Australian National University

Australian National University Institute for Climate, Energy & Disaster Solutions

Australian Energy Emissions Monitor

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Contents

Key Points

- The most recent data show that moving annual emissions from both electricity generation and other uses of natural gas are both gradually decreasing.
- By contrast, consumption of petroleum products is steadily increasing and seems to have been little affected by the high prices experienced during the period April to July 2022.
- Road transport accounts for over 60% of total consumption of petroleum fuels. Other major consumers are coal mining, all other mining, manufacturing and agriculture.
- On current trends, within less than two years, consumption of petroleum fuels will overtake combined emissions from electricity generation and other uses of natural gas as the largest source of fossil fuel greenhouse gas emissions in eastern Australia.
- In the year to February 2023, renewable generation supplied 30% of grid scale electricity generated in the NEM, 68% in South Australia, 32% in Victoria, 24% in New South Wales, and only 14% in Queensland. The corresponding share of the SWIS in Western Australia in the year 2021-22 was 22%.
- On the basis of these figures, Victoria is likely to achieve its legislated renewable generation target shares. However, Queensland, because it started so much later than all other states, is likely to find it difficult to achieve its recently announced, but yet to be legislated, target.
- Total electricity emission reductions between 2015-16 and 2021-22 show a similar pattern: NEM 23%, South Australia 58%, Victoria 32%, Western Australia 24%, New South Wales 16%, and Queensland 13%.
- During the seven months starting August 2022, i.e. since extremely high wholesale electricity prices came to an end, volume weighted spot wholesale prices have been consistently up to $40 per MWh lower in Victoria and South Australia than corresponding prices in New South Wales and Queensland. In other words, the states with higher shares of wind and solar generation have had consistently much lower wholesale prices.

Introduction to the March 2023 issue

Welcome to the March 2023 issue of the *Australian Energy Emissions Monitor*, which is a publication of the ANU Institute for Climate, Energy and Disaster Solutions (ICEDS), 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 contains three sections. The first section, common to every issue, updates trends in energy consumption and the consequent fossil fuel emissions, using the most recent monthly data available at the start of March. This means electricity consumption and emissions to the end of February, and consumption of and emissions from petroleum products and natural gas to the end of November 2022.

The second section updates a set of graphs which summarise progress in the transition of Australia's electricity supply system, state by state, towards zero emission over the longer term (for some states since 1999-2000). The data are for the NEM as a whole, each individual state (region) in the NEM and for the South West Interconnected System (SWIS) in Western Australia. The last full year shown in the graphs is 2021-22, but NEM data is extended in tabular format to the year ending February 2023.

The third section shows monthly volume weighted average spot prices in each of the mainland NEM states from August 2022 to February 2023. The data show some interesting relationships between spot prices in each of the four states and between spot prices and shares of renewable generation.

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

Update on energy combustion emissions in eastern Australia

Figure 1 updates the trend in annual emissions in eastern Australia, i.e. Australia excluding Western Australia (WA) and the Northern Territory, arising from energy consumption to the end of March 2023 in the case of electricity generation, and to the end of November 2022 for gas and petroleum product emissions. The steadily declining trend in emissions from coal and gas used to generate electricity continues and other uses of gas also continue to decline, as they have been since December 2021, though that is harder to see on the graphs. Emissions from use of petroleum fuels increased sharply, though in the graph total that is hidden by the decrease in emissions from electricity and gas.

Currently, emissions from combustion of petroleum products are steadily increasing, while electricity generation emissions and emissions from all other uses of natural gas are both decreasing. If the respective rates of increase and decrease between May and November 2022 continue for the next year or so, the use of petroleum products (other than for electricity generation) will contribute more to Australia's energy combustion emissions than electricity generation by March 2024. A few months after that, petroleum emissions will exceed combined emissions from electricity generation and all other uses of natural gas.

Table 1, derived from *Australian Energy Statistics* for the year 2020-21, shows the shares of total petroleum consumption in Australia attributable to each end use activity, i.e. excluding petroleum refining. Shares of emissions will not differ greatly from shares of consumption.

Table 1: Shares of petroleum product consumption, Australia 2020-21

End use sector	Share of total consumption
Road transport	61%
Manufacturing	7%
All other mining	7%
Coal mining	7%
Agriculture	6%
Domestic aviation	4%
Rail transport	3%
Commercial and services	2%
Construction	1%
Coastal shipping	1%
Residential	1%

Given the enormous contribution of petroleum product consumption to Australia's total greenhouse emissions, it is striking that during the nearly nine months since the change in federal government, serious and comprehensive policy discussion about the problem of petroleum emission has been almost non-existent.

Figure 1: Moving annual energy combustion emissions, eastern Australia, 2014-2023

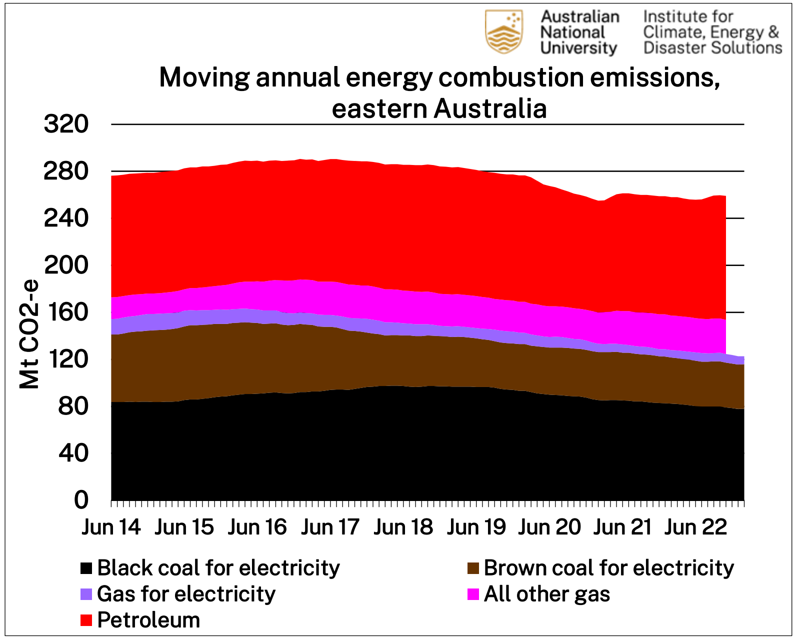


Figure 2: Moving annual energy consumption, eastern Australia, 2011-22

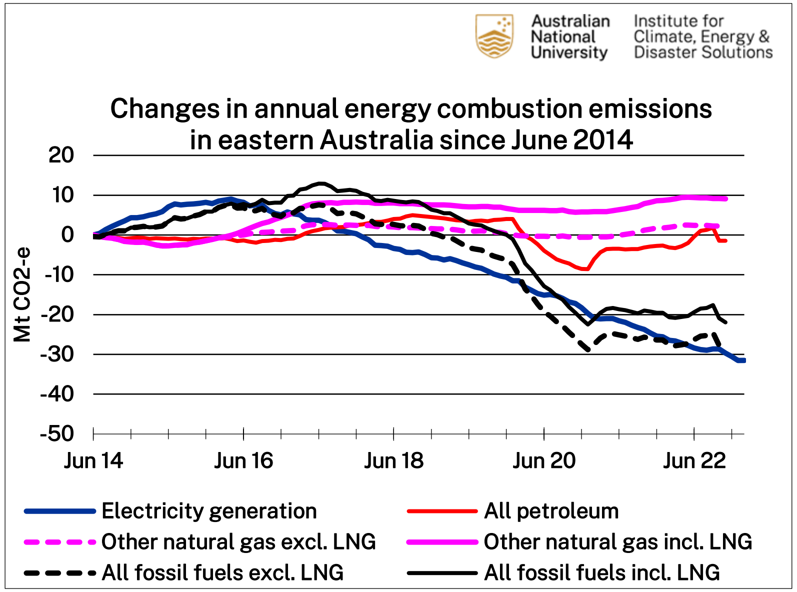
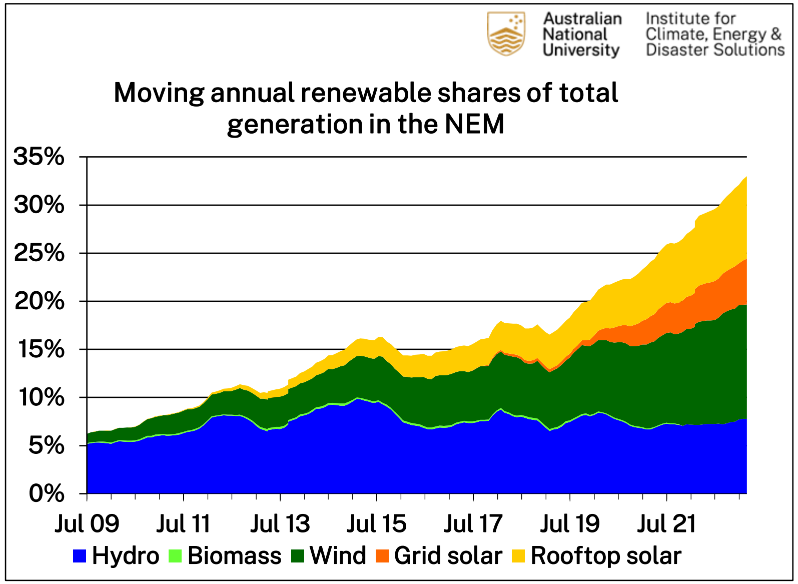


Figure 2 shows the same data, but expressed as changes since June 2014. For electricity, emissions have been in steady decline, once the industry recovered from the Abbott government's removal of the price on emissions and the subsequent unsuccessful attempt to abolish the Renewable Energy Target. For gas, the effect on emissions of LNG production is easy to see. Also easy to see is a sharp increase in emissions from use of petroleum fuels during 2021 as air and passenger vehicle use reverted to their pre-pandemic levels. Since then, rather than levelling out, petroleum fuel consumption has shown slow but steady growth.

Figure 3 shows, on a moving annual basis, the various components of renewable generation in the NEM since July 2009. It is the growth in this generation which, since 2016, has been displacing coal, and some gas generation, thereby causing the steady fall in electricity generation emissions shown in Figure 2.

Figure 3: Moving annual energy consumption, eastern Australia, 2009-22



Electricity system transition in Australia: state by state assessment

The April 2022 *Monitor* included a section containing graphs of annual electricity supplied by fuel/technology in each state of the NEM and also in the South West Interconnected System (SWIS) of Western Australia, through which the great majority of consumers in the state are supplied with electricity. SWIS data is sourced from National Greenhouse and Energy Reporting System (NGERS) public information, which is published with a lag of eight months. For that reason, in order to present the electricity system transition in each state on the same basis, the last year shown in April 2022 was 2020-21. In this *Monitor* all graphs are updated to end in 2021-22.

Readers will recall that the December 2022 *Monitor* included graphs of monthly average generation by each generation type, from January 2016 to September 2022, for the whole NEM and for each of the four mainland states (NEM regions). The purpose of these graphs was to show how seasonal conditions affect both total electrical energy consumed and also the mix of generation types supplying this consumption. The graphs also show the transition towards greater shares of renewable generation, but not very clearly.

The set of graphs which follow show the transition much more clearly, and over a considerably longer period. The graphs are relatively complex, as they show annual data for:

- the quantities of electricity supplied in the state by each fuel/type of generator,
- total electricity consumption (including the contribution of net imports/exports),
- annual greenhouse gas emissions, and
- annual volume weighted spot wholesale price, as calculated by the Australian Energy Regulator (AER).

Note that in the graphs for the four NEM states, the gap between sent out generation and consumption represents net imports from/exports to neighbouring states over the year.

Graphs for the four mainland NEM states start in 1999-2000, the first full year of NEM operation (and before Tasmania joined). The graph for the NEM as a whole starts in 2005-06, the first full year in which Tasmania participated. There is no graph for Tasmania itself, since it has been effectively 100% renewable throughout. The first full year of availability of SWIS data is 2012-13

Figure 4: Electricity system transition in the NEM as a whole

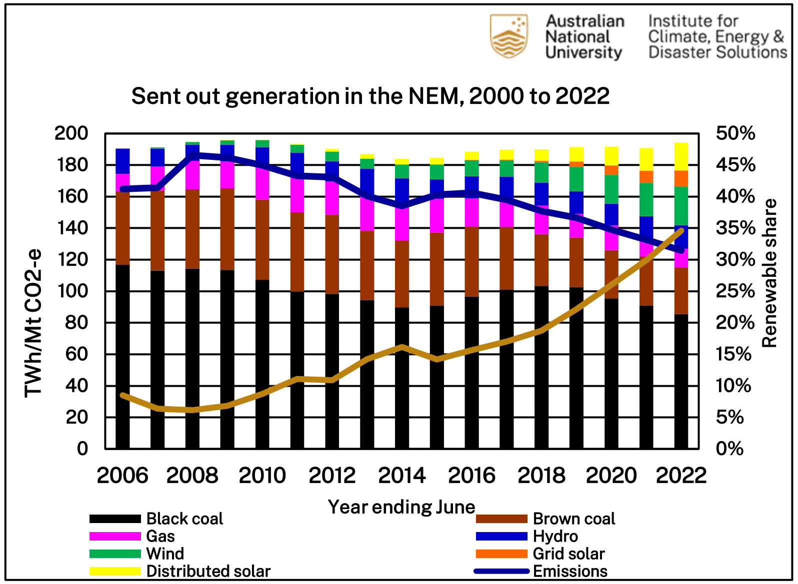


Figure 5: Electricity system transition in South Australia

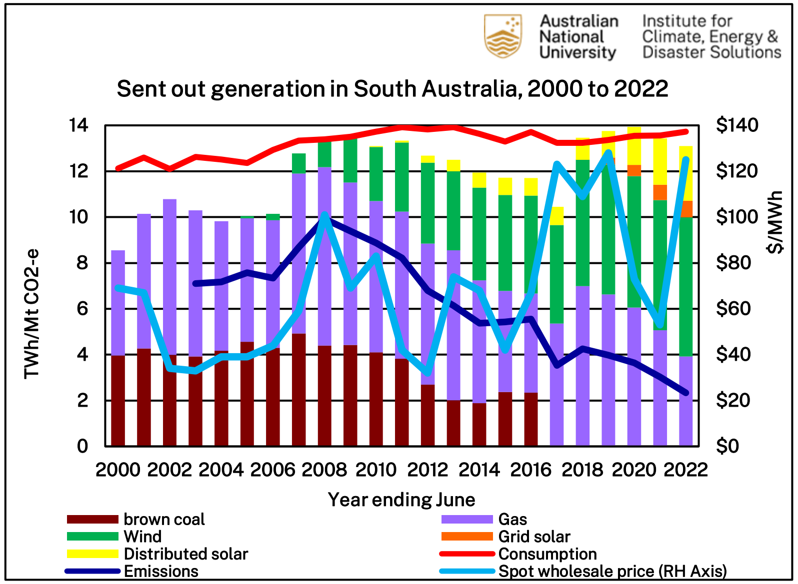


Figure 6: Electricity system transition in Victoria

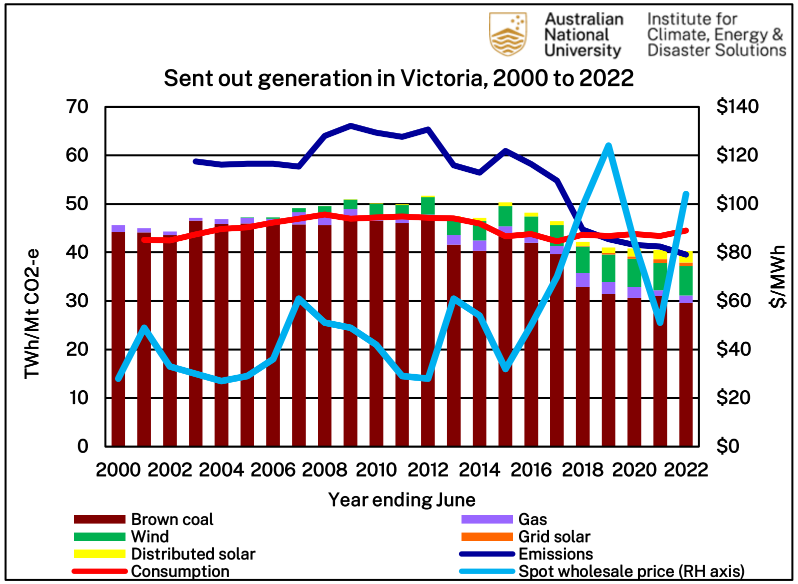


Figure 7: Electricity system transition in New South Wales

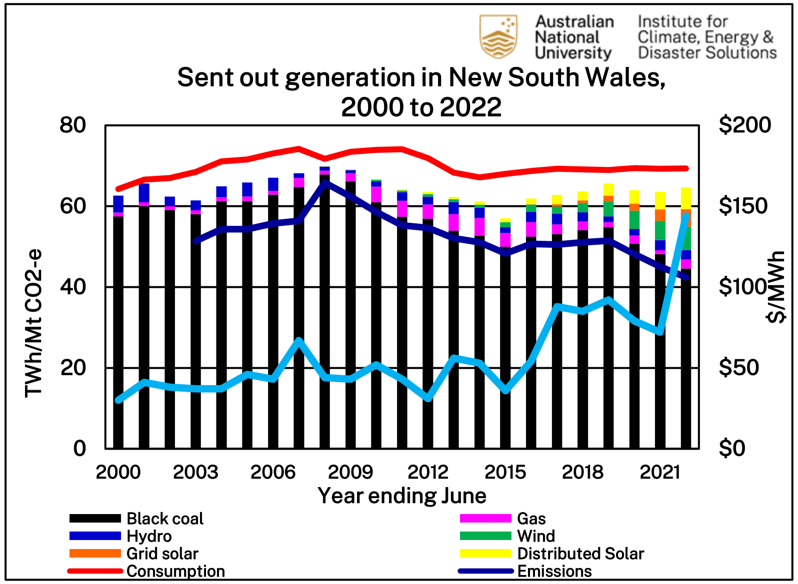


Figure 8: Electricity system transition in Queensland

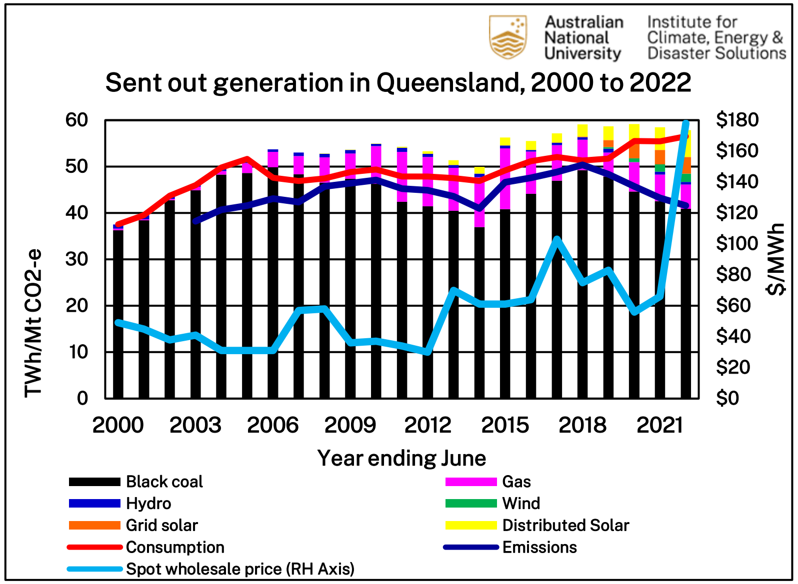
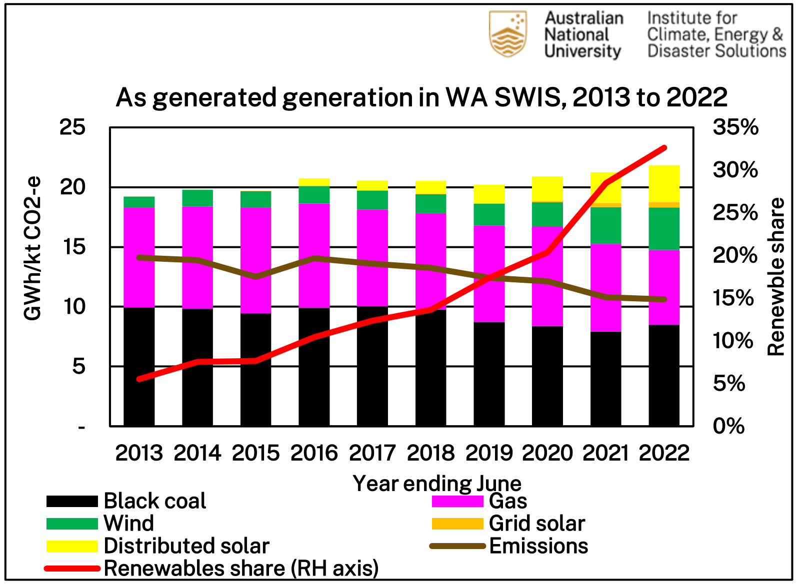


Figure 9: Electricity system transition in WA SWIS



The following tables summarise the comparative transition performance of the five states and the total NEM. All graphs run from 2015-16 to 2021-22. 2015-16 is chosen as the starting year, because that was the year when the Abbott government's attempt to abolish the Renewable Energy Target (and thereby remove the main driver of electricity system transition at that time) effectively ended. It was also the time at which the state governments of New South Wales and Victoria joined South Australia in developing explicit state level policies to increase the shares of renewable generation in their respective states.

Table 2 shows renewable generation shares including generation by distributed (rooftop) solar systems. That means that they include renewable generation attributable, to varying degrees, to explicit state government policies and programs, plus renewable generation attributable to the decisions of individual electricity consumers, financially supported through the Commonwealth Small Renewable Energy System scheme (SRES).

Table 2: Increase in shares of renewable generation from all sources, 2015-16 to 2021-22

State	Share 2015-16	Share 2021-22	Relative increase	Share year to Feb. 2023
Total NEM	16%	34.6%	121%	37.1%
South Australia	43%	70.0%	63%	74.1%
Victoria	14%	35.5%	148%	37.9%
New South Wales	9%	27.7%	192%	31.0%
Queensland	5%	20.4%	340%	23.0%
SWIS	10%	33%	213%	NA

Note that generation data for the SWIS is expressed in *as generated* terms, whereas all NEM generation data are in *sent out* terms. The difference between the two measures is electricity generated in (mainly) thermal power stations that is used within the stations, termed auxiliary load. The effect is that renewable shares for the SWIS shown here are perhaps one percentage point lower than they would be if calculated on a *sent out* basis.

Table 3 shows only the shares of large scale renewable generation. The Victorian renewable energy target legislation defines large-scale renewable generators as all generators larger than 100 kW capacity, which means all which are supported through the Large Renewable Energy Target (LRET), plus hydro generators built prior to the introduction of the LRET.

Table 3: Increase in shares of renewable generation from large-scale sources, 2015-16 to 2021-22

State	Share 2015-16	Share 2021-22	Relative increase	Share year to Feb. 2023
Total NEM	13%	28.2%	112%	30.1%
South Australia	39%	63.4%	62%	68.2%
Victoria	13%	30.1%	138%	32.4%
New South Wales	7%	21.1%	186%	23.7%
Queensland	1%	11.6%%	850%	13.6%
SWIS	8%	22%	186%	NA

For reference, the legislated Victorian renewable generation targets are 40% by 2025 and 50% by 2030. Queensland recently announced a plan to increase its renewable generation share to 50% by 2030, together with its intention to legislate this target. Compared with the Victorian target, the Queensland target would appear to be a major challenge, given how far the state has lagged the rest of Australia until recently.

New South Wales does not have renewable generation targets, but capacity targets, the volume of generation supplied from which will of course depend on the performance of each of the new generators, and the proportions of wind and solar. The most recent target, announced last year, was an additional 12 GW of large-scale renewable generation by 2030. If, for example, the new generators in total achieved an average annual capacity factor of 30%, an additional 32 TWh of renewable electricity would be generated. That is almost exactly equal to half of the total electricity consumption in the state, excluding consumption of distributed solar, in 2021-22.

Finally, Table 4 shows the electricity generation emission reductions achieved in each state from 2015-16 to 2020-21. Unsurprisingly, the states with the fastest growing shares of renewable generation achieved the largest emission reductions.

Table 4: Decrease in emissions, 2015-16 to 2021-22

State	Decrease
Total NEM	-23%
South Australia	-58%
Victoria	-32%
New South Wales	-16%
Queensland	-13%
SWIS	-24%

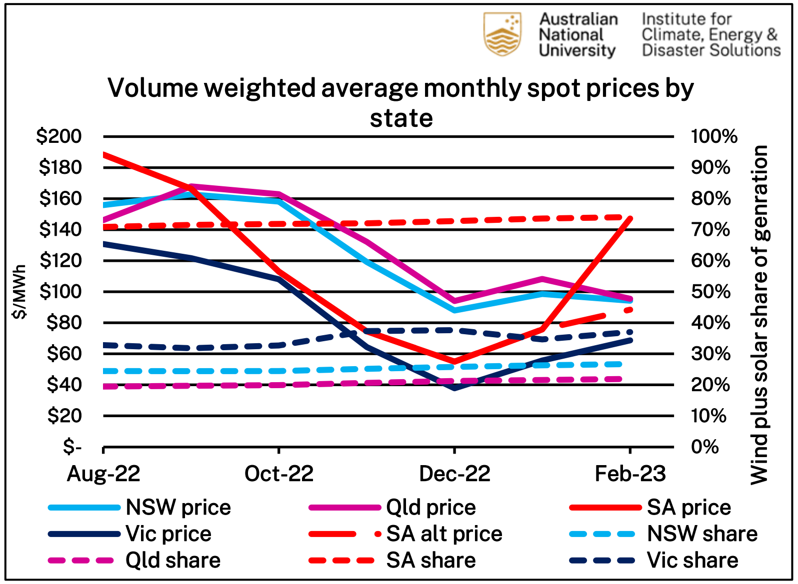
Recent wholesale prices in the four mainland NEM states

As has been widely reported, wholesale prices in the period from April to July 2022 reached very high levels, as a result of the disruption to global energy markets caused by the Russian invasion of Ukraine. In August 2023, however, prices fell back to the sort of levels shown in the years prior to 2022, as shown in Figures 5 to 8 above, or lower. Volume weighted average monthly prices from August 2022 to February 2023 are shown in Figure 10, together with the average monthly shares of combined wind and solar grid generation in each of the four mainland states.

A fairly clear and consistent pattern can be seen in the data. New South Wales and Queensland, the two states with lower renewable generation shares and greater dependence on coal, have higher and generally quite similar wholesale prices. Victoria and South Australia, with higher renewable generation shares, have considerably lower wholesale prices which are also, for much of the period, quite close.

In general terms, the reasons for the consistent relationship in New South Wales and Queensland is that for much of the time the marginal source of supply, which sets the price for each trading interval, is one of the coal fired generators in each state. Marginal costs of New South Wales generators are normally slightly higher than those of Queensland generators. However, Queensland has suffered from significant unavailability of some of its coal capacity over the period and, in addition, large net exports from Queensland to New South Wales have been a consistent part of the relationship between the two states.

Figure 10: Monthly volume weighted average wholesale prices and renewable generation shares, since August 2022



In Victoria, brown coal generators, which have lower short-run marginal costs than black coal generators, are often the marginal supply, giving Victoria an immediate price advantage over New South Wales and Queensland. In addition, the larger shares and faster growth of wind and solar generation in Victoria are steadily eroding the influence of brown coal generators over wholesale prices. That is of course even more strongly the case in South Australia. However, during the winter months when total renewable generation is lower, South Australia is more reliant on gas generation, which is, of course, considerably more expensive than coal generation. That accounts for the much higher average price in August, when gas supplied 26% of generation, a share which fell to 12% in December.

Linkage through the two interconnectors between Victoria and South Australia is also a key factor affecting the close price relationship. In total over the longer term, Victoria is a net exporter to South Australia. There are, however, many occasions when South Australian wind and solar generation exceeds total state demand, meaning that the excess supply can be exported to Victoria.

Finally, the large increase in volume weighted average price in South Australia was the consequence of very high electricity demand on three extreme heat wave days – 9, 16 and 23 February. During several trading periods on these three days, spot wholesale prices rose to very high levels (over $8,000/MWh during one period on 16 February). The alternative SA price line in Figure 10 shows the effect on average monthly price of removing just the 12 highest-priced periods out of the 1,344 pricing periods in the month.

A similar extreme price effect occurred in New South Wales on 5 March. On all these occasions in both states, the Australian Energy Market Operator (AEMO) was able to ensure that supply to all electricity consumers was uninterrupted, i.e. load shedding (blackouts) was avoided, without having to depend on voluntary demand reduction by large demand side market participants.

As this issue of the *Monitor* was being finalised, the Australian Energy Regulator (AER) announced its draft Default Market Offer prices for retail consumers supplied by each of the regulated distribution networks in New South Wales, Queensland and South Australia during 2023-24. The Victorian Essential Services Commission did the same for the five distribution networks in the state. Default Market Offer prices effectively function as a maximum cap on prices - a retailer can charge. Electricity retailers offer a wide array of market prices which are lower than the Default Market Offer, and the great majority of electricity consumers are on contracts priced below the Default Market Offer.

It is important to understand that the wholesale component of Default Market Offer is not the same as the ex post spot prices shown in Figure 10. Rather, they are ex ante prices, based mainly on ASX electricity futures prices, which are higher than spot prices because they include the cost of hedging against risk and uncertainty. Wholesale prices faced by each retailer are also significantly affected by load shape, relative demands of their customer base at different times of the day and in different seasons of the year.

Considerable publicity has been given to the announcement of these Default Market Offer prices, mainly noting that the draft prices are significantly higher than those for 2022-23 (based mainly on the expectation of further turbulence in global coal and gas markets). Some of the commentary has also observed that the draft price for South Australian Power Networks (SAPN - the sole distributor in the state) is higher than corresponding prices for most of the network businesses in other states. It is important to understand that these higher prices are not a consequence of expected higher wholesale prices in South Australia, but because of higher distribution costs of SAPN, which has a higher proportion of lightly loaded power lines in rural areas than most of the other networks regulated by the AER. Of these network businesses, only Essential Energy in New South Wales has a higher proportion, and the draft price set for Essential is even higher than that for SAPN. (Ergon Energy in Queensland has an even higher proportion.)

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 Australian Energy Market Operator (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 the *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, and 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.

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. This includes 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 generators 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.