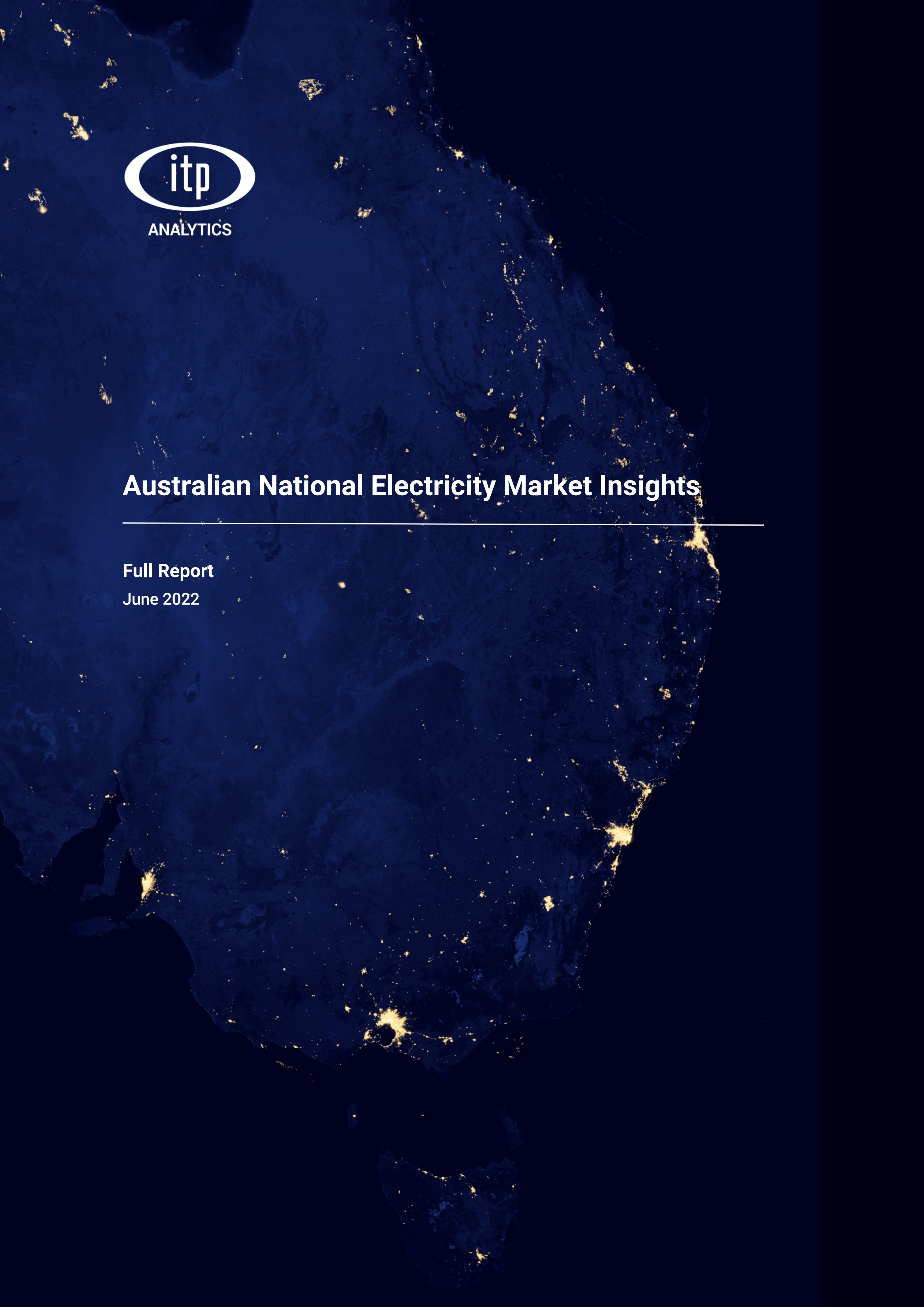


ANALYTICS

Australian National Electricity Market Insights

Full Report

June 2022

About Us

ITP Analytics offers a range of consulting services in energy market analytics:

National and state-wide capacity expansion modelling – revealing least-cost energy transition pathways and delivery cost forecasts, facilitating the testing of regulatory reform and the implications of technological change.

Distribution level capacity expansion modelling – analysing the implications of DER uptake (including EVs) and policy measures driving the gas to electricity transition.

Mini- and micro-grid feasibility and optimisation – collaboratively with our engineering division, taking into consideration trends such as falling storage costs, emerging regulatory reform to drive fringe-of-grid disconnection and novel ownership models.

Generation and storage project feasibility and optimisation – using sophisticated, bespoke modelling tools to assess the optimal management of generation, storage, and loads, taking into consideration complex tariff structures.

Regulatory environment analysis – providing recommendations to government about reform processes or opportunities, and advice to industry about the implications of forecast change.

Find more about our recent and ongoing work at itpau.com.au/projects.

Contact

ITP Analytics
Level 1, 19-23 Moore St
Turner ACT 2612

info@itpau.com.au

itpau.com.au

Contents

Introduction

ITP Analytics is publishing quarterly reports analysing potential pathways for the transition of the Australian National Electricity Market (NEM). Our intent is to inform policy-making and public discussion. This report is the second of the series.

The analysis published in each report will be based on results produced by our open-source Capacity Expansion Model (openCEM). openCEM is a freely available electricity grid modelling tool developed by ITP. It is designed to be used by decision makers, energy system planners, regulators, project developers, and investors to determine how policy objectives such as electrification, renewable energy, or emission reductions targets can be achieved at the lowest cost, while maintaining energy security. For a given policy objective, it reveals:

- when, where, what type and how much generation, storage and transmission capacity should be added;
- how new generation and storage need to be operated in coordination with existing generation capacity to satisfy demand at the least cost.

Model outputs include all capacity and dispatch decisions for the system under consideration, as well as a breakdown of capital and operating costs, utilisation, capacity, energy, and transmission statistics.

Each quarterly report has two parts. The first part will describe how the NEM may transition to an increasingly renewable energy future using illustrative scenarios based on the most popular alternative policies that represent the current political spectrum. These scenarios will be revised each quarter with updated input assumptions.

The second part of the report will be a more in-depth study of a specific topic of interest. In this report we examine the employment indications of some of the policies in Part 1, including how many and what kinds of jobs will be created and lost under each scenarios.

The development of openCEM was partially funded by the Australian Government (ARENA) and the Governments of NSW, Victoria, and South Australia. Our development partners were the Centre for Energy and Environmental Markets at the University of New South Wales; the Climate and Energy College at the University of Melbourne; software development specialists ThoughtWorks, and the US Strategic Energy Analysis Center of the National Renewable Energy Laboratory.

Further detail about how openCEM operates is available in Appendix C and at opencem.org.au.

In this report we have included detailed openCEM output, including electricity delivery cost forecasts for each State. In future reports this, and more detailed and granular information, including retail and spot price forecasts, will be available via subscription.

Policy Comparison

Introduction

In this section, we compare five scenarios:

- The 2020 Integrated System Plan (ISP) Step Change scenario, which at the time of publication was considered the most likely future scenario by the Australian Energy Market Operator (AEMO).
- The 2020 Integrated System Plan (ISP) Step Change scenario, with higher coal and gas prices, predicted by recent analysis.
- Three scenarios based on the most popular alternative policies that represent the current political spectrum; net-zero emissions targets in the electricity sector of 2050, 2040, and 2030.

Inputs

The table below summarises the key points of difference for each scenario.

Scenario	Net Zero Year	High Coal & Gas Prices
Step Change		
Step Change with High Coal & Gas Prices		✓
Net Zero by 2050	2050	✓
Net Zero by 2040	2040	✓
Net Zero by 2030	2030	✓

Coal and gas prices come from predictions from the World Bank[1] and the Australian Competition and Consumer Commission[2] based on recent increases and changes in the market due to international events in Europe and elsewhere:

AEMO ISP	ITP Estimates

Year	Black Coal (AUD/t)	Black Coal (AUD/GJ)	Increase over ISP	Gas (AUD/GJ)	Increase over ISP
2022	173.28	10.70	465%	27.91	256%
2023	129.96	4.56	196%	27.49	250%
2024	124.76	4.38	189%	23.43	211%
2025	119.71	4.20	183%	21.46	191%
2026	115.26	4.04	177%	19.48	172%
2027	110.81	3.89	172%	17.51	153%
2028	106.37	3.73	161%	15.54	135%
2029	101.92	3.58	149%	13.56	118%
2030	97.47	3.42	143%	11.59	100%
2031	93.86	3.29	138%	11.71	100%
2032	90.25	3.17	134%	11.84	100%
2033	86.64	3.04	129%	11.93	100%
2034	83.03	2.91	124%	11.97	100%
2035	79.42	2.79	119%	12.01	100%
2036	62.91	2.33	100%	12.08	100%

[1] https://thedocs.worldbank.org/en/doc/ff5bad98f52ffa2457136bbef5703ddb-0350012021/related/CMO-October-2021-forecasts.pdf
[2] https://www.accc.gov.au/regulated-infrastructure/energy/gas-inquiry-2017-2025/lng-netback-price-series

2037	62.10	2.30	100%	12.13	100%
2038	61.56	2.28	100%	12.16	100%
2039	60.75	2.25	100%	12.18	100%
2040	60.48	2.24	100%	12.21	100%
2041	60.21	2.23	100%	12.23	100%
2042	60.21	2.23	100%	12.25	100%
2043	60.21	2.23	100%	12.26	100%
2044	60.21	2.23	100%	12.28	100%
2045	60.21	2.23	100%	12.30	100%
2046	60.21	2.23	100%	12.32	100%
2047	60.21	2.23	100%	12.34	100%
2048	60.21	2.23	100%	12.36	100%
2049	60.21	2.23	100%	12.38	100%
2050	60.21	2.23	100%	12.40	100%

Brown coal is used in only 3 power stations in Australia, all in Victoria — Loy Yang A, Loy Yang B, and Yallourn. This brown coal is not exported from Australia, and prices are not published or forecasted. Due to this, we have not changed the brown coal price from the AEMO ISP for our modelling for this report.

All scenarios use the same base inputs from the 2020 AEMO ISP:

Input	Source
Electricity Sector Carbon Budget	Step Change Scenario (891 Mt CO2-e from 2024–2050)
Technology Costs	
Generator Retirements	
Transmission Builds	

AEMO ISP Scenario

In consultation with Australia's major electricity market stakeholders, the Australian Energy Market Operator (AEMO) has found that their Step Change scenario, a high-renewables, aggressive fossil fuel retirement objective, is the most likely pathway forward for the Australian electricity market. We based price pathways on the Step Change scenario for fuel, technology builds and maintenance, and technology adoption speed. 2022 AEMO ISP scenarios are still under review, so 2020 Step Change assumptions were used for the modelling in this report.

Emissions

Net-zero emissions targets were implemented as a constraint of zero tonnes of emissions in the year that the policy aims for. The Federal emissions target for each scenario is taken from the 2020 AEMO ISP Step Change scenario, which is a value determined by the CSIRO to restrict global warming to 1.8ºC by the year 2100.

Economy-wide net-zero targets differ in timing from net-zero targets in the electricity sector. 100% renewables in the electricity sector implies that the sector is also producing net-zero emissions. Generally, policies have more ambitious net-zero targets for the electricity sector than the rest of the economy, as it is simpler and less costly to reduce emissions in the electricity sector.

Results

Marginal Cost of Delivery

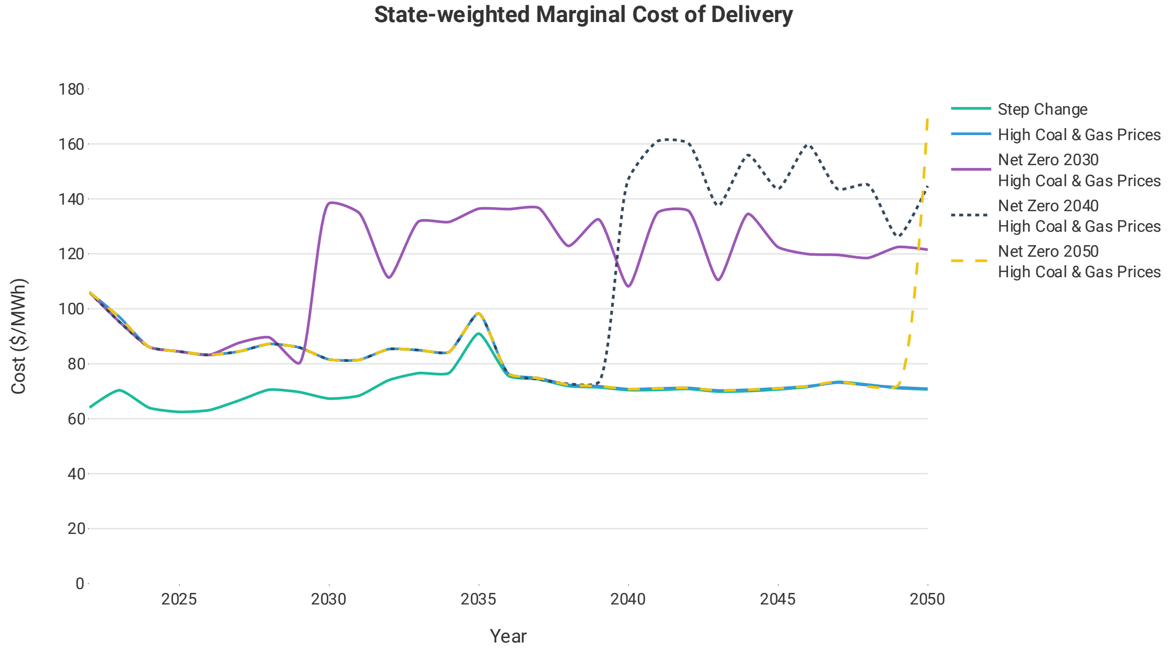


Figure 1: State-weighted marginal cost of delivery

openCEM calculates a marginal cost of dispatching each technology based on its fuel costs, other operating costs, repayment costs, and a profit margin, and makes a "stack" of prices for each timestep based on this. As there are no competitive market mechanisms, this is not the same as a spot price in the actual market, but it offers a way of comparing the cost of delivering electricity for each scenario. It can be construed as a proxy for wholesale prices because it embodies a combination of short and long running marginal costs for the system.

Figure 1 shows the average of all the regional marginal prices in a year, weighted by the total demand in each region. Peaks in the delivery cost occur at different times for each scenario. For example, in the Net Zero 2030 scenario, the delivery cost increases significantly in 2030, when the model must achieve 100% renewables. In the years before 2030, substantial wind, solar, and battery capacity is built to achieve this, and the additional build repayment costs contribute significantly to the higher delivery cost from 2030 onwards (refer to Figure 6 for cost breakdown information).

The other scenarios follow this trend. In the Net Zero 2040 and 2050 scenarios, reaching net zero in 2040 and 2050 requires substantial expenditure on renewables and storage in the years leading up to those years, so the delivery cost peaks then.

The Net Zero 2030 scenario maintains a lower cost of delivery once it has reached net zero than the Net Zero 2040 scenario, when it has reached net zero, as the Net Zero 2030 scenario builds more transmission earlier on, allowing for more efficient builds and use of generators in later years.

Technology Mix

In 2050, the technology mix is almost identical in all scenarios with a net-zero emissions constraint, as all scenarios are satisfying the same demand growth. This results in the total system cost converging in 2050 for all but the scenarios with no net zero target. openCEM arrives at roughly the same technology mix in every scenario with a net-zero constraint in 2050, regardless of the starting point.

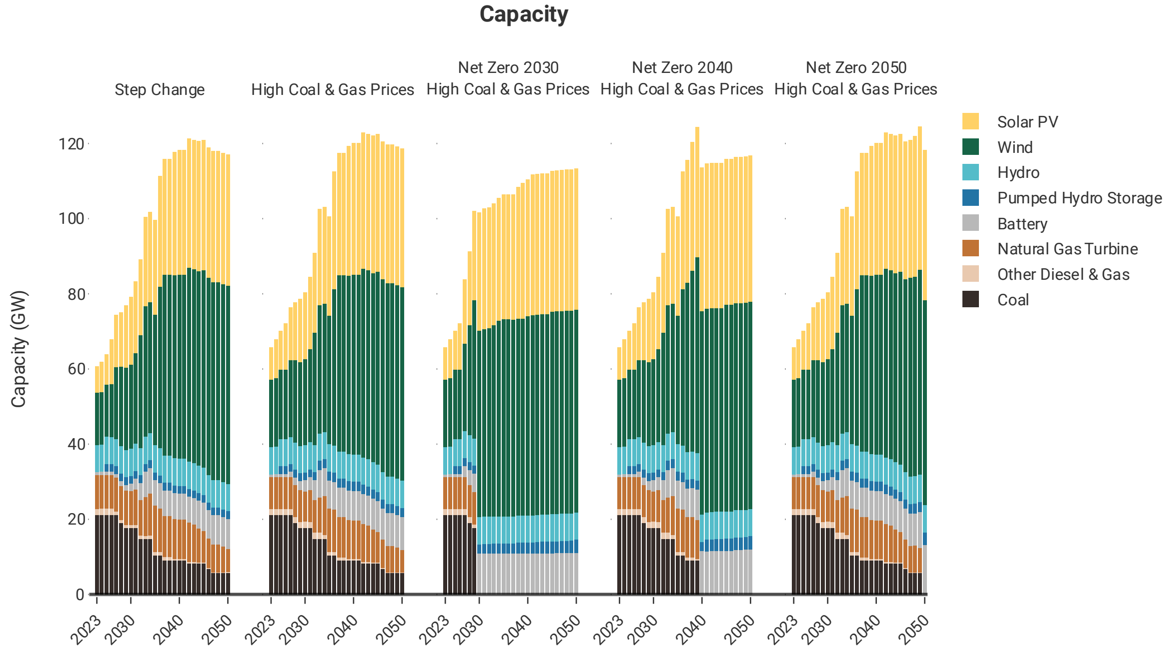


Figure 2: Capacity by scenario

In Figure 3 below, bars above zero indicate that the comparison scenario has built more of that technology than the Step Change base case, and bars below zero indicate that it has built less.

High coal and gas prices result in slightly less natural gas turbines being built than in the base case, and approximately 7 GW of wind and solar are brought forward into the period from 2022 to 2025. By the 2040s, the high fuel prices result in slightly more solar, pumped hydro, and batteries in the NEM, and slightly less wind than the base case.

When a net zero 2030 target is added to high coal and gas prices, significantly less natural gas turbines are built, and they are replaced by 50 GW of wind, solar, and battery builds being brought forward to the late 2020s and early 2030s. The result at the end of 2050 is more solar, wind, pumped hydro, and 4 GW more batteries than the base case, with 5 GW less natural gas.

The net zero 2040 target with high coal and gas prices results in the same bringing forward of wind, solar, and battery builds, with less difference to the base case, as by 2040 the Step Change scenario used for the base case has already built significant renewable capacity. By the same mechanism, the net zero 2050 target with high coal and gas prices results differs from the same scenario without a net zero target only in 2050.

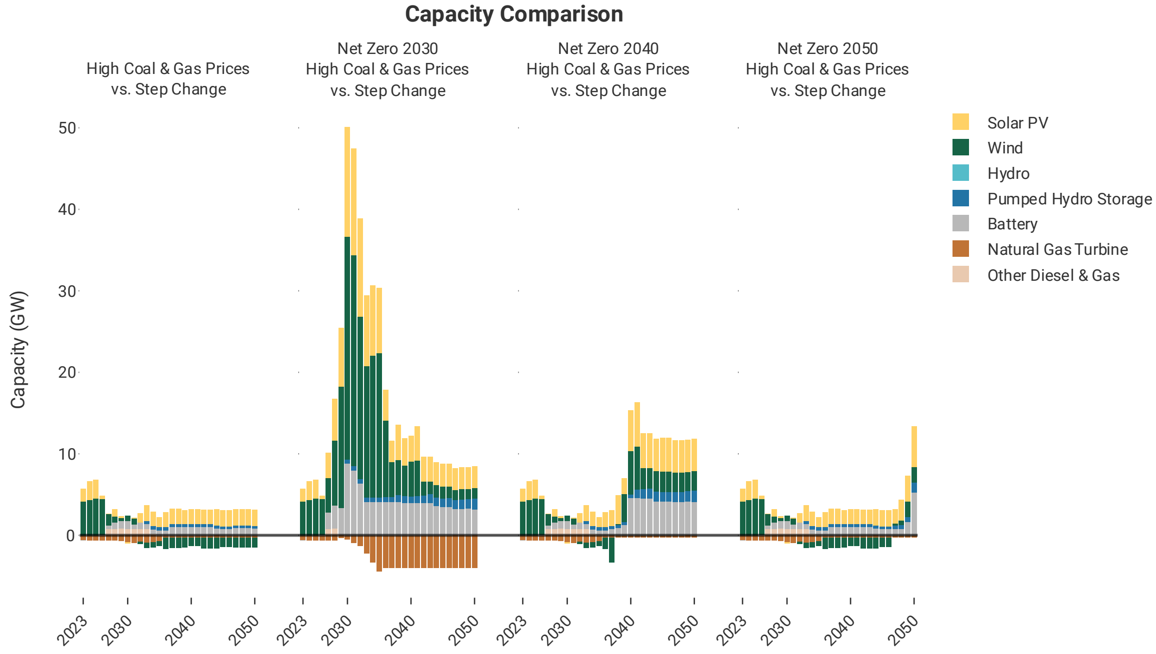


Figure 3: Capacity comparison by scenario

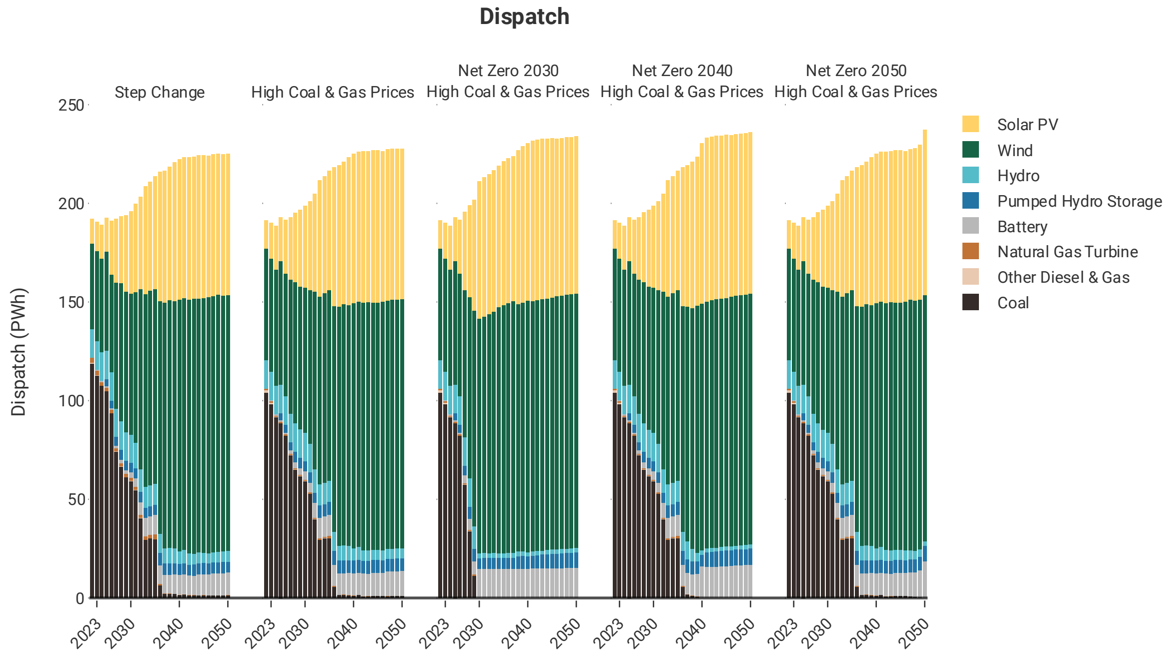


Figure 4: Dispatch by scenario

Figure 5 below illustrates the difference in dispatch of technologies between each scenario and the base case. High coal and gas prices reduce the amount of coal and gas generation that is used in the years where the prices are higher, and an increase in dispatch of renewable wind, solar, and batteries. In the Net Zero 2030 and 2040 scenarios, less hydro is dispatched in the years after the net zero target. This has been replaced by an increase in the dispatch of solar, wind, battery, and pumped hydro.

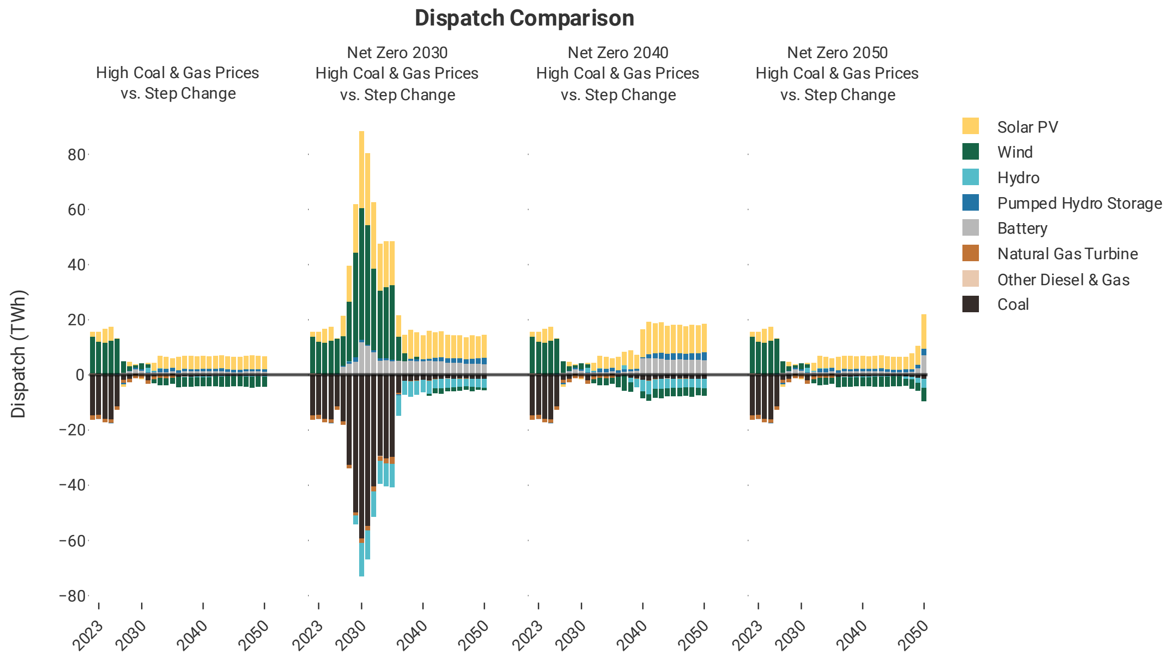


Figure 5: Dispatch comparison by scenario

None of the policies specify a rate of increase in renewables before they reach net-zero. In an unconstrained model, the least cost approach results in almost all the required renewables being built in the year before net-zero is required. In this modelling we have not sought to constrain build decisions to reflect labour market limitations. Doing so is possible and would tend to spread rapid capacity expansion over several years, depending on assumptions made about job mobility.

In general, solar and wind dominate the generation mix as emissions reduce, due to their low cost, which is predicted to continue decreasing. To match supply with demand, these technologies need support from storage, and the results show that the least-cost, zero-emissions way to do this is with a combination of batteries and pumped hydro.

In the Net Zero 2050 scenario, coal retirements are only significantly impacted in 2050, with retirements accelerated to a greater degree by Net Zero 2040 and 2030 targets.

Cost Breakdown

System costs in scenarios with increasing amounts of renewables are dominated by loan repayment, and operation and maintenance costs. None of the scenarios use a carbon price to reduce emissions.

Fuel costs increase dramatically in the early years for scenarios with high coal and gas prices, and reduce as the fuel prices decrease and more renewables are built to dispatch instead of fossil fuel generators.

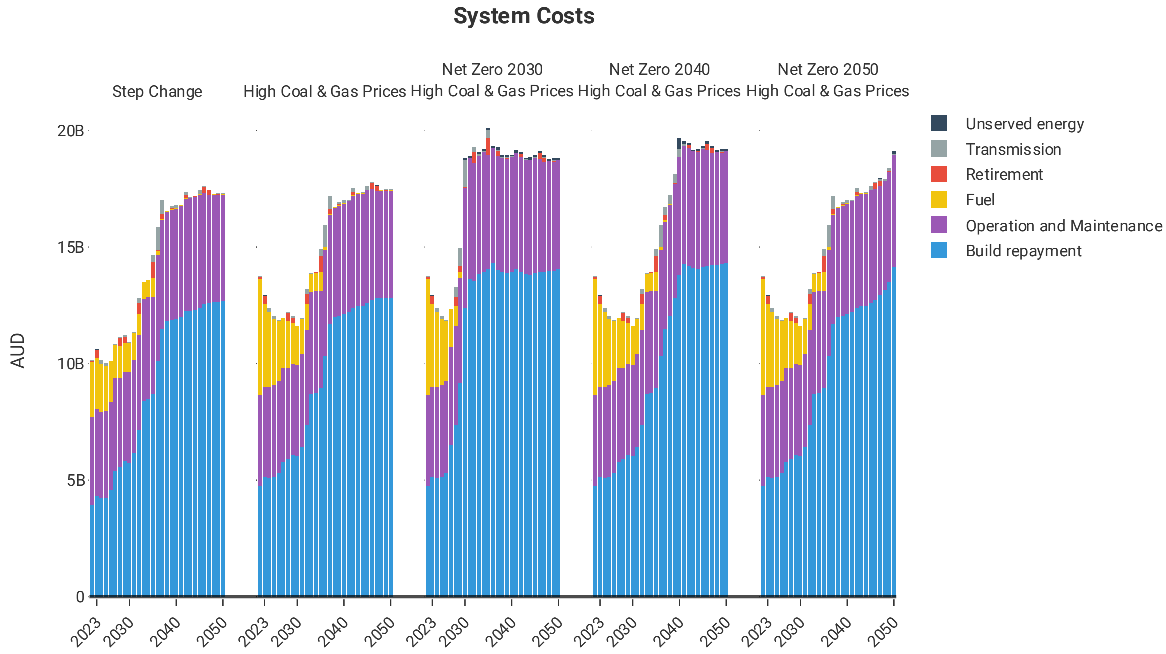


Figure 6: System costs by scenario

The graph above shows that the unaltered Step Change scenario has the lowest costs, as expected, as it is unconstrained by emissions targets or carbon prices, and openCEM can utilise the cheapest available combination of technologies to meet the demand in the NEM in each year.

In all scenarios, the rate of increase in renewables in the years preceding a net-zero target influences the resulting unserved energy cost in those years. This is influenced by the trajectory for emissions reduction, which we have assumed in this analysis to have a steep increase in the years approaching a net-zero target. The unserved energy costs seen in the cost graph could also in practise be reduced by demand management.

The Net Zero scenarios demonstrate how openCEM finds the least-cost pathway to meet a net-zero target in a particular year with minimal other constraints. It builds the most renewables in the year before the net zero target and begins paying them off in the year of the target.

Total system costs are similar across all scenarios in 2050, and the rate at which they increase is linked to the rate of emissions reduction. Total system costs step up significantly in years when a scenario requires an emissions target to be met.

Social Cost of Carbon

A Social Cost of Carbon (SCC) assigns a dollar value to the damage caused to the environment and society from each additional ton of carbon dioxide equivalent emissions (tCO_2e). Various methods for estimating a social cost of carbon have been published. These methods assess the cost of climate change on various parts of the economy, including labour productivity and agriculture, human health, and impacts on natural ecosystems that are typically unpriced.

Below we compare four different proposals for an SCC:

- \$30 and \$150/tCO_2e, held constant, simply for illustration.
- \$73/tCO_2e based on a value adopted by the Biden administration (as an interim measure) in 2021[a].
- A trajectory proposed to the Australian Capital Territory government by the ACT Climate Change Council in 2021[b]. The authors note that their recommendation is similar to trajectories published by the then interim United States Intergovernmental Working Group (IWG) on the Social Cost of Greenhouse Gases, and further that the IWG warned that all its interim working values for the Social Cost of Carbon, including a 152 USD (about 200 AUD) 2020 precautionary value were likely underestimates.

	Social Cost of Carbon (AUD/tCO_2e)						
Trajectory	**2022**	**2026**	**2030**	**2035**	**2040**	**2045**	**2050**
\$30/tCO_2e	30	30	30	30	30	30	30
United States Government	73	73	73	73	73	73	73
\$150/tCO_2e	150	150	150	150	150	150	150
ACT Climate Change Council	204	213	222	233	243	254	265

To explore the wider economic costs of each policy scenario, in the graph below we sum electricity system costs and the total carbon dioxide equivalent emissions of each scenario in tonnes, multiplied by the four different proposals for a social cost of carbon.

This graph illustrates that striking the optimal balance between financial system costs and emission costs depends on assumptions about the SCC. It is apparent that while the cost of damage caused by greenhouse gas emissions is difficult to definitively assess, it is worthy of much greater focus and public discussion.

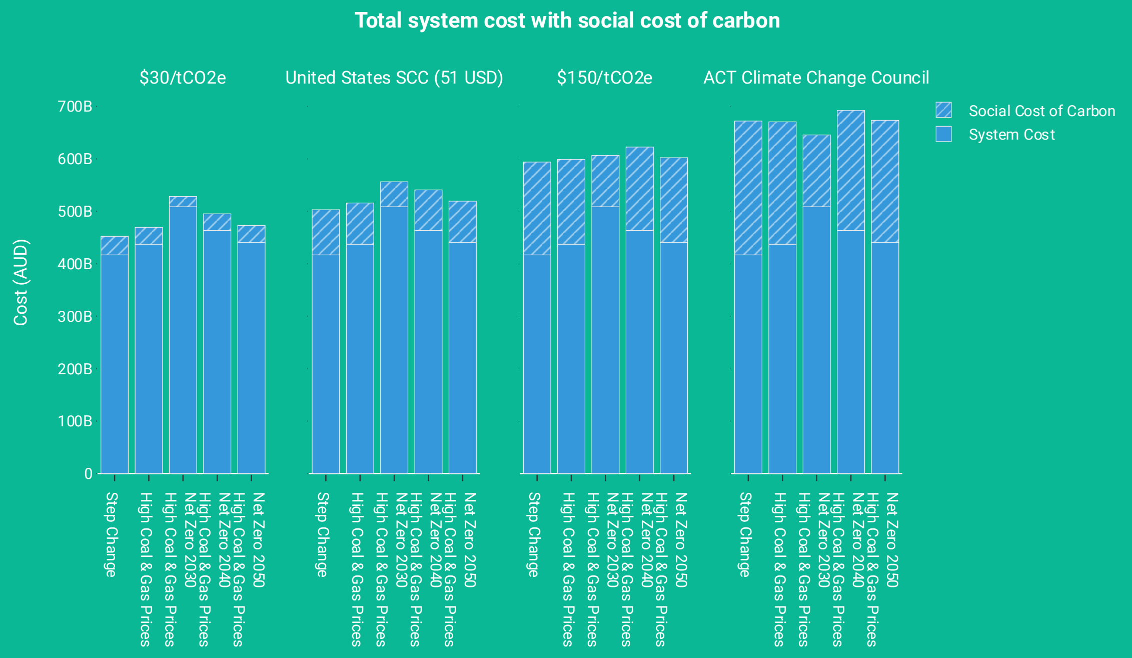


Figure 7: Social cost of carbon by scenario for a range of cost trajectories

Note that this analysis sums electricity system costs and climate damage costs only. Broader economic impacts are not assessed by openCEM. These wider effects may be beneficial, such as the value of increased investment and employment, or negative such as the impact of higher electricity prices on energy intensive industry.

[a] https://www.washingtonpost.com/climate-environment/2021/02/26/biden-cost-climate-change/ and https://www.whitehouse.gov/wp-content/uploads/2021/02/TechnicalSupportDocument_SocialCostofCarbonMethaneNitrousOxide.pdf

[b] The Social Cost of Carbon and Implications for the ACT, ACT Climate Change Council (2021) https://www.environment.act.gov.au/cc/act-climate-change-council/council-publications

Emissions

Scenarios with a net-zero emissions target in a particular year reach that target along a reverse-sigmoid trajectory, as seen in Figure 8. openCEM and other models often determine this trajectory to be the most efficient when performing these kinds of optimisation problems.

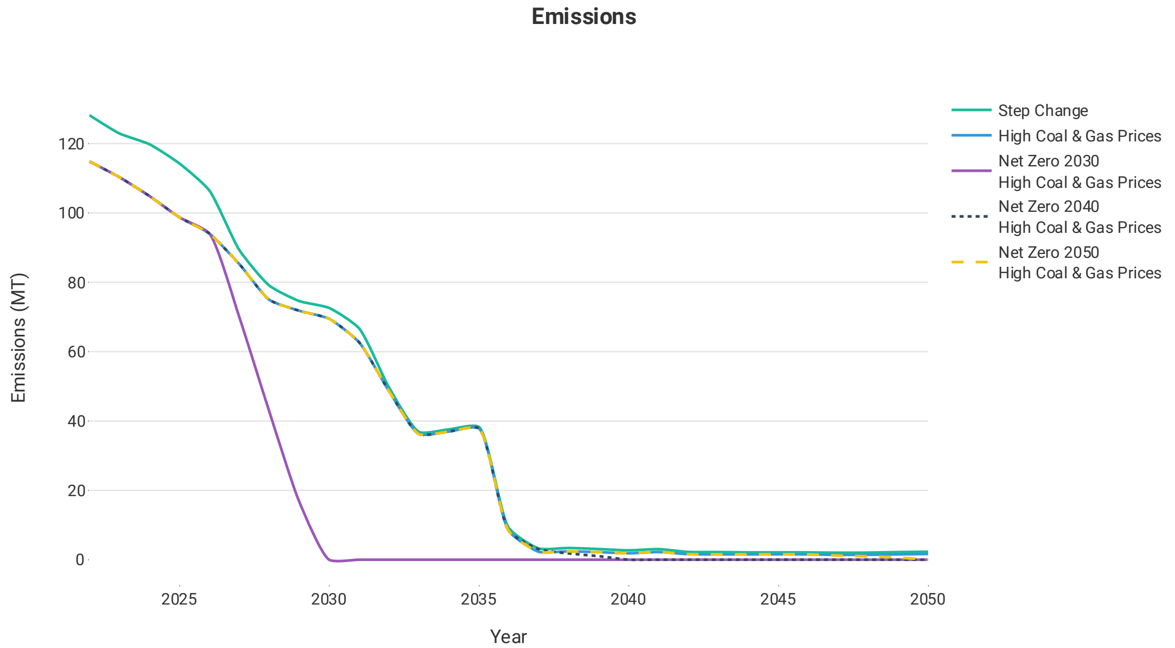


Figure 8: Emissions

Australia's updated national carbon budget from 2021–2050 is 3521 MT for 1.5 °C global warming, and 6161 MT for 2 °C[3]. Subtracting 499 MT emitted in 2021[4], this leaves us with 3022 and 5662 MT from 2022–2050. In 2021, electricity generation contributed 32.9% to Australia's total emissions[4], and the NEM provided approximately 85% of total generation in Australia[5]. For this analysis we assume that the electricity sector will maintain its proportion of emissions out to 2050, even though it is likely that the electricity sector will reduce its emissions faster than other sectors like transport, agriculture, and industrial processes, and reach 2050 with a smaller share of emissions. This is because the mature renewable generation technologies offer low-cost abatement opportunities, compared to changing technology in other sectors.

Following the assumptions above, Australia's remaining quota for total CO_2e emissions in the electricity sector from 2022–2050 is 1583 megatons to stay within 2°C global warming, and 845 megatons to stay within 1.5°C. The Step Change scenario already reduces emissions according to a predicted high uptake of renewables, which allows for all the scenarios to achieve the 2° target.

[3]https://www.climatecollege.unimelb.edu.au/files/site1/docs/%5Bmi7%3Ami7uid%5D/ClimateTargetsPanelReport.pdf
[4] https://www.industry.gov.au/data-and-publications/national-greenhouse-gas-inventory-quarterly-update-june-2021
[5] https://www.industry.gov.au/sites/default/files/2020-12/australias-emissions-projections-2020.pdf

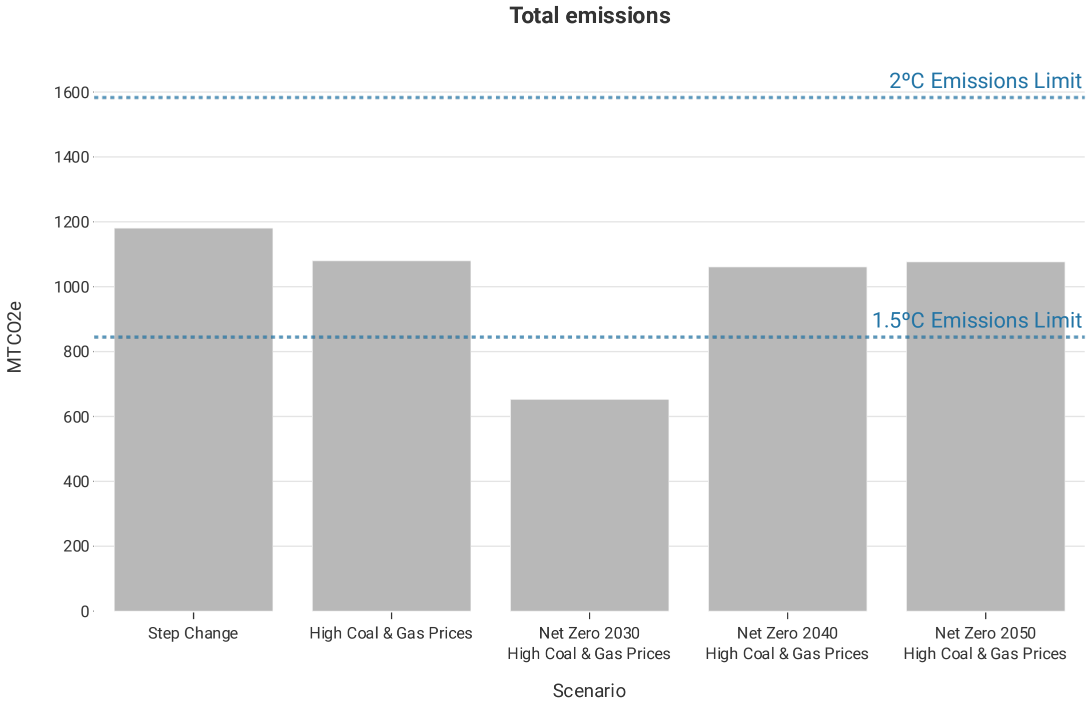


Figure 9: Total emissions and emissions limits by scenario

The Net Zero 2030 scenario is the only one that achieves the 1.5° target, and it emits significantly less than the Net Zero 2040 scenario. This shows how important the timing of a net zero target is, as the difference between achieving net zero in 2040 or 2050 is quite small, where bringing forward the target to 2030 has a marked impact.

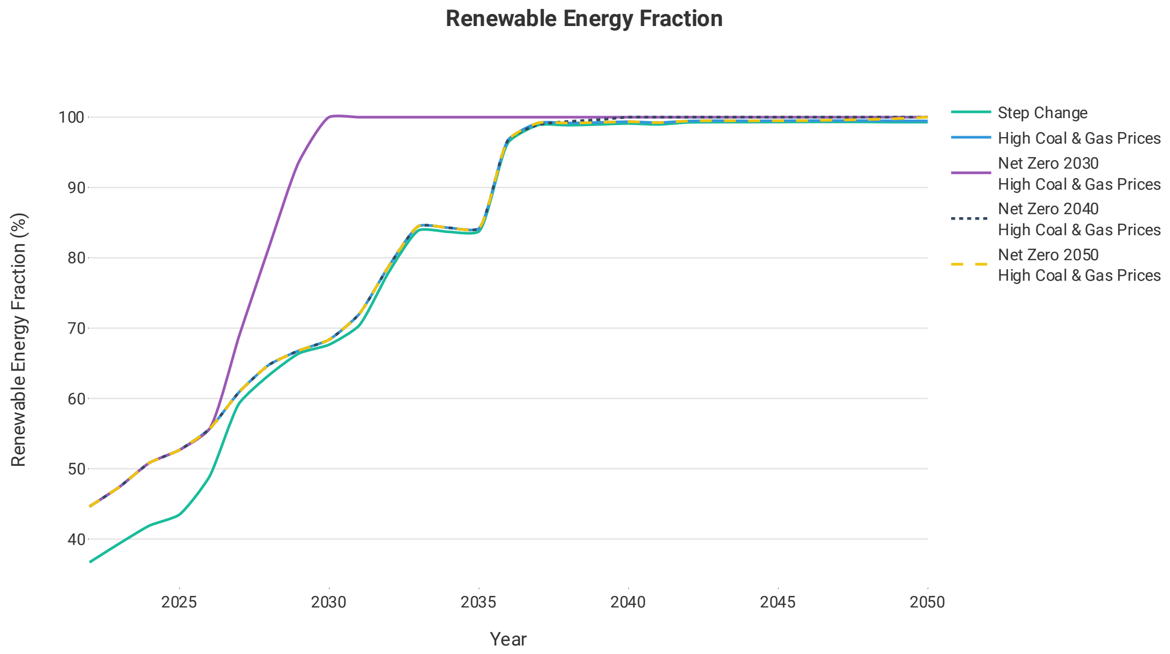


Figure 10: Renewable energy fraction

Until there is a net-zero target, the renewable energy fraction in all scenarios follows a similar trajectory, shaped by technology costs and the emissions trajectory of the Step Change scenario.

In-depth

Employment Impact Modelling

Introduction

ITP has developed an employment model to assess the number of construction, manufacturing and operation & maintenance (O&M) jobs in each energy sector based on openCEM modelling. The model provides a means to evaluate the location, sector and number of jobs produced for any scenario processed using openCEM. The model can be used, for example, as a tool to develop a policy portfolio aimed at maximising job growth and security for a given sector or region. To demonstrate the capability of the employment model, it has been run on each of the scenarios produced in this Quarterly Report.

Employment Factor Estimation

The inputs required to make employment predictions are employment factors (jobs per MW installed) for each technology type, and openCEM capacity expansion decisions (MW installed) for each scenario.

Employment factors for construction, manufacturing and O&M jobs for the renewable energy sector were taken from the University of Technology Sydney (UTS) report, *Renewable Energy Employment in Australia*[6], except for battery employment factors which were based on our own industry analysis. Employment factors for non-renewable generators were taken from UTS's *Calculating Global Energy Sector Jobs*[7].

This investigation focuses on direct jobs in the energy sector. It does not include indirect jobs, such as consultancy, finance, or other professional services, nor does it include induced jobs, such as employment created due to local economic stimulus of workers at generation sites. It is acknowledged that there are a significant number of jobs in coal and gas extraction that are not included in this analysis. This is discussed further in Appendix B.

Employment Model Generation

The model estimates jobs created annually for each technology type in each ISP sub-region. The first input to this model is a table containing each technology type to be evaluated, the employment factors and the installation duration for those technology types. The second input is the openCEM output that the user wishes to evaluate. The model generates job data for each energy sector, as well as separate data for jobs in construction, manufacturing, and O&M, as well as a breakdown of renewable vs. non-renewable jobs. These are evaluated for every year of the openCEM simulation; in this report from 2022–2050.

The employment model calculates the construction jobs for a particular generator for a number of years prior to its commissioning, based on the length of time it takes to build that kind of generator. For this reason, capacity that appears in an openCEM simulation in a particular year will increase the number of construction jobs several years prior.

[6] https://assets.cleanenergycouncil.org.au/documents/resources/reports/Clean-Energy-at-Work/Institute-for-Sustainable-Futures-renewable-energy-jobs-methods-report.pdf
[7]https://opus.lib.uts.edu.au/bitstream/10453/43718/1/Rutovitzetal2015Calculatingglobalenergysectorjobsmethodology.pdf

Results

For each of the scenarios modelled in Part 1 of this report, detailed estimations for jobs nationally, in each state, and each region have been generated. Additional to the technology breakdowns, summaries for construction, manufacturing, operation and maintenance and total have been created.

Scenario Comparison

All scenarios computed experience peaks and troughs but reveal an overall trend of increasing energy sector jobs over time. This is because most renewable energy generation technologies have a higher operation and maintenance employment factor than non-renewable generators. Ultimately, the scenarios mostly differ in the timing of job creation. This provides a good indication of what the energy job market could look like over the next few decades for each of these scenarios.

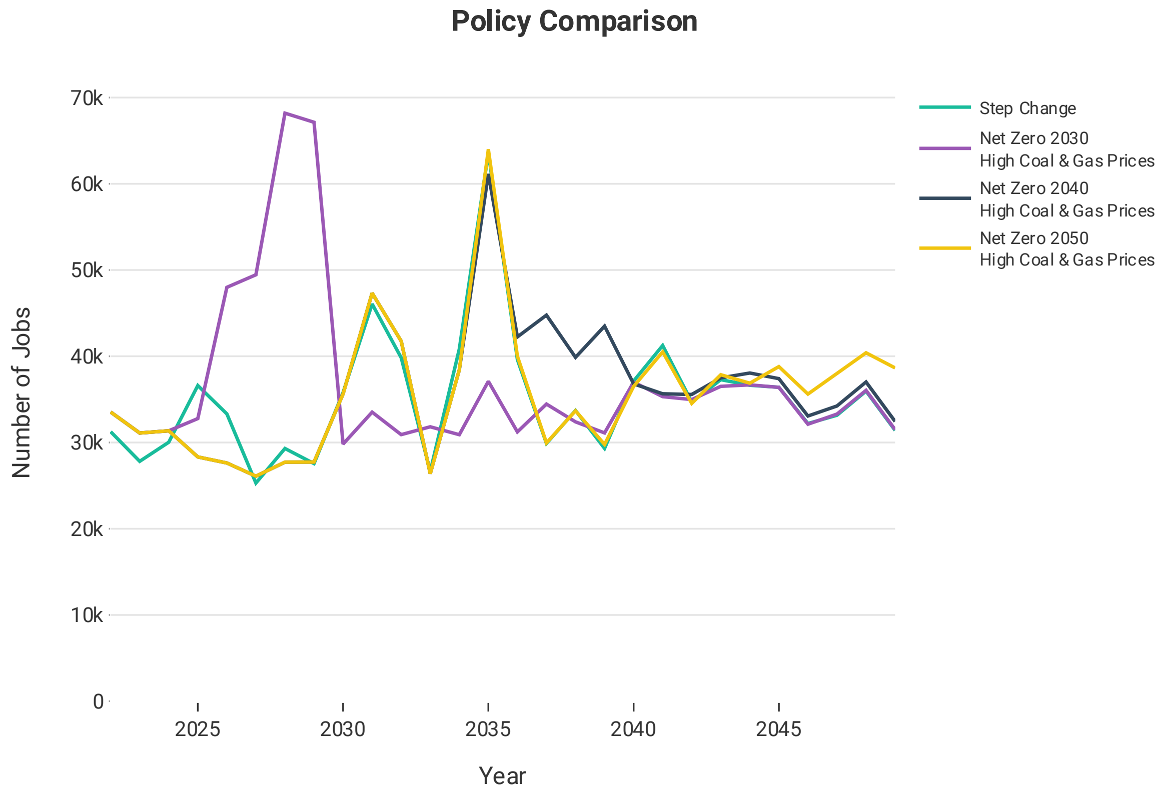


Figure 11: Number of jobs

Initial employment data for the step change scenario largely agree with the data from the Clean Energy Council's *Clean Energy at Work*[8] Report which used a very similar methodology. The difference here is that we also explore, for example, the implications of higher coal and gas prices.

[8] https://assets.cleanenergycouncil.org.au/documents/resources/reports/Clean-Energy-at-Work/Institute-for-Sustainable-Futures-renewable-energy-jobs-methods-report.pdf

Technology Breakdown

The distribution of jobs across each technology is shown in Figure 12. Notably, distributed technologies tend to produce a large proportion of jobs. This stems from the higher employment factors for installing and maintaining distributed capacity in homes and businesses compared to the more efficient building and maintenance that can occur on a utility scale generator. These values stay the same between scenarios, as openCEM takes distributed PV and battery generation as an input, based on the ISP, and it does not add extra distributed PV and batteries. However, values produced by the employment model could inform policy analysis considering the merits of the high employment but less cost efficient distributed energy against cost-efficient utility scale solar with a lower employment factor.

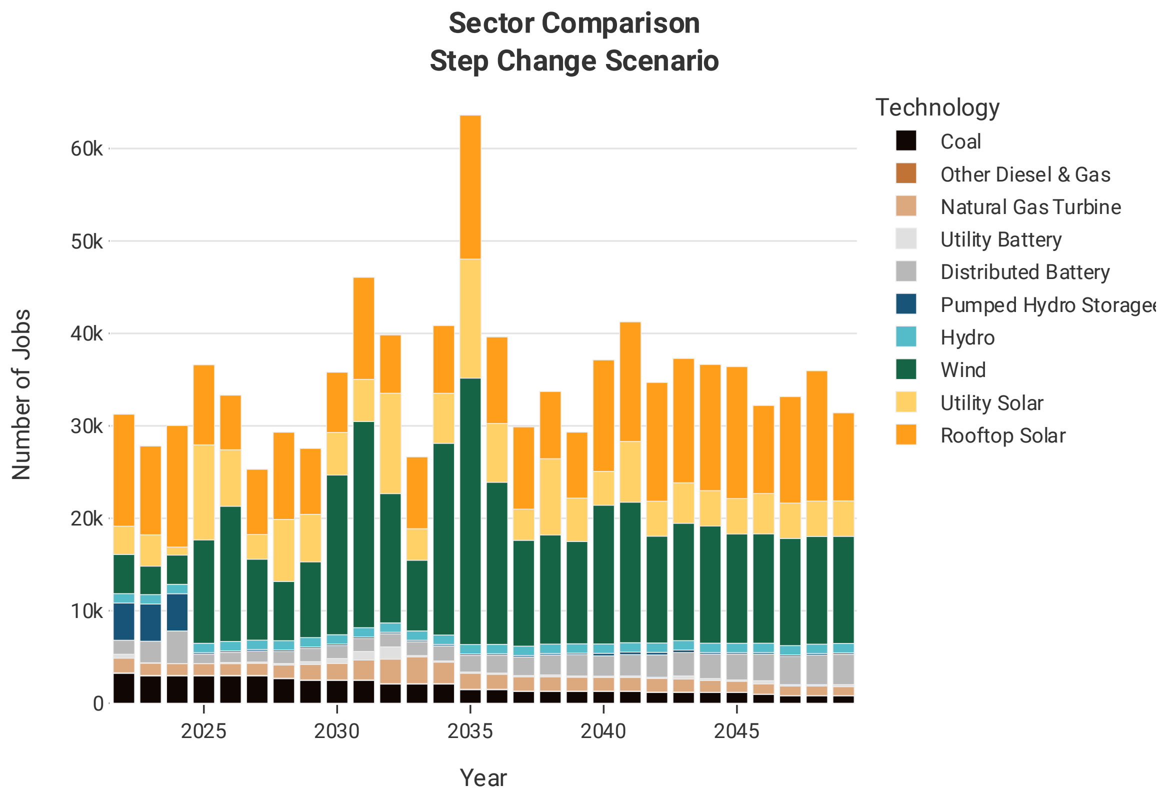


Figure 12: Sector comparison for Step Change scenario

Renewables vs Non-Renewables

In the Step Change scenario, the non-renewables sector currently occupies 14.7% of the total jobs, although this is partially due to the absence of any construction occurring in the non-renewable sector. By 2035 the number of jobs in the non-renewable sector is projected to have halved while O&M jobs in the renewables sector double.

It is important to note, however, that this analysis does not include jobs in the coal and gas extraction industries. Further work is required to investigate where coal and gas extraction jobs are located and how and when they will be impacted by the energy transition. Additionally, coal mined in Australia is mostly exported, so the impact of reduced coal consumption by domestic power plants will contribute only a portion to a reduction in total coal jobs in Australia.

To some extent, additional jobs may also be created in resource industries providing largely to renewable technologies including lithium mining and aluminium manufacturing, and due to capacity expansion for any future green hydrogen export industry.

Job Volatility

The modelling suggests that the construction of new renewable energy capacity is likely to be a source of considerable job volatility over the coming decades (Figure 13), noting that we have not sought to constrain model build decisions to reflect real-world labour market limitations.

The modelled volatility is due to the temporary creation of construction and manufacturing jobs during installation phases. These periods also often coincide with the retirement of coal plants. It is apparent that future labour demand volatility may exacerbate the existing current lack of skilled labour[9] in the energy sector, with reduced job security arising from sporadic construction demand. Careful planning will be necessary to smooth demand for renewable energy construction jobs and allow for appropriate training and certification.

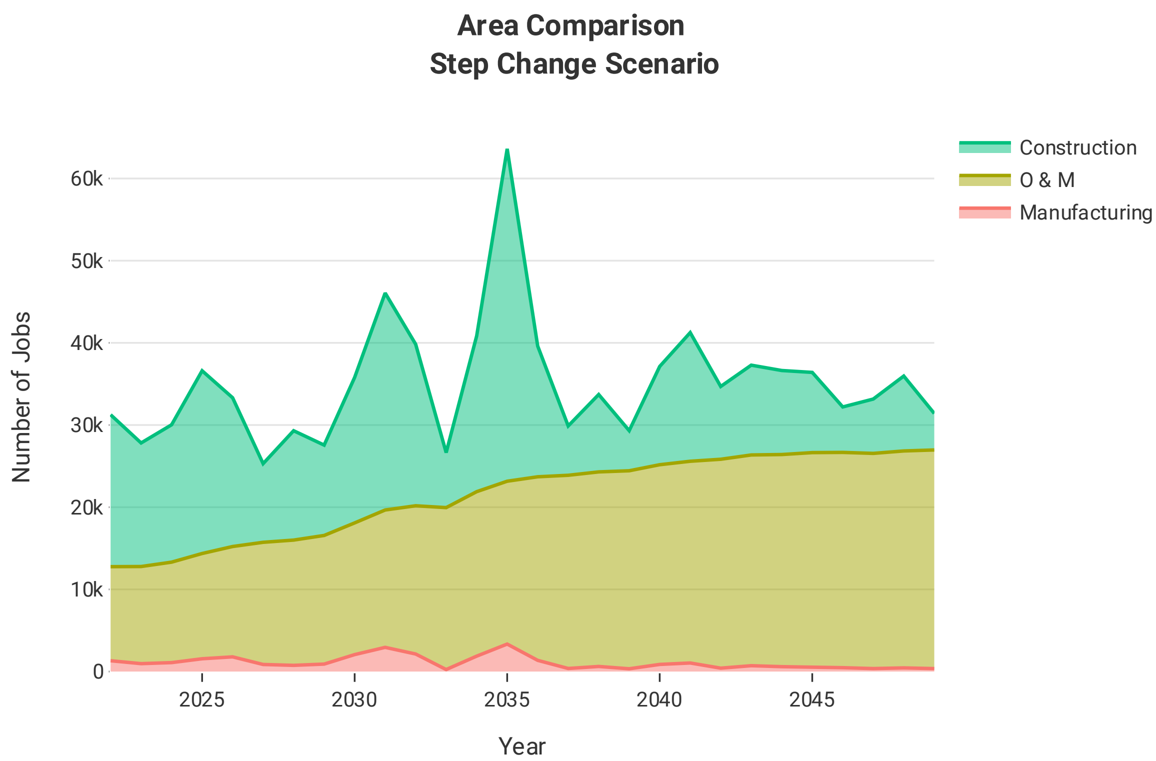


Figure 13: Area comparison for Step Change scenario

[9]https://reneweconomy.com.au/could-a-skills-shortage-stall-the-renewable-energy-revolution/

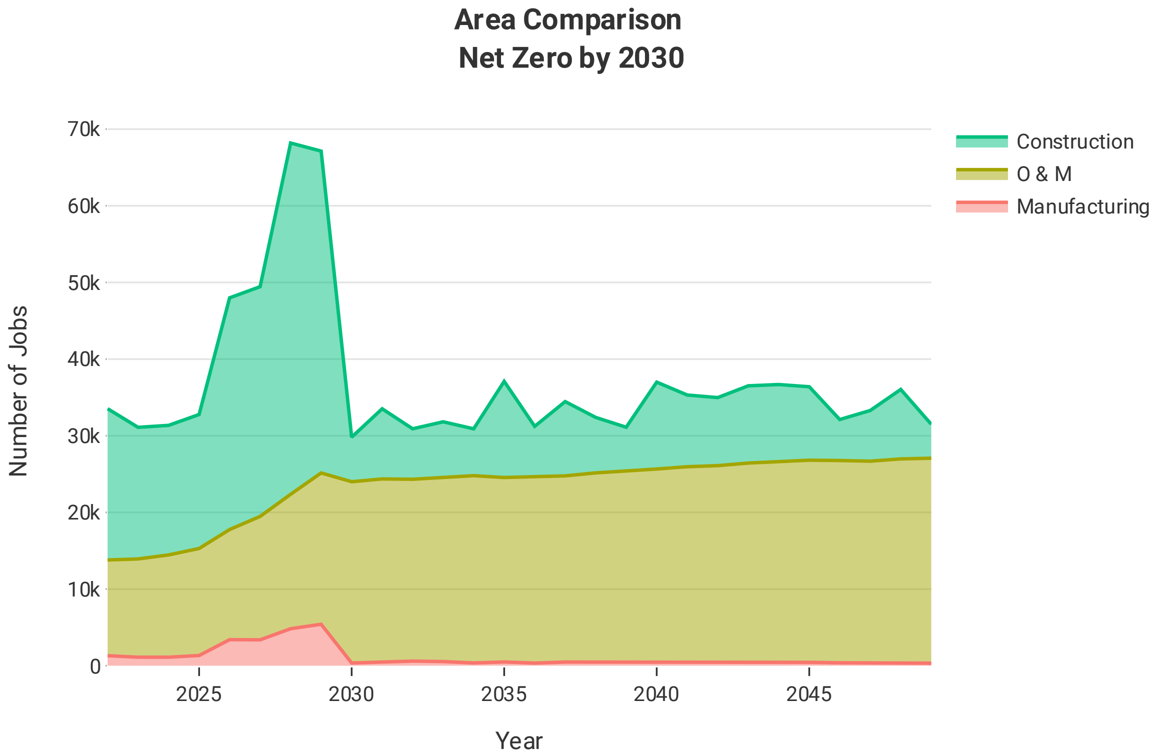


Figure 14: Area comparison for Net Zero 2030 scenario

O&M jobs are longer-term and increase following the commissioning of a generator, remaining active as long as the generator is online. As such, they tend to dictate long-term behaviour of energy market jobs. This is in contrast to construction and manufacturing jobs that appear at the commencement of construction and disappear once construction has been completed. For this reason, the scenarios which install renewable energy capacity earlier, such as Net Zero by 2030, end up with higher total job-years. Figure 13 and Figure 14 show how different types of jobs interact in the Step Change and Net Zero 2030 scenarios.

State Comparison

Our employment model allows for an assessment of impacts in each State and AEMO ISP sub-region. Our results show that in Queensland an increase in renewable energy jobs results from the retirement of the Gladstone and Bayswater coal-fired plants in 2035. While the Bayswater plant is near Newcastle, openCEM responds to its retirement by building renewable capacity in South-East Queensland along with high-capacity transmission lines to Sydney.Figure 16

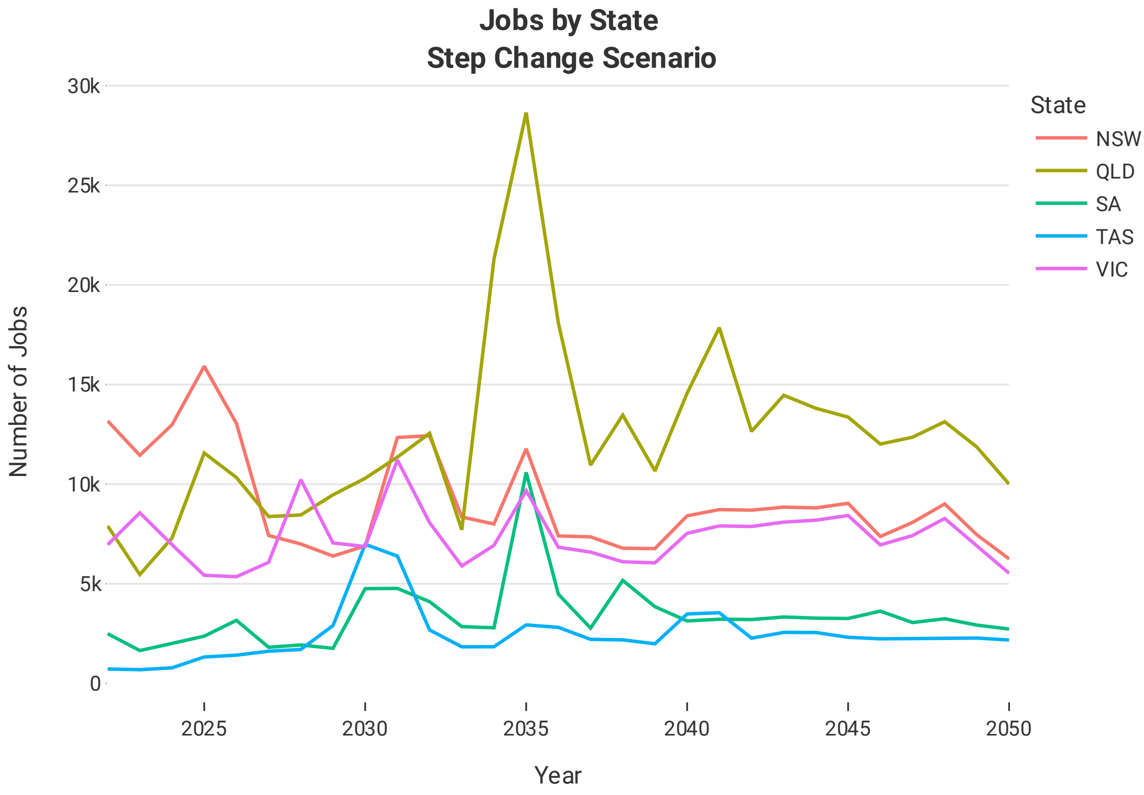


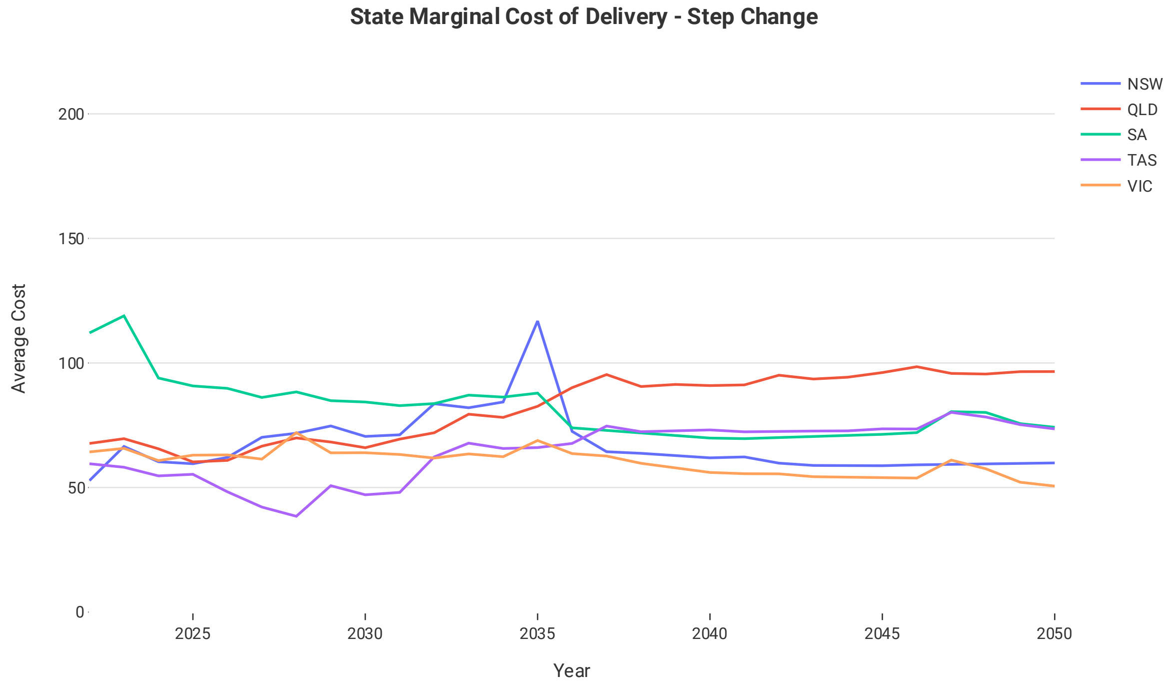
Figure 15: Jobs by state for Step Change scenario

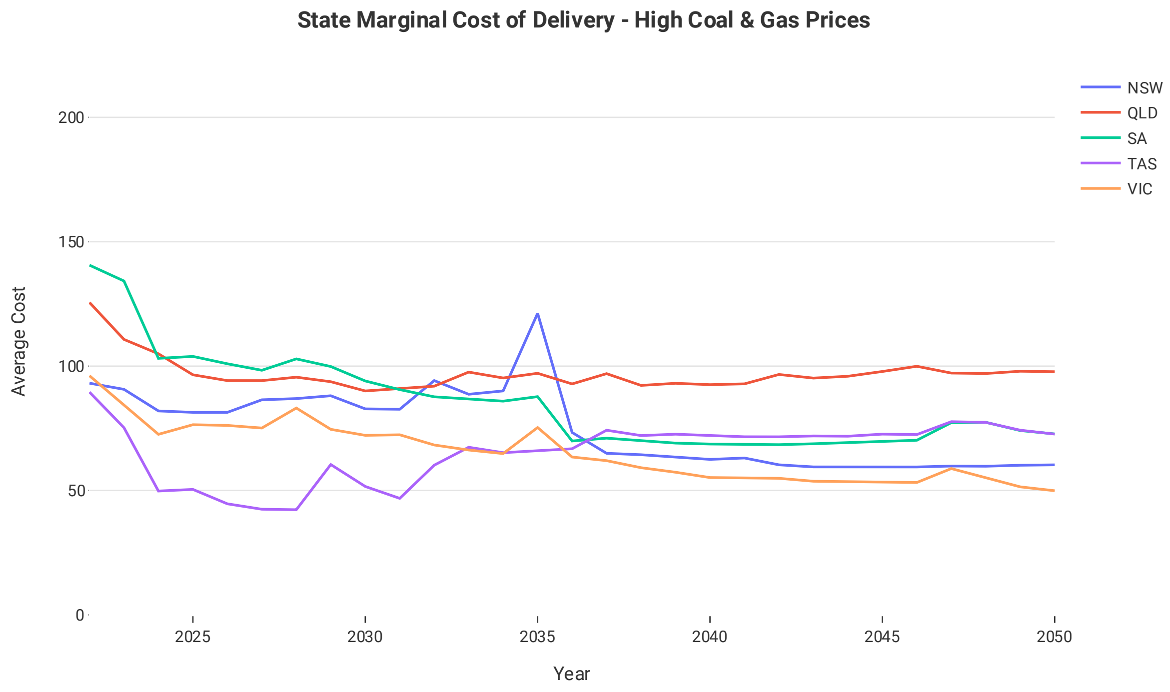
High coal and gas prices result in openCEM bringing forward renewable energy project construction forward from 2026 to 2022 in Victoria. Along with that, the jobs for those renewable energy projects are also brought forward by the same number of years, as seen in Figure 16.

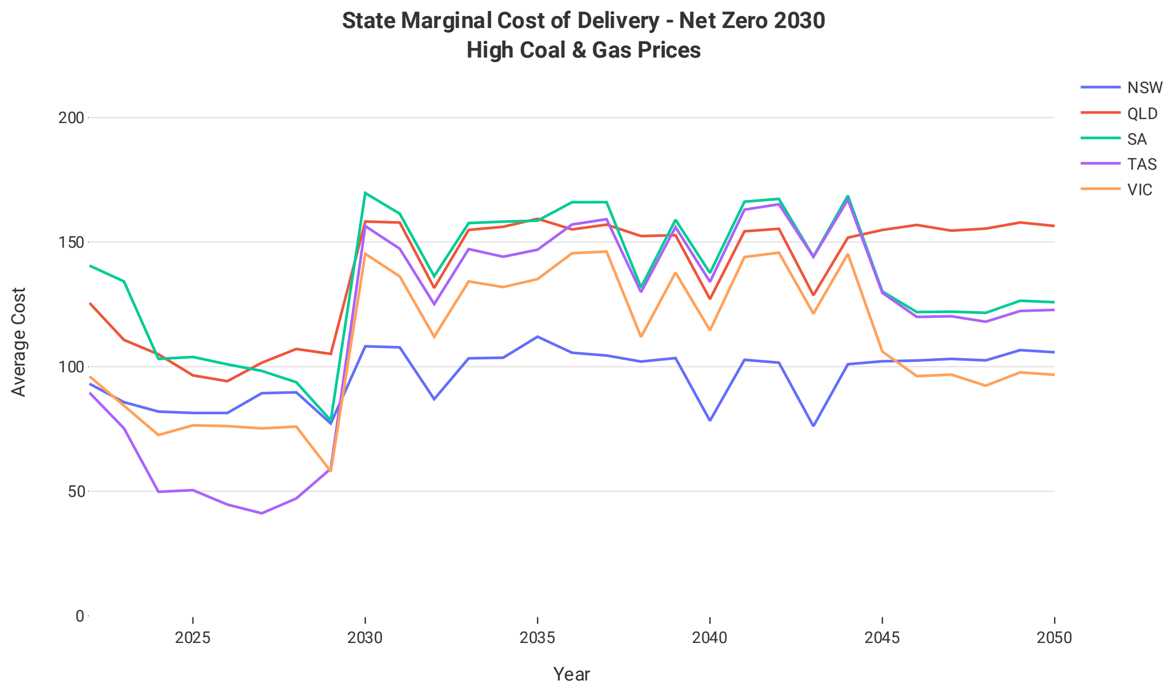
Figure 16: Jobs in Victoria for Step Change and High Coal & Gas scenarios

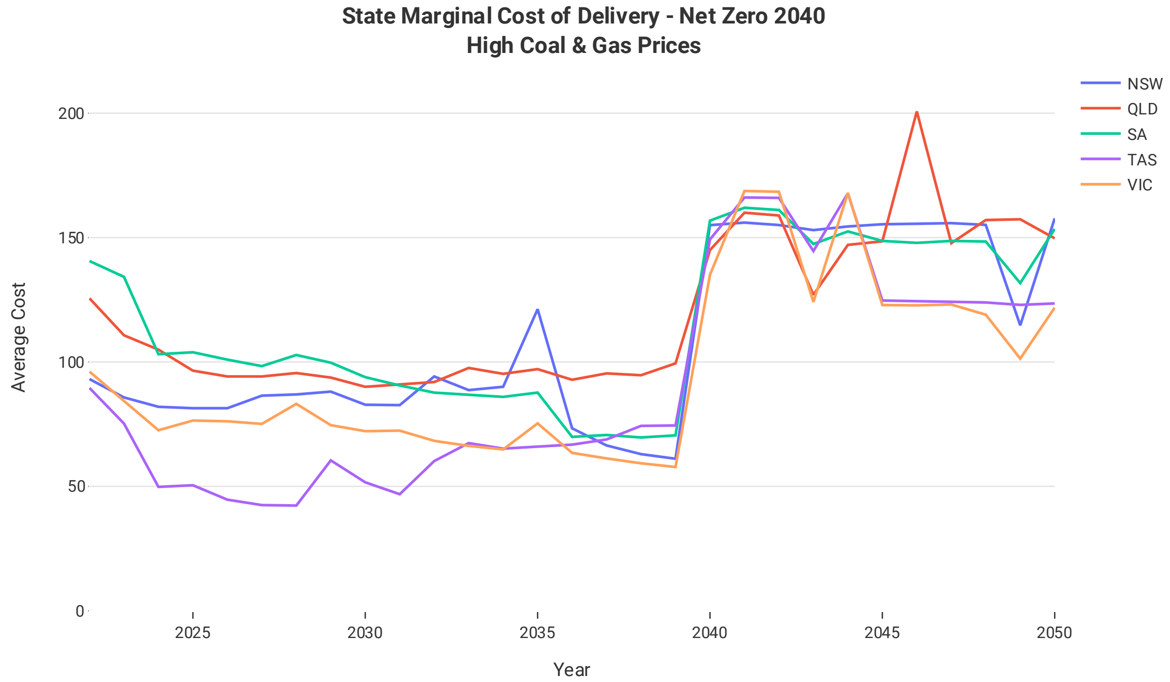
Appendices

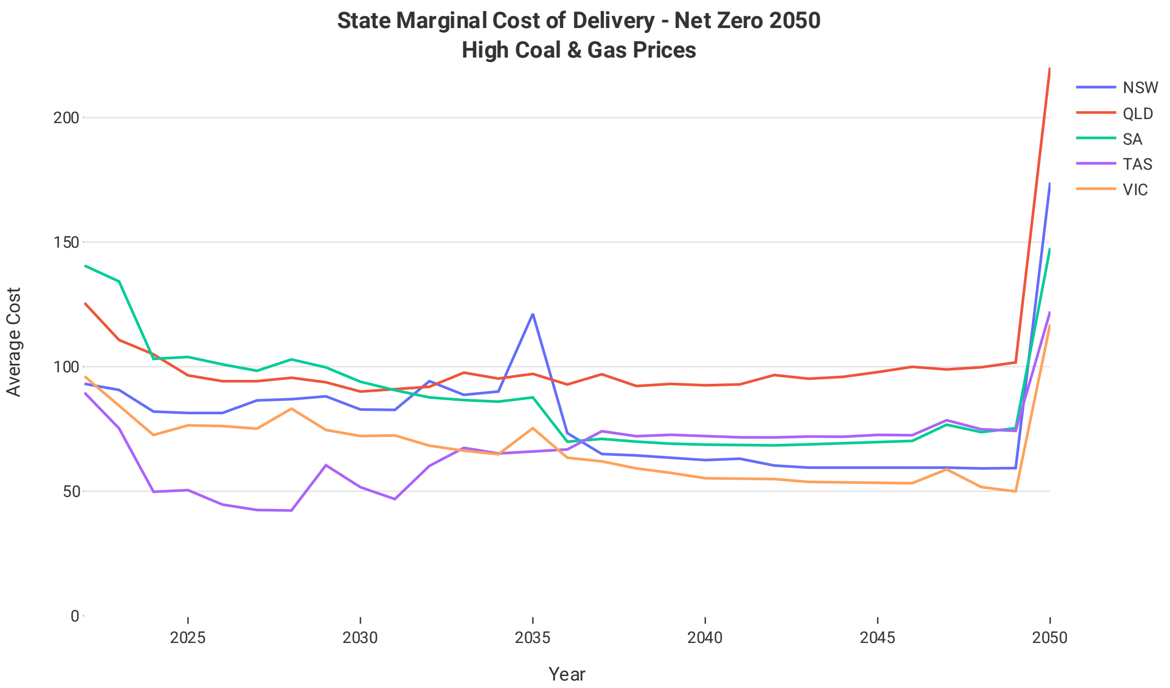
Appendix A. State Marginal Cost of Delivery






State Marginal Cost of Delivery - Net Zero 2030
High Coal & Gas Prices
NSW
QLD
SA
TAS
VIC
Average Cost
0
50
100
150
200
2025
2030
2035
2040
2045
2050
Year


State Marginal Cost of Delivery - Net Zero 2040
High Coal & Gas Prices
NSW
QLD
SA
TAS
VIC
Average Cost
0
50
100
150
200
2025
2030
2035
2040
2045
2050
Year


State Marginal Cost of Delivery - Net Zero 2050
High Coal & Gas Prices
Average Cost
Year
0
50
100
150
200
2025
2030
2035
2040
2045
2050
NSW
QLD
SA
TAS
VIC

Appendix B.

Notes on the Employment Model Methodology

A job-year is defined as the value for the number of full-time jobs required to complete an operation in one year. For example, if an operation takes 1 person 5 years to complete, it would be 5 job-years.

Importantly, a 5 job-year operation could not necessarily be competed in 1 year by 5 people, so it is necessary to specify values for the duration of construction and duration of manufacturing. This investigation assumes that manufacturing will occur for the same period as construction and therefore these values are equal.

Therefore, with employment factor being Job-Years / MW, the formula for new jobs each year in construction and manufacturing is:

$$\text{New Jobs} = \frac{\text{Employment Factor}}{\text{Duration of Construction}} \times \text{MW Installed}$$

Employment Factor Sources

For this analysis the employment factor values for renewable technology types have been taken from the report "Renewable Energy Employment in Australia Methodology" (UTS Institute for Sustainable Futures, 2020), with the exception of battery storage employment factors which were based on our own industry analysis. For non-renewable technology types, the employment factor values have been taken from the report "Calculating Global Energy Sector Jobs" (UTS Institute for Sustainable Futures, 2015).

The employment factors used are specified below in Table 1.

The UTS report publishes both a global and Australian employment factor for manufacturing. In this analysis only the Australian employment was relevant. Further, this investigation assumes that all manufacturing for non-renewable technology types is completed overseas, so the manufacturing employment factor for non-renewables is set to zero.

Finally, this analysis assumes there is there is no change in employment factors over time.

Table 1

Technology	Construction Factor	Manufacturing Factor	AU Manufacturing Factor	O&M Factor	Average Duration	Renewable?
Unit	Job-Years / MW	Job-Years / MW	Job-Years / MW	Jobs / MW	Years	1 for Yes
Coal	11.2	5.4	0	0.14	4	0
Brown Coal	11.2	5.4	0	0.14	4	0
Reciprocating Engine	1.3	0.93	0	0.14	1	0
Open Cycle Gas Turbine (OCGT)	1.3	0.93	0	0.14	1	0
OCGT new	1.3	0.93	0	0.14	1	0
Closed Cycle Gas Turbine (CCGT)	1.3	0.93	0	0.14	2	0
CCGT new	1.3	0.93	0	0.14	2	0
Distributed Battery	2.06	6.6	0.331	0.1	1	1
Utility Battery 2h	0.21	6.6	0.331	0.02	1	1
Utility battery 4h	0.21	6.6	0.331	0.02	1	1
Pumped Hydro 24h	7.2	3.5	0.699	0.08	4	1
Pumped Hydro 168h	7.2	3.5	0.699	0.08	4	1
Hydro	7.4	3.5	0.699	0.14	4	1
Wind	2.8	1.7	0.377	0.22	2	1
Wind H	2.8	1.7	0.377	0.22	2	1
Utility PV	2.3	4.4	0.092	0.11	1	1
Rooftop PV	5.8	4.4	0.153	0.16	1	1

Appendix C. Model Details

How openCEM works

openCEM is a capacity expansion and dispatch model that simulates the national electricity market (NEM) under a set of technical, cost and policy assumptions. Based on those assumptions, openCEM computes future capacity expansion (i.e. building large-scale generators and storage systems) and dispatch decisions over a number of years into the future that achieve a system-wide lowest annualised cost of operation.

openCEM divides the NEM into 16 planning zones based on the AEMO ISP NTNDP zones to account for differences in renewable energy resources, fuel costs, electricity demand and connection costs. Each zone contains its own list of generator and storage capacity, and aggregates plants by technology in each respective zone. Wind and solar technologies in a given zone have their own hourly power output traces, building and fuel costs.

A cost minimisation search is performed sequentially for a number of future years in which a financial year is simulated using a time-sliced approach to compute capacity decisions and then in full to compute dispatch decisions. New capacity decisions are assumed to be operational during the simulated year. The net of all existing and new capacity computed for one year is carried forward as the starting point to the next. For the first year, initial capacity consists of reported firm capacity by the Australian Energy Market Operator (AEMO) in 2020.

Energy can flow without restriction between all the zones in a region but notional interconnectors of fixed capacity (marked red in the figure) limit the amount of energy transmitted between regions.

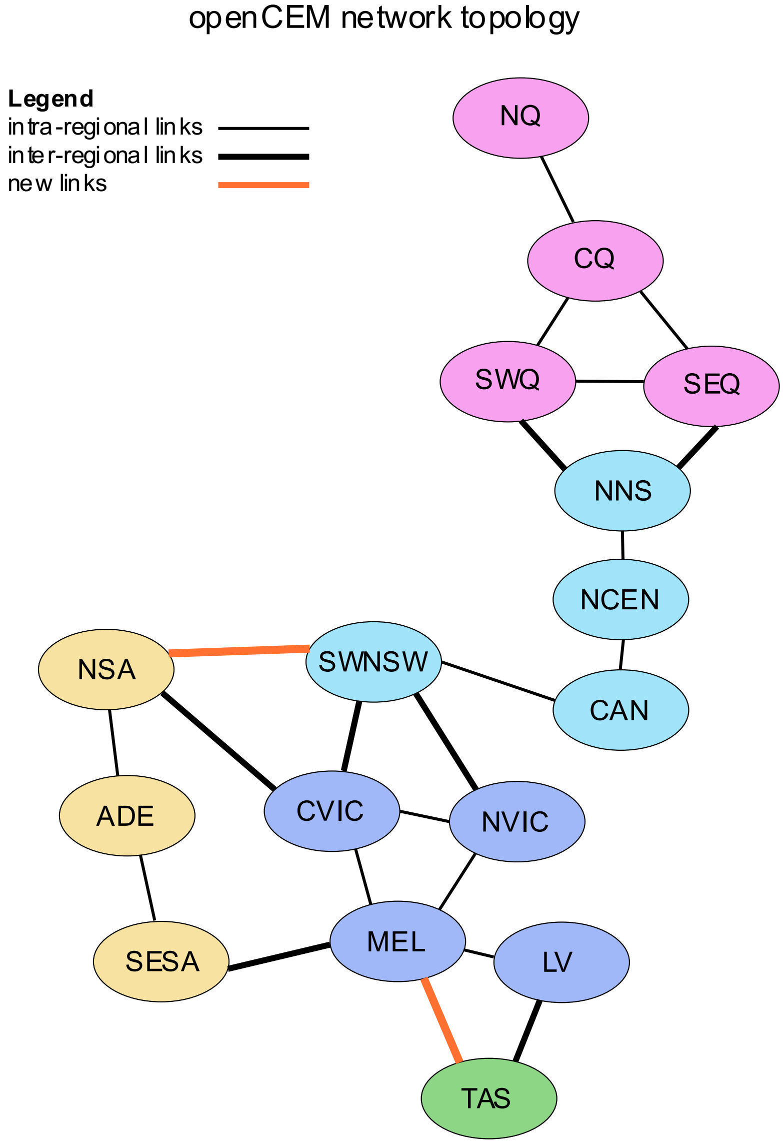
By default, openCEM uses AEMO Integrated System Plan (ISP) 2020 data for technology and fuel costs, build limits, existing generation, electricity demand traces and renewable energy resource traces (i.e. wind and solar). For CST, openCEM by default uses "collector" only traces that estimate thermal output performance from a collector field. With collector only traces, CST plants in openCEM can be configured to feature different storage sizes.

Notes on Assumptions

Emissions Pathways

The emissions pathways that openCEM produces are optimised for the lowest cost of the system, so they often start reducing slowly and are more aggressive closer to the emissions target in the scenario, when technologies are cheaper. This is typical of this kind of model, and reflects trends in emissions in the last 20 years, but is harder to predict with high confidence out to 2050. Factors such as investor attitudes towards certain technologies, and new technological and political developments can have a strong effect on the adoption of certain technologies, which openCEM cannot predict.

Network map


openCEM network topology
Legend
intra-regional links
inter-regional links
new links
NQ
CQ
SWQ
SEQ
NNS
NCEN
NSA
SWNSW
CAN
ADE
CVIC
NVIC
SESA
MEL
LV
TAS

Appendix D. Other Reports and Additional Data

This report is released on a quarterly basis and will in future offer an option to purchase detailed output data from each scenario, including delivery costs broken down by state, detailed dispatch and capacity figures, and all other data shown in graphs, broken down by region, technology, and year.

ITP Analytics also has an employment model that works in tandem with openCEM to predict how different technology mixes, location, and timing affect jobs in each region in Australia. This information will also be included as an option for purchase in future reports.

Other publications from ITP Analytics and its parent company ITP Renewables are available at itpau.com.au/knowledge.

ANALYTICS