in wind and solar generation in both WA and the NT has been significantly slower than in the NEM.

At the end of February, the Clean Energy Regulator is expected to release summary public data from the National Greenhouse and Energy Reporting Scheme (NGERS) for 2020-21. This will include so-called Designated Facility data, which includes annual generation and emissions from virtually all grid-scale generators in the country. The next issue of the *Monitor* will contain an analysis of data from generators in WA and the NT, going back to 2012-13, the first year in which these data were published. It is hoped that this will provide an indication of the approximate level and rate of increase in renewable generation in these two jurisdictions.

A closer look at renewable generation growth in the NEM

Figure 7 shows moving annual shares of renewable generation in the NEM, including generation from rooftop solar. Since the start of 2018, i.e. over the past four years, the renewable share has increased at a rate of about four percentage points per year. In the year to January 2021 the share reached 33.1%, i.e. just under one third of all electricity supplied in the NEM.

Figure 7: Moving annual shares of renewable generation in the NEM, 2008-21

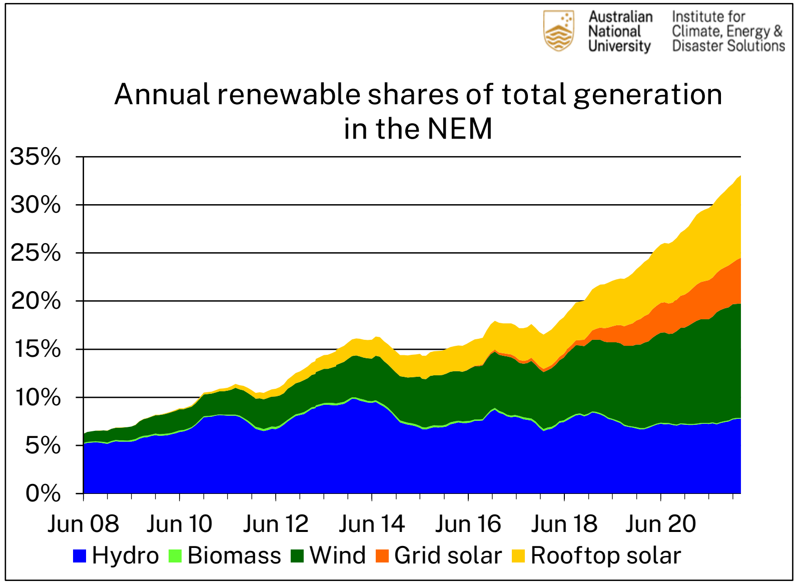


Figure 8: Monthly shares of variable renewable generation, 2015-22

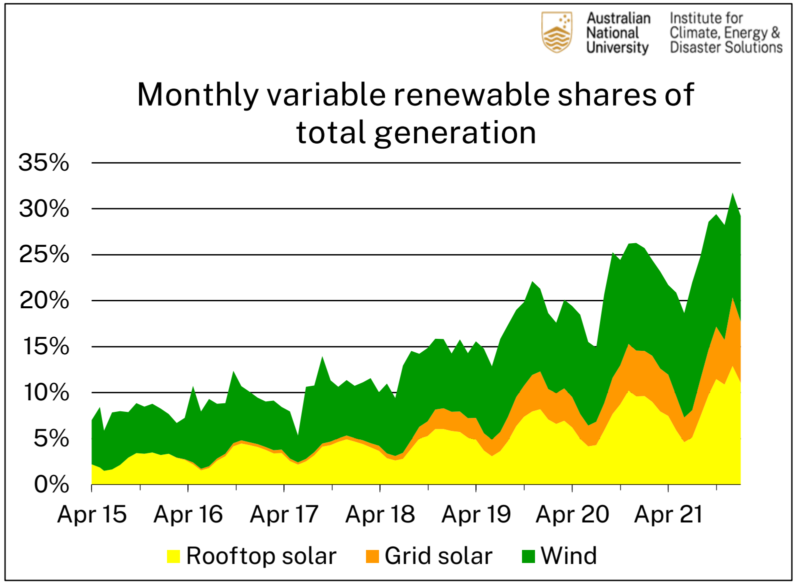


Figure 8 shows how the variable renewable share, i.e. wind and solar, varies on a monthly basis, reaching a maximum of 31.8% in December 2021

Underlying the growth in renewable generation is of course the growth in generation capacity installed, and this is shown in the next two graphs. Figure 9 shows the month by month increase in capacity of wind and solar generators supplying the NEM grid. It is clear that the growth in both wind and solar capacity has been very slow (zero in the case of wind) over the past few months and, in the case of wind, markedly slower since mid-2019 than it was in the few years prior to that. Undoubtedly some part of this slowdown is attributable to the well-publicised transmission connection delays affecting both some windfarms and some solar farms in Victoria. That said, the Clean Energy Regulator lists, under the Large-scale Renewable Energy Market Data tab on its website, roughly 2,300 MW of additional wind capacity and 2,000 MW of additional solar capacity in NEM states that is either already accredited but not yet supplying or committed to be built. Total NEM capacity in January 2022 was 8,000 MW wind and 5,900 MW solar.

Figure 9: Growth in grid connected wind and solar generation installed

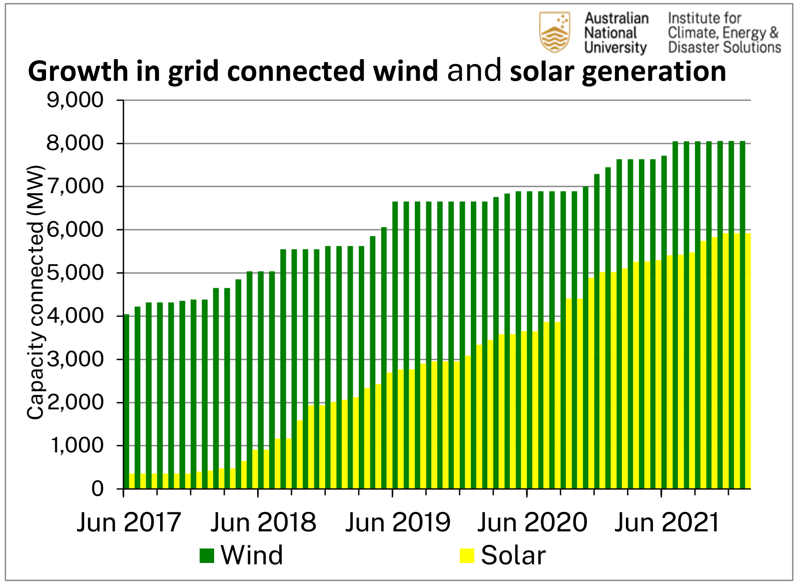


Figure 10: Growth in small solar capacity since 2007

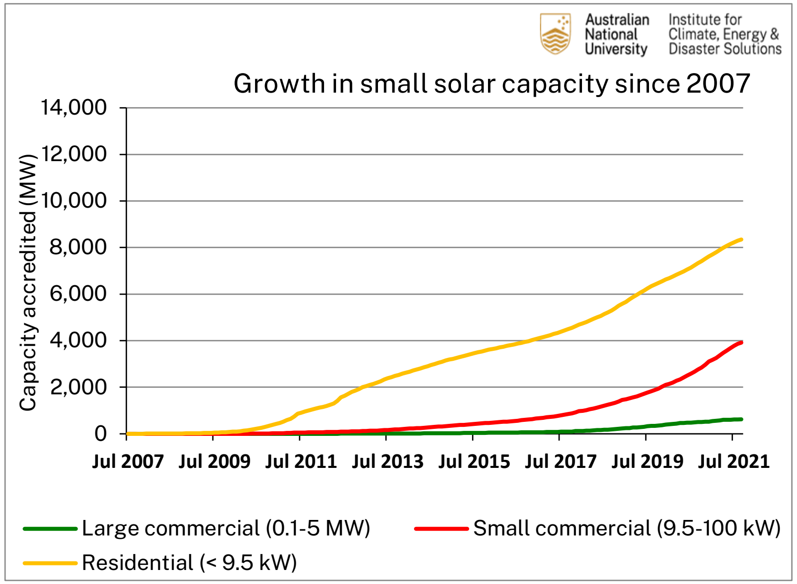


Figure 10 shows the growth in small solar capacity installed since 2007. All data are sourced from the PV Postcode data on the Australian Photovoltaic Institute's Live Solar website. This source, which is extracted from the Clean Energy Regulator's Small-scale Renewable Energy Scheme Postcode installation data, provides total capacity installed, by month, sorted into eight capacity ranges up to 100 kW, which is the ceiling for the Scheme. A ninth grouping reports capacity in the range 100 kW to 5 MW, which are the smallest installations participating in the Large-scale Renewable Energy scheme.

In order to simplify the presentation, and to allow for some interpretation of the data, we have aggregated these grouping into three categories. Installations of capacity up to 9.5 kW are defined as residential, while installations of between 9.5 and 100 kW are defined as small commercial. These definitions are of course quite arbitrary, but are judged to approximate reality. There are undoubtedly some individual residential installations that are larger than 9.5 kW and some commercial installations that are smaller. There are also a number of installations larger than 9.5 kW supplying apartment buildings and groups of houses. Installations in the 100 kW to 5 MW range are classified as large commercial, but these also include other types of installations, such as small community owned solar farms feeding into a local distribution network. Available data extends only to September 2021, when total capacity in these three groups was 12,900 MW.

It can be seen that for some years after the advent of residential scale installations there were scarcely any larger commercial installations. However, over the past three years the increase in commercial scale capacity has been larger than the increase in smaller, residential capacity. Commercial installations now account for slightly more than one third of total installed capacity.

Effect of the pandemic on energy consumption and emissions

Responses to the pandemic over the past two years have had major impacts on economic and social activities in Australia. The nature and severity of the impacts have varied widely between states because of differences in the responses implemented by state governments. For a variety of reasons, the two largest states, New South Wales and Victoria, have been much more severely affected than any of the other states. In this final section of the February 2022 *Monitor* we use month by month daily average energy consumption as a means of assessing the effect on energy consumption of the various economic and social disruptions. Data have been compiled for New South Wales and Victoria, and also for Queensland. Prolonged border closures, and a range of other factors, have meant that, overall, disruptions in that state have been much less severe than in either New South Wales or Victoria, though some sectors of the Queensland economy, such as tourism, have been badly affected.

The analysis looks at consumption of electricity, gas, road transport fuels (as defined in the *Monitor*) and bulk diesel. We exclude jet fuel, consumption of which has been drastically reduced, as explained in the December 2021 Monitor, because state by state sales of jet fuel depend on a number of commercial and operational factors not directly related to activity within the state, and are therefore not a useful guide to the impact of the pandemic on energy consumption at the state level.

The following pages show three separate graphs, of energy consumption in New South Wales, Victoria and Queensland. These are followed by a discussion of what these graphs show. This is followed by three graphs of the resultant energy combustion emissions, and then a short final commentary.

We start the discussion with some observations on the underlying similarities and differences between energy consumption in the three states, unrelated to the pandemic disruptions.

The most important similarity, in common with the whole of Australia, is that road transport accounts for the great majority of transport undertaken by both people and goods, and that road transport in Australia is overwhelmingly dependent on petroleum products. Changes in the movement of either people or goods will therefore affect consumption of road transport petroleum fuels.

Figure 11: Daily average energy consumption by month, NSW

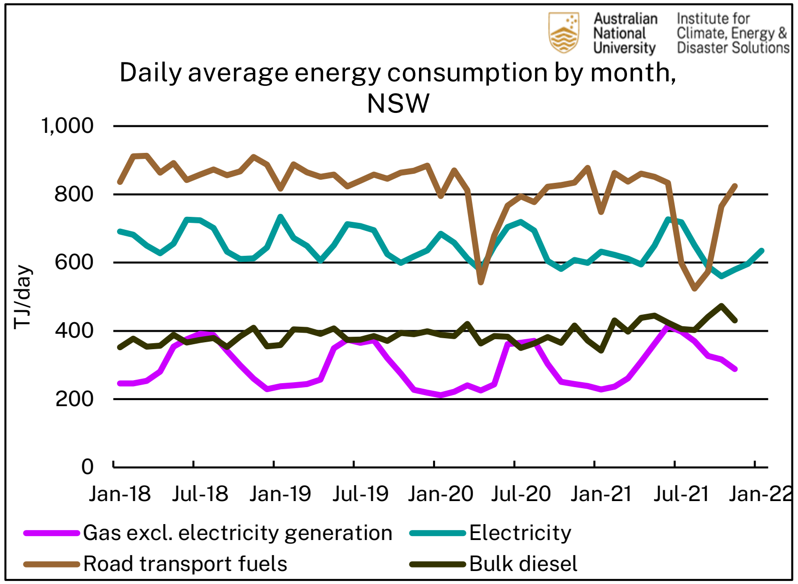


Figure 12: Daily average energy consumption by month, VIC

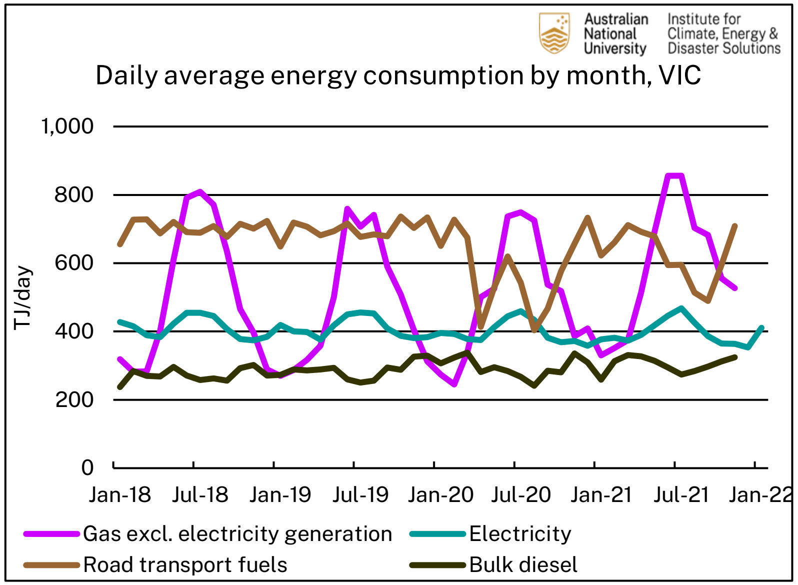
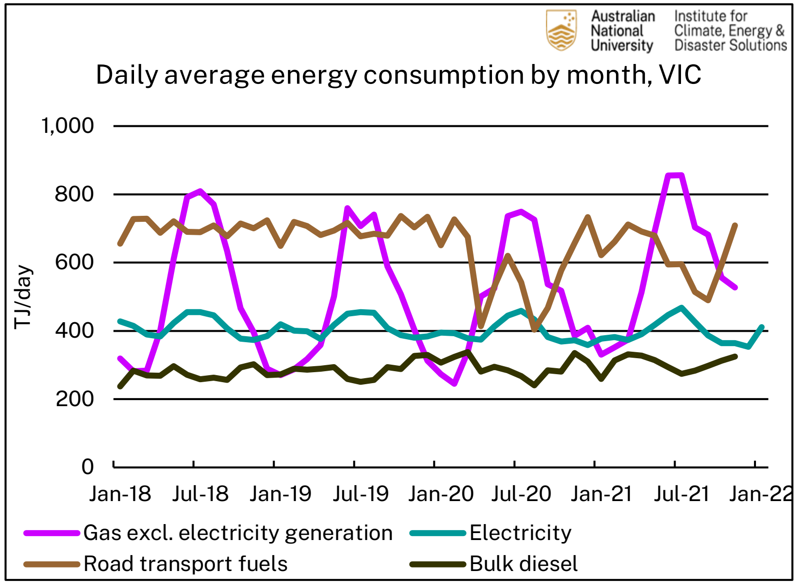


Figure 13: Daily average energy consumption by month, QLD



Consumption patterns of other energy sources differ significantly between the three states. Bulk diesel is used in a wide variety of industries, including agriculture, mining, construction and public transport, all of which have been relatively little affected, in terms of their level of activity, by the pandemic. That is particularly the case for agriculture and mining, which are by far the largest bulk diesel consuming sectors in New South Wales and Queensland. It is the relative level of consumption by these two industries which explains why bulk diesel consumption is so much higher in those two states, particularly Queensland, than in Victoria.

Gas consumption patterns vary even more widely between the three states. In Victoria, buildings, particularly residential buildings, account for the majority of gas consumption, and most gas in buildings is used for space heating, with water heating the next most important use. In New South Wales, which for this purpose includes the ACT, a considerable volume of gas is also used in buildings, again for space and water heating, but far less than in Victoria, both because of climate differences and because a smaller fraction of buildings are connected to gas supply. Manufacturing accounts for over half of total consumption (excluding electricity generation). In Queensland roughly half of all gas consumption occurs at the three LNG plants, and much of the remainder is used in manufacturing.

Electricity consumption in all three states is spread widely across all sectors of the economy. In all three states a significant fraction of electricity is used for space conditioning in both residential and non-residential buildings, and the way this use is affected by climate is seen in the seasonal variation in consumption. In New South Wales, electricity is used for both space heating in winter and cooling in summer, so there are two annual peaks. In Victoria, gas dominates winter space heating, meaning that electricity consumption peaks in summer. Consumption also peaks in summer in Queensland because there is very little demand for winter space heating.

With this background, what conclusions can be drawn about the effect of the pandemic on energy consumption?

First, and most obvious, is the effect on consumption of road transport fuels, which was discussed at length in the December 2021 *Monitor*. Two additional points of interest in the three-state comparison are, firstly, that all three states, including Queensland, experienced a sharp drop in consumption, right at the beginning of the pandemic experience, before individual state responses started to diverge. The second point if that the effect of the lockdown triggered by the Delta outbreak during August to October last year was much deeper, though of shorter duration, in New South Wales than in Victoria.

Consumption of bulk diesel, for the reasons explained above, shows neither an underlying seasonal pattern, not any obvious effect of the pandemic. Month to month variations often reflect the underlying logistics of bulk fuel deliveries to consumers.

Month to month variation in the consumption of gas is dominated by seasonal demand for space heating in Victoria and New South Wales. The only apparent anomaly during the past two years is the much higher winter peak consumption in Victoria during winter 2021, compared with the three preceding winters. Bureau of Meteorology climate data for the past four years provide no indication that winter 2021 was on average any colder than the four previous winters. An alternative explanation for the increased gas consumption is that many more people were working and schooling from home, and/or confined to their homes for other reasons, than in the preceding winter (much more gas is used to heat residential buildings than to heat commercial buildings in Victoria). This hypothesis could only be confirmed or otherwise by examination of data, if it exists, on the numbers and time spent working from home during the two winters. That said, higher gas consumption is also apparent during summer 2020-21, suggesting that other factors may be at work.

For electricity, the main consumption anomalies appear to be the lower levels of consumption over the extended 2020-21 summer months in New South Wales, and to a lesser extent, Victoria. More electricity is used for summer cooling in non-residential buildings than in residential buildings, so reduced summer electricity consumption could well be a consequence of the reduction in all kinds of commercial activities caused by the pandemic. This hypothesis is consistent with the observation that no comparable reduction in summer electricity consumption is seen in Queensland. Interestingly, data to date suggest that electricity consumption in both New South Wales and Victoria may again be lower this summer than in the summers prior to the arrival of the pandemic.

Figure 14: Daily average energy emissions by month, New South Wales

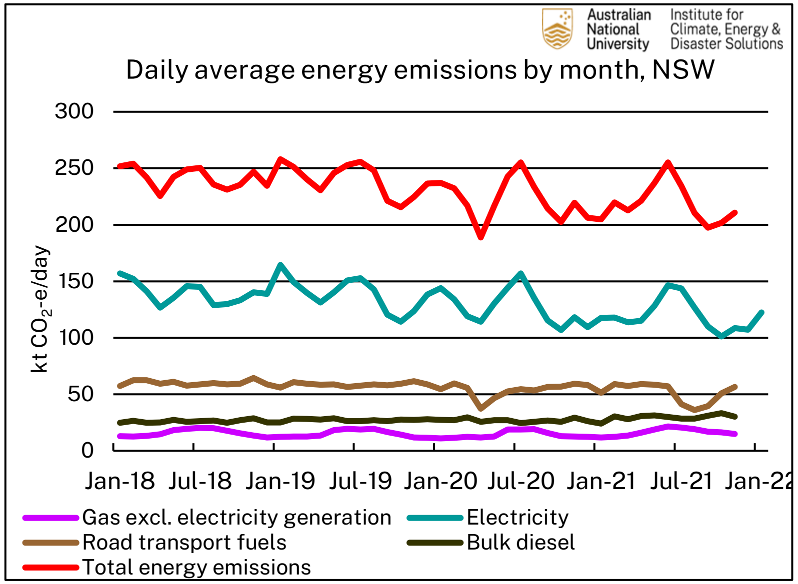


Figure 15: Daily average energy emissions by month, Victoria

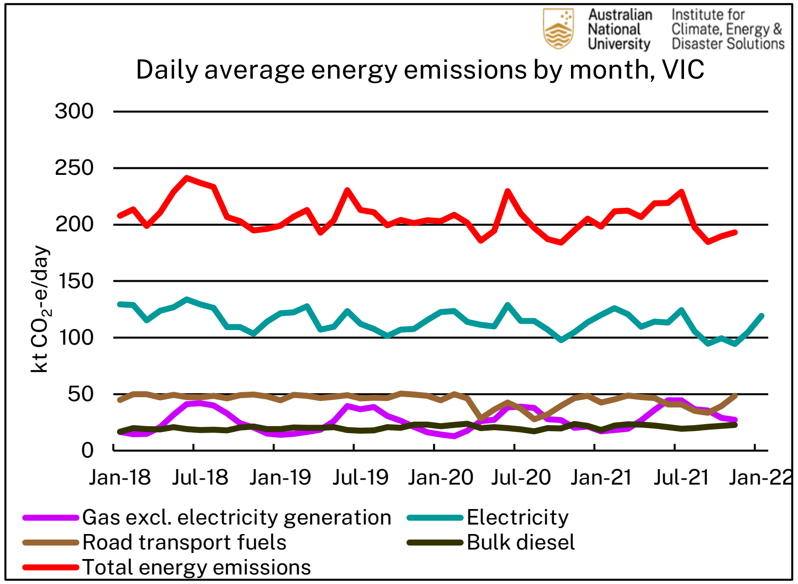
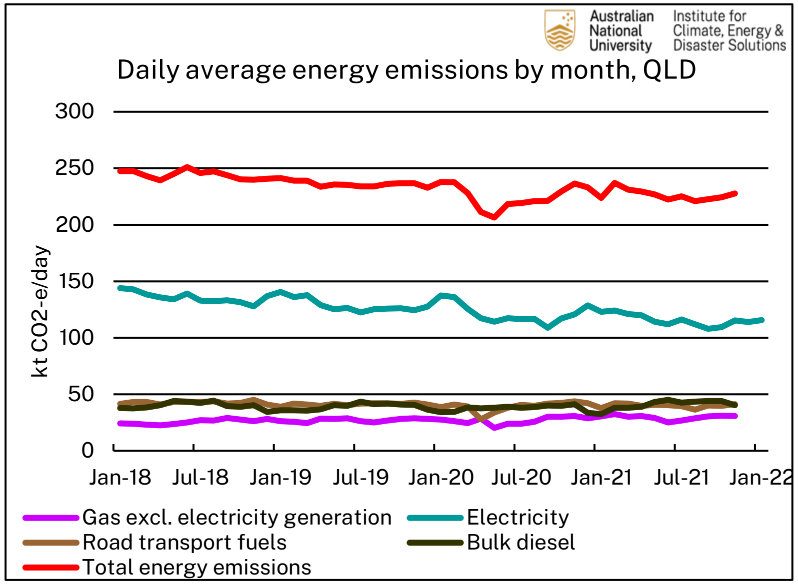


Figure 16: Daily average energy emissions by month, Queensland



Figures 14, 15 and 16 show the continuing dominance of electricity as a source of energy emissions in all three states. One important qualification applies to interpretation of the electricity emissions data: while electricity consumption data in Figure 11 is electricity actually consumed in New South Wales, the emissions data is from electricity generated in the state only. Since New South Wales is a significant net importer of electricity from both Queensland and Victoria, the emissions attributable to electricity consumed in the state are higher than shown in Figure 14. Emissions attributable to electricity consumed in both Victoria and Queensland are correspondingly lower than shown in Figures 15 and 16.

During 2020 it was frequently reported that some other countries, particularly in Europe, were recording reductions in energy combustion emissions as a result of the pandemic. There is no evidence of any such effect in Australia. The only factor definitely contributing to lower energy emissions is the continuing gradual decarbonisation of electricity generation in the NEM.

Appendix: Notes on methodology and data sources

Data on electricity generation and electricity consumption is for the five states constituting the National Electricity Market (NEM) only, i.e. data exclude Western Australia and the Northern Territory. All data are monthly totals, sourced from AEMO, accessed through NEM-Review. Data on gas consumption are also for the five eastern states only; sourced from the Australian Energy Regulator's weekly *Gas Market Report*. The main source of petroleum consumption data is monthly sales of petroleum products, compiled by the Department of Industry, Science, Energy and Resources and published as *Australian Petroleum Statistics*. Unlike the sources used for electricity and gas data, petroleum data covers the whole of Australia at the state level. The emission factors used for petroleum products and gas are based on *National Greenhouse Accounts Factors* and, in the case of petroleum products, are CO_2-emission factors only, because the (much smaller) emission factors for methane and nitrous oxide depend on the type of equipment in which the petroleum products are used.

Many of the graphs in *Australian Energy Emissions Monitor* are presented as moving annual totals. This approach removes the impact of seasonal changes on the reported data. Annualised data reported in *Australian Energy Emissions Monitor* 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 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. Both demand and generation, as shown in the *Monitor* 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. Large users include the three pumped hydro schemes in the NEM, but since these both consume and generate electricity, net consumption, averaged over time, is only the difference between consumption and generation , termed round-trip losses.

Generation is defined to include only electricity supplied by large generators connected to the transmission grid. The numbers reported by AEMO are "as generated" generation, meaning the generation required to supply total demand, including auxiliary loads. However, most of the analysis and results presented in the *Monitor* show sent out generation, meaning as generated generation, minus auxiliary loads. To estimate auxiliary loads, the *Monitor* uses auxiliary load factors for each power station, published by AEMO and used in all its modelling work, including the modelling supporting the Integrated System Plan. Similarly, the Monitor uses AEMO figures for the emissions intensity (emissions per unit generated) of each power station.

Demand 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. This has been growing very rapidly and in the year to December 2021 totalled over 16 TWh. Also excluded is generation from landfill and sewage gas plants, and various other small generators, totalling about 2 TWh. All these types of small generator supply into their local distribution network, not the NEM grid. 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.

Special note for Monitor 2-2022

The analysis of factors contributing to the decrease in emissions from generation in the NEM was undertaken in terms of as generated electricity. As explained above, reduced auxiliary load, energy supplied by rooftop solar and reduced total demand for grid supplied electricity (where total demand includes all electricity used by consumers, including that supplied by embedded generators) all have the effect of reducing the requirement for electricity supplied by grid generators. The contribution of each factor was calculated by holding as generated emissions intensity constant at the June 2008 value and calculating the total emissions with the reduced levels of demand. Finally, the effect of changed generation mix was effectively the residual difference between emissions with reduced demand and actual emissions.