Clean Energy Investor Group

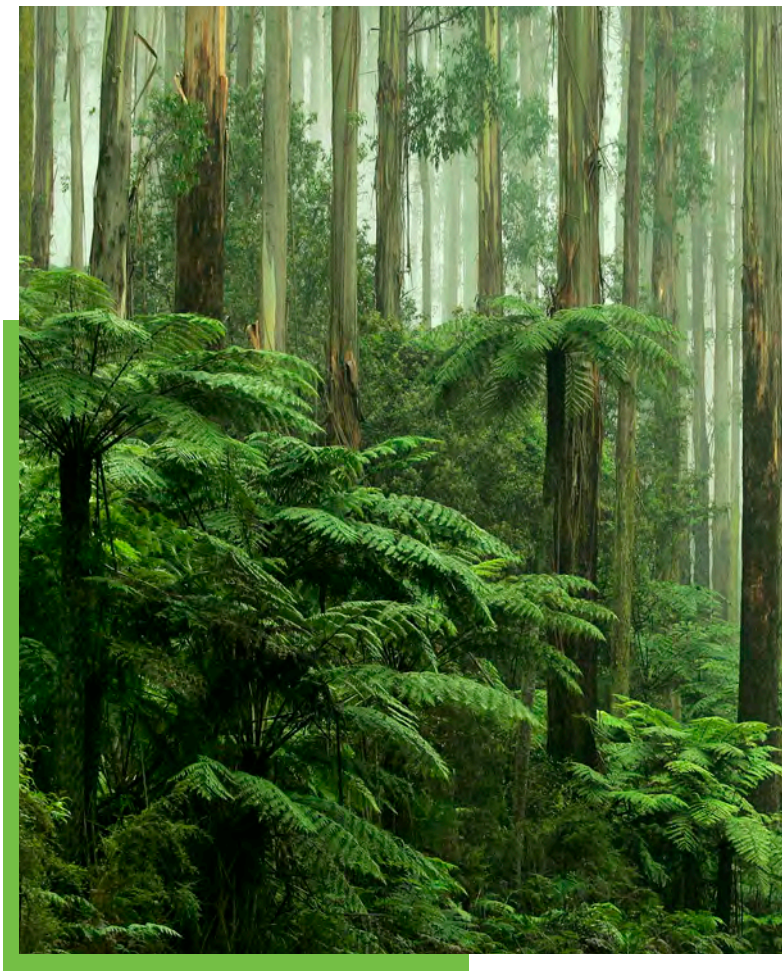
Baringa

DECARBONISING AUSTRALIA

Accelerating our energy transition with a credible 1.5°C scenario

Acknowledgement

In the spirit of reconciliation, the Clean Energy Investor Group acknowledges the traditional custodians of country throughout Australia and their connections to land, seas, and community. We pay our respects to their Elders past and present, extending that respect to all Aboriginal and Torres Strait Islander peoples.



Foreword

Australia needs to attract private investment worth hundreds of billions of dollars if it is to meet 1.5°C commitments under the Paris Agreement, with much of this required sooner rather than later.

The good news is that it is still possible to decarbonise and meet these 1.5°C commitments, unlocking investment for all jurisdictions while maintaining a secure and reliable National Electricity Market (NEM). Investors will respond to the call if governments provide the right settings.

There is no escaping the fact that this will mean earlier closure of coal-fired power stations and accelerating investment in renewable energy. Gentailers need to see this as an opportunity instead of looking to protect their assets at the expense of Australian taxpayers.

Coal plants are valuable sites with good access to the grid, which means they can be repurposed to host renewable projects that benefit traditional coal communities and the working families they support.

It will also improve the long-term prospects of gentailers. Missing this investment opportunity could see them lose their vertically integrated business models if they don't have enough renewable capacity in future to meet growing customer consumption of electricity.

There's a great deal of work to be done in successfully delivering Australia's energy transition, which will require a coordinated effort from federal, state and territory governments, the electricity sector, and the investment community. We have no time left to lose in unlocking this investment opportunity.

Simon Corbell
CEO, Clean Energy Investor Group

"Investors will respond to the call if governments provide the right settings."

Executive Summary

Australia has committed to efforts limiting temperature increases to 1.5°C under the Paris Agreement. A successful and timely energy transition demands that our governments and the electricity industry reengage with these commitments.

Recent developments like the formation of the National Energy Transformation Partnership show that we are moving in the right direction, but current progress is not fast enough and Australian Energy Market Operator (AEMO) scenarios that model National Electricity Market (NEM) decarbonisation in line with the Paris Agreement are not commercially credible.

With time quickly running out, we need to see steep emission reductions in the electricity industry. This will enable the clean electrification of other sectors and drive economy-wide decarbonisation, most importantly in the transport and industrial sectors.

In addition to more ambitious government targets and immediate action within the energy industry, decarbonising the NEM also needs a credible pathway to attract major global investment. Although some existing market projections map a path to 1.5°C, they rely on implausible assumptions like extreme uptake of hydrogen and electrification, a highly truncated coal exit, or unrealistic renewable buildout rates to reach generation targets.

Consulting firm Baringa Partners has developed a practical and commercially credible scenario for decarbonising the NEM in line with staying below 1.5°C. This model is commercially credible and has been validated by investors.

Making this work requires the coordinated closure of coal with a focus on shutting the most-polluting plants first, average renewable buildout of 5.5 GW per year between 2024 and 2034, and credible hydrogen uptake starting in the early-mid 2030s.

A steep coal closure schedule, prioritising the highest-emitting brown coal, is critical in keeping the electricity sector within its carbon budget. Coal closures must be balanced with a practical view on building replacement generation to ensure the reliability and security of the system.

Relative economics mean onshore wind is expected to dominate the generation buildout. Government support for offshore wind farms could help to alleviate the social license challenges associated with onshore projects, although our model only includes 4 GW of offshore capacity.

We expect less large-scale solar to be built due to the growing penetration of rooftop solar. Significant volumes of firming technologies including batteries, pumped hydro and other forms of dispatchable capacity will also be required alongside variable renewables. Baringa has modelled this dispatchable capacity as gas, but ideally new technologies become available and this need for capacity will be met by green sources like hydrogen turbines.

This ambitious but credible transition plan, underpinned by government, is projected to deliver lower wholesale energy prices in the medium and long term after a short-term increase caused by greater reliance on gas as coal closures are accelerated. This will have a positive impact on other industries including transport and industry, delivering broader benefits to the wider economy. Energy developers, financial markets and policy makers should use this scenario in shaping their strategies.

Despite the challenges that lie ahead, there is still time to meet Australia's 1.5°C commitments. The federal government's policies have undoubtedly moved us forward, but more is needed from all stakeholders.

Overview

Market projections influence where and when NEM investment is made, with energy developers, financial markets and governments using these projections to shape their strategies.

Developers use these market projections to understand the revenue potential of their projects, weigh upside and downside risk, inform the scale and location of projects, and seek financial backing.

Lenders and financiers use market projections to form a view of future investment opportunities and undertake due diligence on projects seeking financial support. Governments use projections to assess the potential impact of new policies and programs.

Current models lack ambition, credibility

Current market scenarios for decarbonising the NEM either fall short of government commitments or rely on assumptions that are not credible with mainstream investors.

Those falling short include the Australian Government emissions projections from 2021, Australian Labor Party modelling done by Reputex, and AEMO's Integrated System Plan (ISP) Step Change scenario modelling based on CSIRO and ClimateWorks assumptions.

AEMO has produced two scenarios that align with the government's commitments, but these Strong Electrification and Hydrogen Superpower models include assumptions that lack market credibility. These extreme assumptions include unrealistic targets for hydrogen uptake, electrification, coal closure and rate of renewable buildout. This leaves investors and market participants to guess what published aggregate outcomes mean for future investment consistent with a 1.5°C pathway.

An ambitious but credible alternative

Investors assess project revenue potential based on current and announced policies. They do not typically speculate on reform. Many investors and lenders require a high bar of legislated policy or a clear implementation plan. Alternative scenarios are considered as upside and downside cases to understand risk and potential.

Baringa's current bankable case for NEM decarbonisation aligns with an approximate 2°C economy-wide carbon budget. Widely used to inform investment decisions, it assumes current market design, committed policies, and network development from the AEMO ISP optimal development pathway. Generation is built out to meet forecast demand, with economics determining what is built, where and when.

In this study, Baringa has developed an ambitious but credible 1.5°C pathway in order to progress NEM decarbonisation. This market scenario is constrained by a 1.5°C carbon budget for the economy, as well as existing government commitments including a 43% carbon reduction by 2030 and net zero by 2050. It draws upon carbon budgets published by ClimateWorks for non-electricity sectors to develop the NEM carbon constraint.

This 1.5°C scenario incorporates a credible view on coal closure, the buildout of new generation, and future electricity demand driven by electric vehicles, broader electrification, and uptake of hydrogen. Annual emissions and overall carbon budgets are aligned with this NEM pathway.

Electricity-sector decarbonisation pathway*	NEM-specific	43% reduction by 2030**	Net Zero by 2050**	1.5°C aligned (Paris Accord)**
AUS Govt emissions projections (2021)	No	No	N/A	N/A
ALP modelling (Reputex)	Yes	Yes	N/A	N/A
AEMO ISP modelling (CSIRO, Climateworks) – Step Change	Yes	No – underachieves	Yes	No – underachieves
AEMO ...– Strong Electrification	Yes	Yes	Yes	Yes
AEMO ...– Hydrogen Superpower	Yes	Yes	Yes	Yes
Net Zero Australia (consortium)	No	Unclear	Yes	No

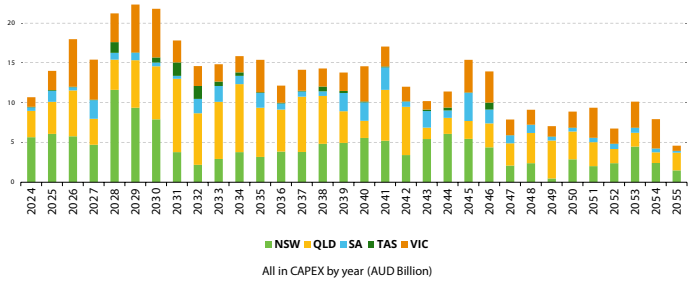
- While these scenarios align with government commitments, they rely on assumptions which are not currently credible with mainstream investors (extremes of hydrogen uptake and electrification, highly truncated NEM-wide coal exit schedule, substantial year-on-year generation buildout).
- The NEM detailed market projections underpinning these scenarios are also not published, leaving investors and market participants to speculate what the published aggregate outcomes mean for future investment.

* Existing pathways do not incorporate recently announced VIC offshore wind targets, VIC storage targets, or QLD renewable energy targets.
** Economy-wide target

Iterative modelling was used to define a NEM pathway that is ambitious but achievable. Minor adjustments to the carbon budget were identified to achieve the necessary levels of ambition and credibility. This is a more credible and achievable buildout rate, and more sustainable from a supply chain and workforce perspective.

The investment opportunity

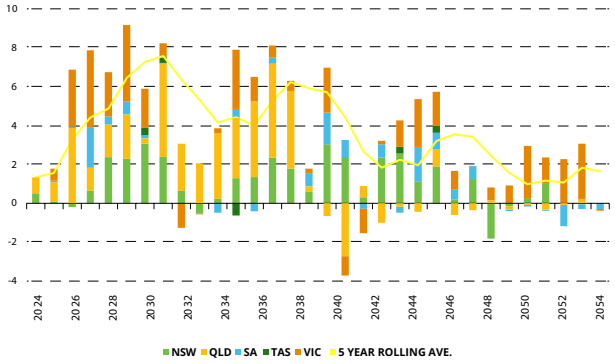
Baringa's Investor Credible scenario estimates that decarbonising the NEM in line with staying below 1.5°C will require private investment worth $421 billion. Queensland ($141 billion), New South Wales ($140 billion) and Victoria ($93 billion) need the most investment.



All in CAPEX by year (AUD Billion)

The investment gap

This private investment in generation and storage is $116 billion more that current government and market investment plans. The right policy settings will unlock these opportunities, with Victoria ($39 billion), Queensland ($35 billion) and NSW ($33 billion) attracting most new investment.

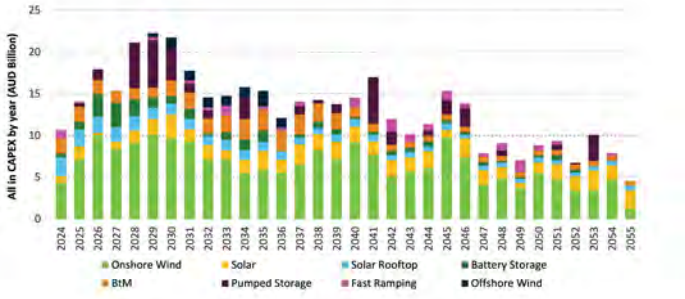


Additional CAPEX by year (AUD Billions)

Total investment by technology

Onshore wind ($208 billion) accounts for almost half of the total investment, with significant investment also required in other methods of generation including utility-scale solar ($53 billion), rooftop solar ($31 billion), and offshore wind ($9 billion).

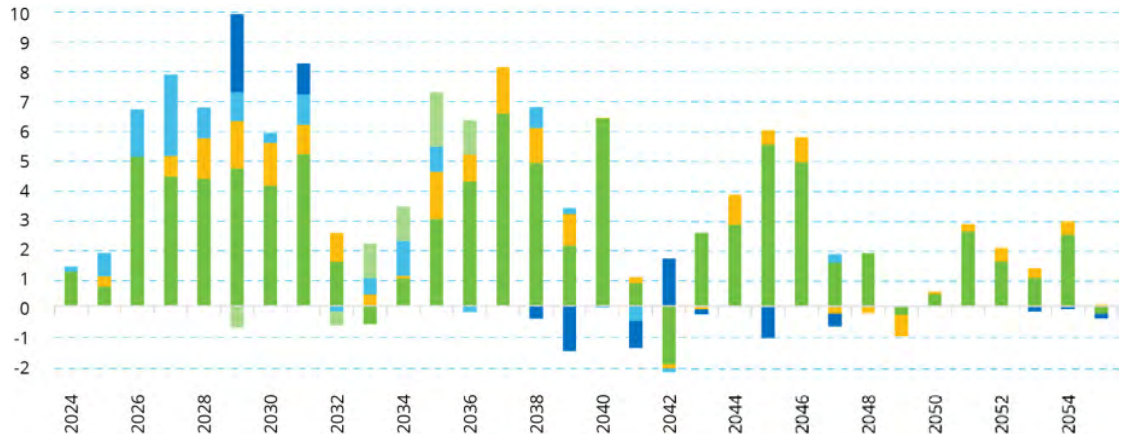
Behind-the-meter storage ($42 billion), pumped storage ($41 billion), utility-scale battery storage ($23 billion) and new fast ramping capacity ($15 billion) provide system security. A further $41 billion of public investment will also be needed for transmission.



Additional investment by technology

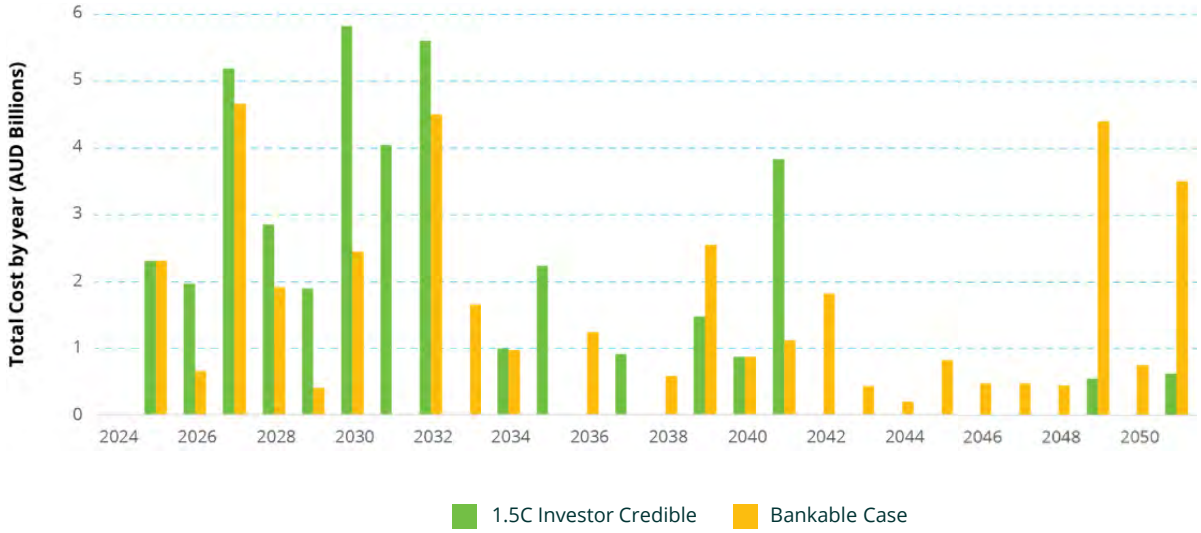
The 1.5°C Investor Credible scenario suggests onshore wind requires most additional private investment compared to Baringa's bankable case. There are also big investment gaps to close in solar and battery storage. Most of this investment will be required in the 2020s and 2030s.

TOTAL ADDITIONAL INVESTMENT (AUD BILLIONS)	
Onshore Wind	83
Utility Solar	17
Battery Storage	11.3
Pumped Storage	0.26
Offshore Wind	4.1
TOTAL	**116**



More investment in transmission

Total public investment of $41B is only $2B higher than AEMO's ISP, the transmission background used in Baringa's Bankable Case. But this investment needs to be brought forward in the 1.5°C Investor Credible scenario.



Key Insights

Governments need more ambition

The Australian Government reiterated its support for staying as close to 1.5°C as possible at COP27 late last year, acknowledging that this would require a faster and more orderly transition to renewable energy. The Victorian Government has announced targets of 95% renewable energy and all coal closures by 2035, along with storage targets. The Queensland Government has a target of 80% renewables by 2035, together with pumped hydro targets and reduced reliance on coal.

These announcements are a significant step in the right direction, but still fall short of what is needed for a 1.5°C aligned pathway. And although announcements are important, investors need these translated into policies and legislated targets before they will consider them credible and bankable. This is particularly important when these announcements do not have the benefit of bipartisan support.

Baringa's 1.5°C Investor Credible scenario achieves 98% renewable energy in Victoria and 94% in Queensland by 2035. The necessary coal closure schedule will also require more renewable energy sooner than previously expected. In other words, Victoria's 95% target needs to be brought forward from 2035 to 2030, Queensland's 2035 target needs to move to 2031 and NSW's 2030 target to 2028.

Coal closures accelerated

The NEM coal closure schedules will define the carbon trajectory of the electricity sector. For the 1.5°C Investor Credible scenario we have developed an independent view on these coal closures, which is as ambitious as possible while retaining credible timing and staging.

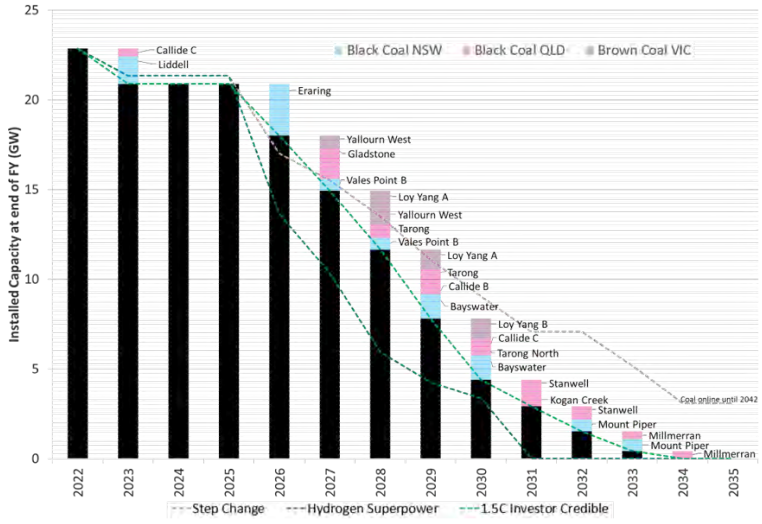
There is an emphasis on closing brown coal plants as these have the highest carbon intensity. Other generators are sequenced within each state based on technical life, with newer generators closing later.

The 1.5°C Investor Credible scenario sees a rapid decline in NEM emissions in the late 2020s and early 2030s. This is later than assumed in AEMO's 1.5°C aligned scenarios because we have different assumptions around a credible coal closure schedule.

NEM-side emissions are largely stable and low from the late 2030s onwards, allowing for natural gas turbines to contribute dispatchable capacity. This may well be replaced by green hydrogen or new storage technology, further reducing emissions.

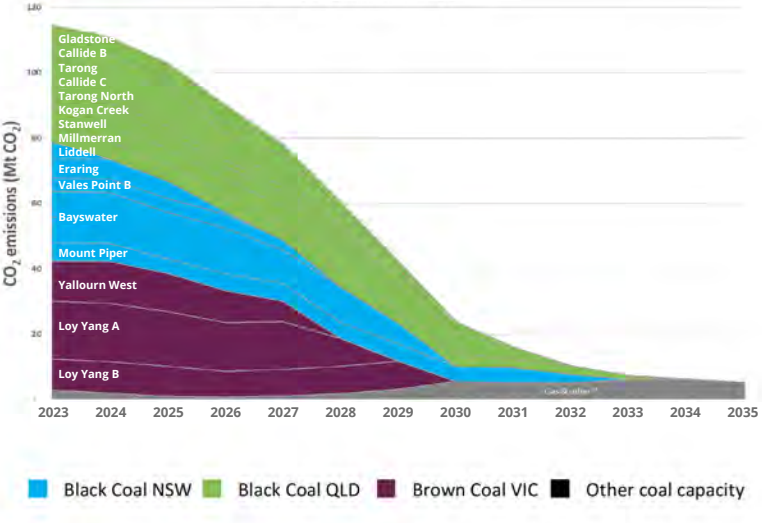
The 1.5°C Investor Credible scenario considers the need for reliability and security across each NEM region. It minimises excessively peaky workforce and supply chain requirements, with a coordinated coal closure schedule smoothing the buildout of replacement capacity. It also ensures that average wholesale spot prices are neither too low for investors nor too high for consumers.

NEM coal closure schedule



*Coloured shading indicates a unit is no longer online by the end of the financial year

NEM CO_2 emissions by plant

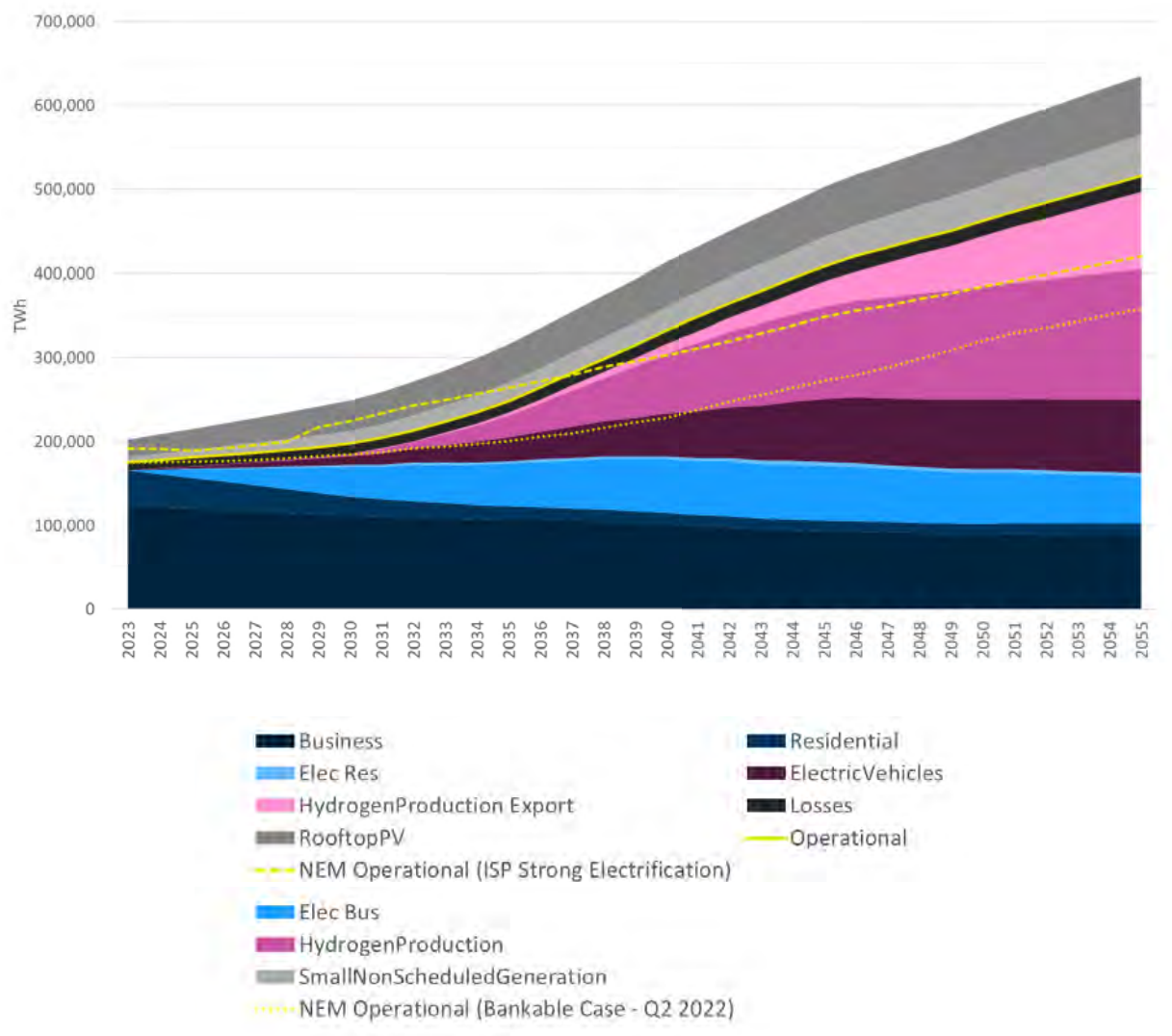


Decarbonisation increases future demand

The energy market transition will be defined by rapid coal closure, replacement generation and storge until 2035, at which point the focus will shift to the electricity demand trajectory. This will dictate how much additional generation and storage capacity is required in the NEM.

This demand is expected to increase significantly as other sectors of the economy electrify. Growth in the hydrogen industry is also a major driver of future NEM demand projections, with Baringa assuming a mix of electrification and hydrogen uptake, as well as the development of a modest hydrogen export industry.

1.5°C Investor Credible NEM Demand



Renewable buildout is achievable

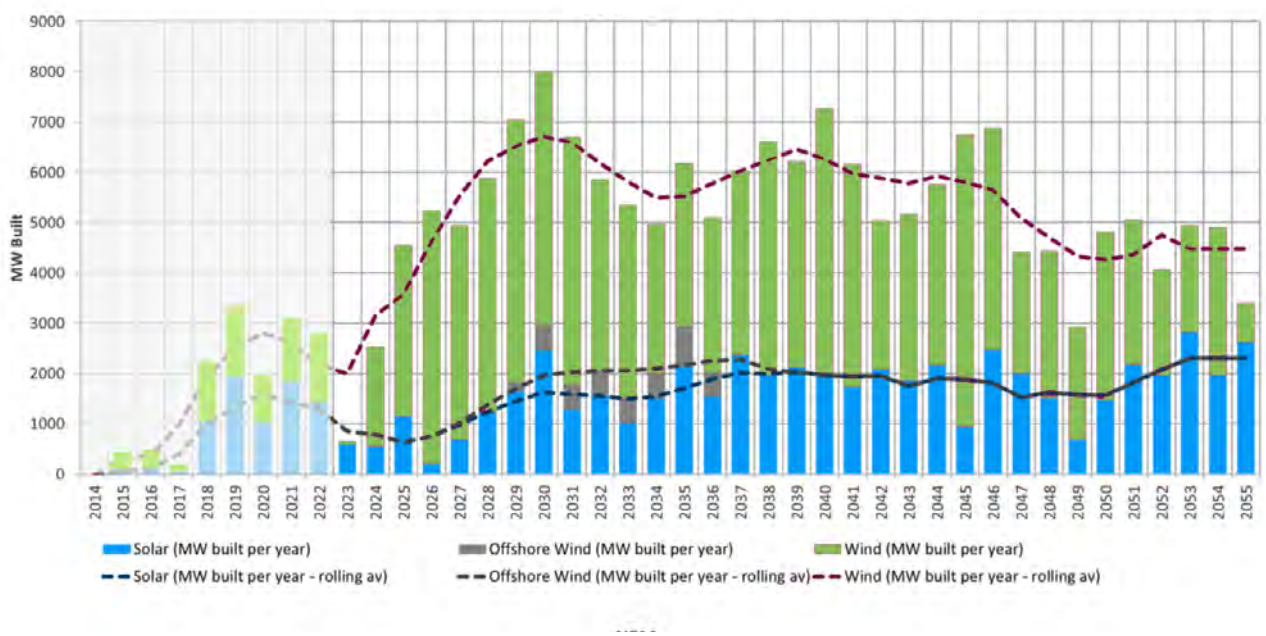
An accelerated energy market transition requires rapid buildout of renewable energy capacity. These build requirements are expected to remain high as other sectors electrify and hydrogen electrolysis comes online.

Volumes in the 1.5°C Investor Credible scenario peak at just over 8 GW in any single year, with an average of 5.5 GW per year between 2024-2034. By comparison, AEMO assumes annual maximums of up to 15 GW for its Strong Electrification scenario and 24 GW for its Hydrogen Superpower scenario.

Renewable energy buildout by region is linked to the timing of coal closures and demand growth, but the model also allows for new build in one region to service the needs of a neighbouring region via interconnection. In NSW, deployment needs to accelerate due to the retirement of the Liddell and Eraring power stations. Queensland needs to accelerate wind and solar buildout in the short term, increasing to about 2.5 GW per year for wind and 1 GW per year for solar.

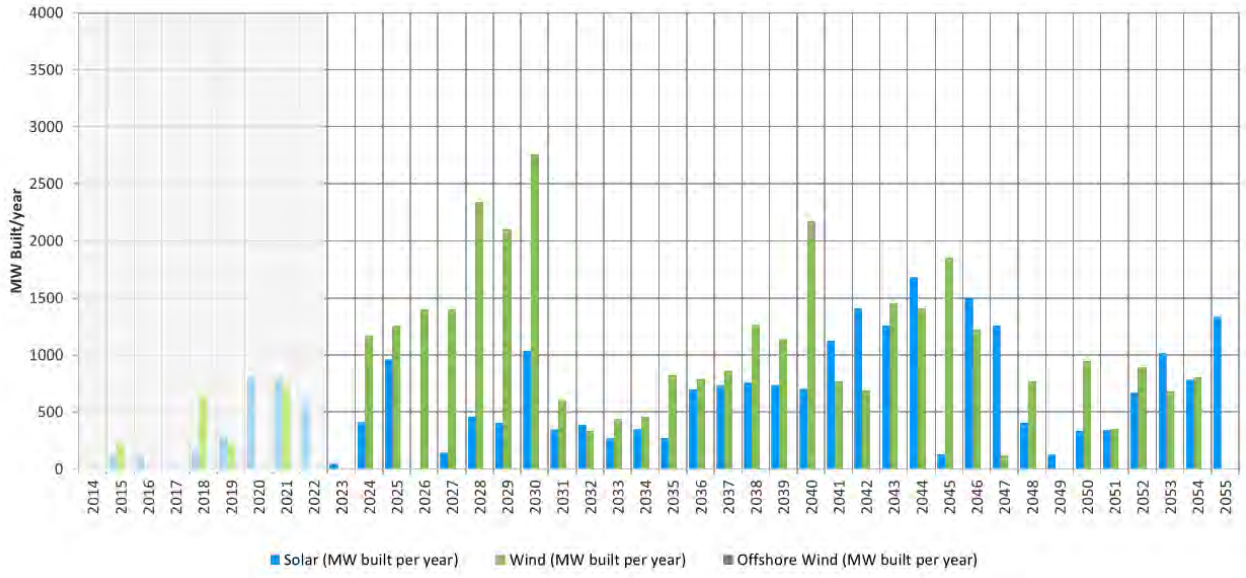
Victorian deployment of onshore wind and utility-scale solar PV is lower than NSW and Queensland, given greater land and network constraints. The Victorian Government is focused on developing an offshore wind industry that will deliver projects by the end of the decade. Other states and territories may explore offshore wind as an option to alleviate onshore build constraints.

NEM

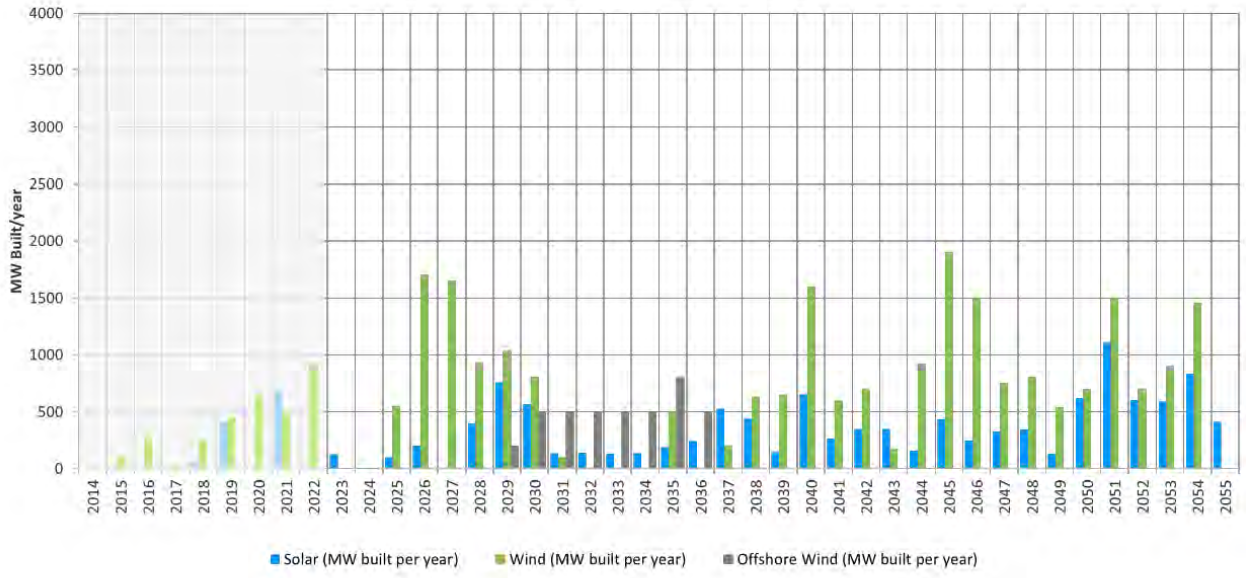


Renewable buildout by state

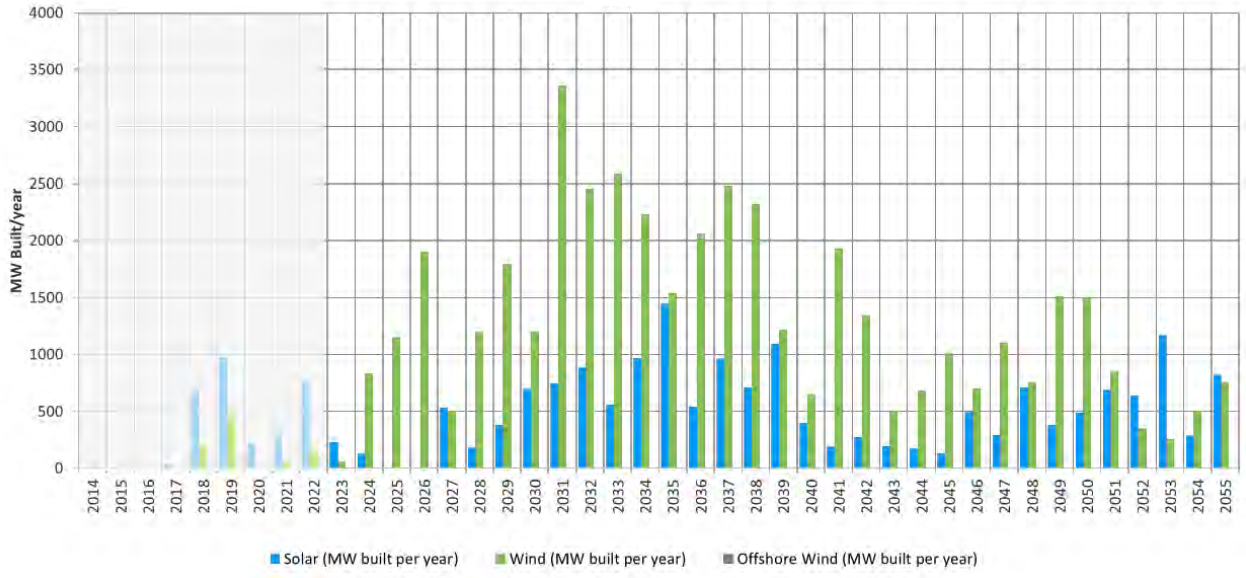
NSW



VIC



QLD

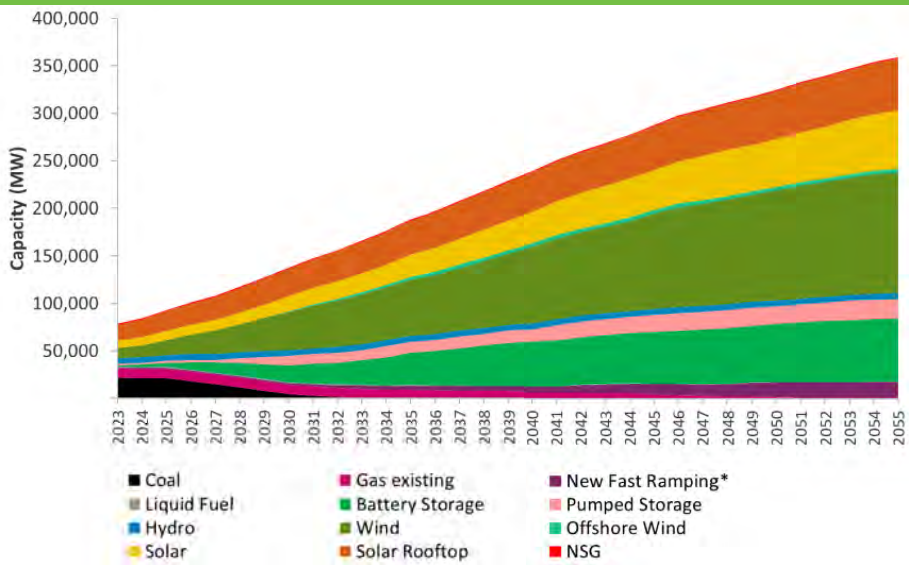


Wind will dominate coal replacement

When compared with Baringa's bankable case, this 1.5°C Investor Credible scenario projects that most of the renewable capacity needed to replace coal and meet increased demand for electrification will come from onshore wind. Utility-scale solar PV will also be needed in the long term, but volumes are assumed to be lower due to competition with rooftop solar.

Most of the new generation will meet increased operational demand, which is significantly higher than the energy required to replace coal generation.

Total Capacity mix - NEM (MW)

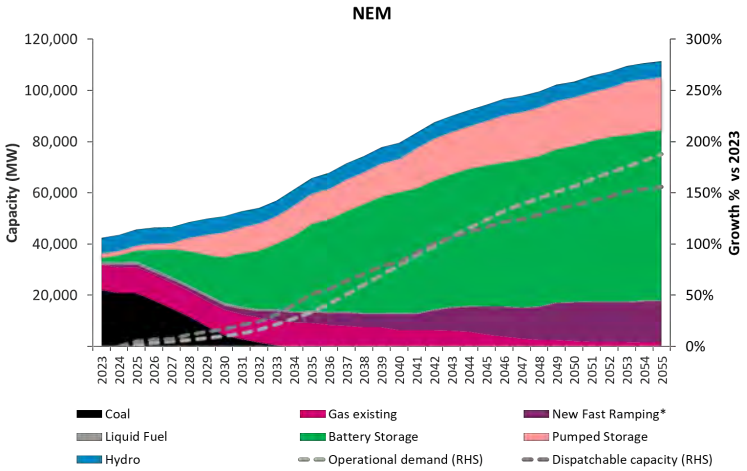


Batteries provide most dispatchable capacity

Batteries will play a leading role as dispatchable capacity replaces coal and meets increased operational demand. Most additional capacity will be delivered by onshore wind (115 GW), utility-scale solar (54 GW) and rooftop solar (38 GW).

The 1.5°C Investor Credible scenario anticipates system stability and inertia requirements will be met by a combination of hydro, pumped storage, synchronous condensers, and battery energy storage systems with advanced inverters underpinned by government support for commercial-scale demonstration.

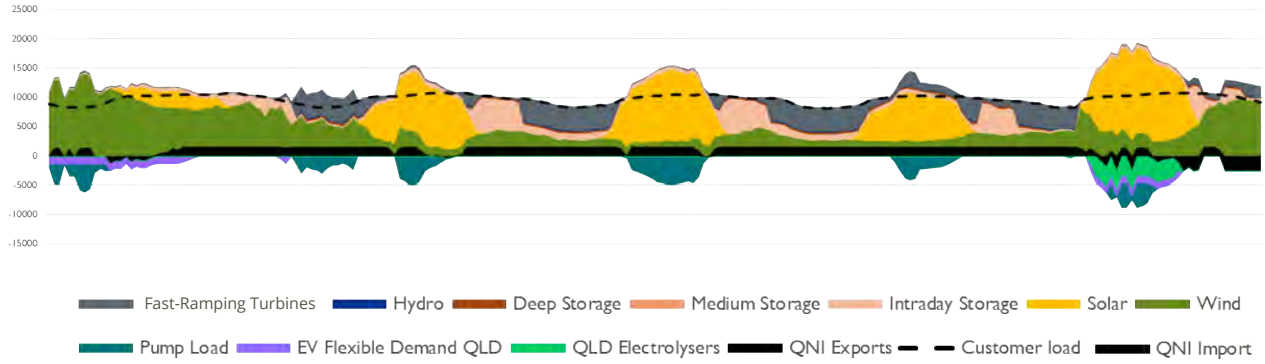
Dispatchable Capacity mix(MW)



Managing variable supply

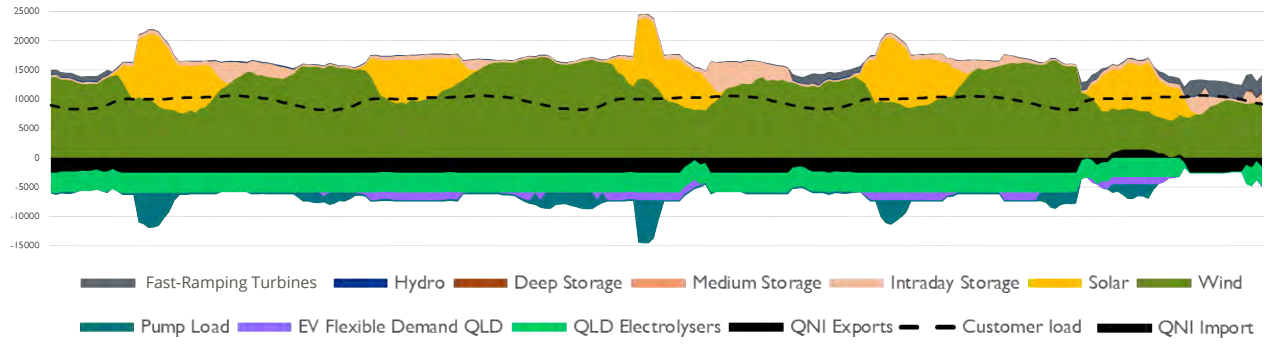
Fast-ramping turbines and storage fill the gap to meet demand during low periods of renewable generation. The fast-ramping turbines are a mix of existing gas plants and new green dispatchable technologies, and are required to operate for between 5-15% of the year. This small volume is unlikely to require any new gas supply.

Low renewable energy week



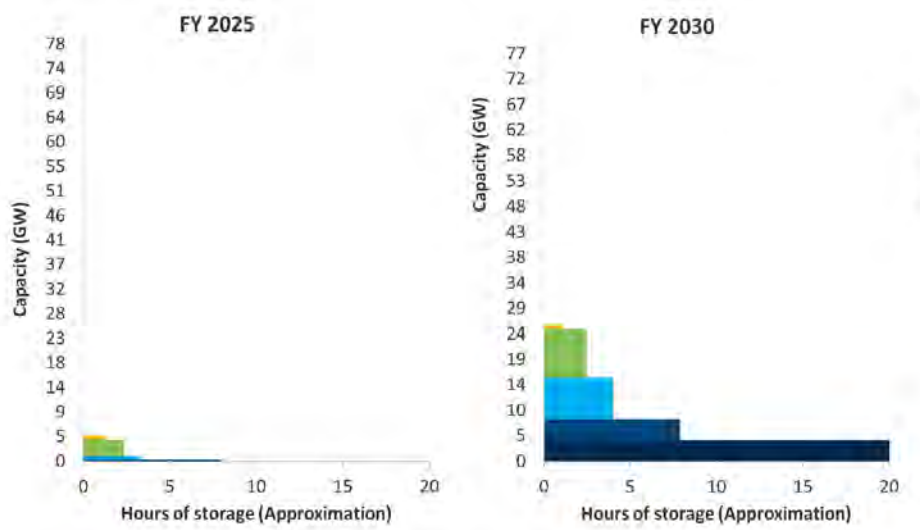
During a normal renewable energy week, flexible demand, pumped load and interconnector flows absorb excess renewable generation, reducing renewable energy spill and improving the economics of renewable assets.

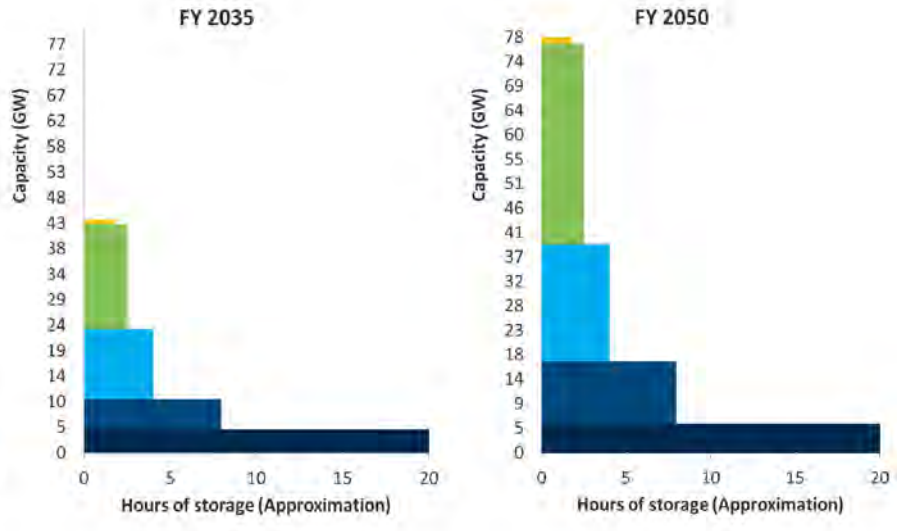
Representative normal renewable energy week



Storage capacity and duration

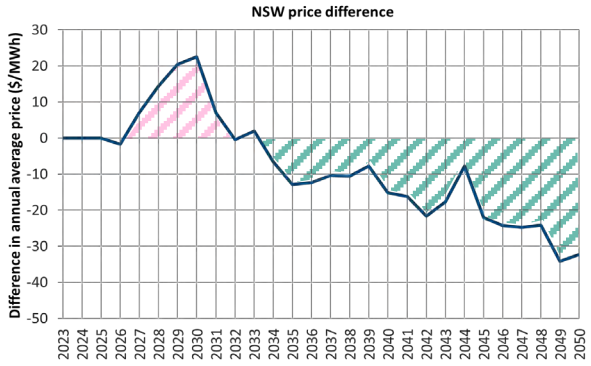
NEM storage capacity and duration also needs to grow alongside renewables deployment.

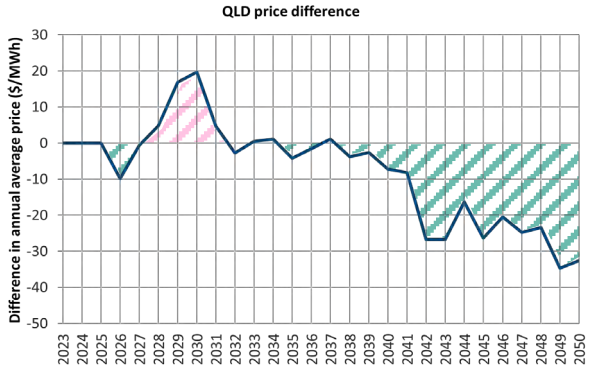


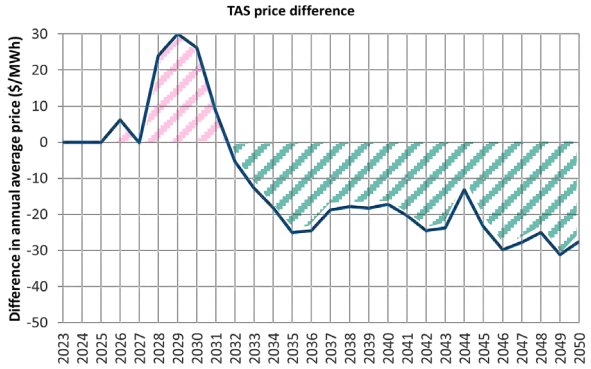


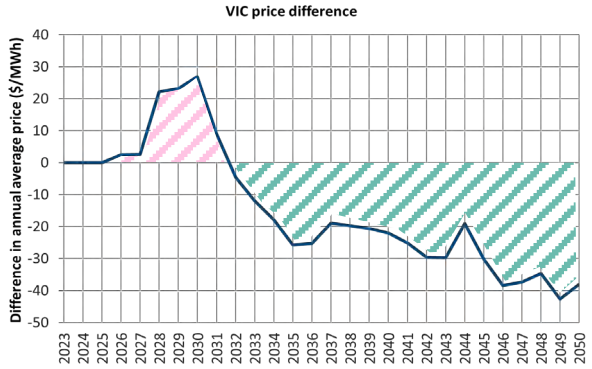
Wholesale prices to fall after early increase

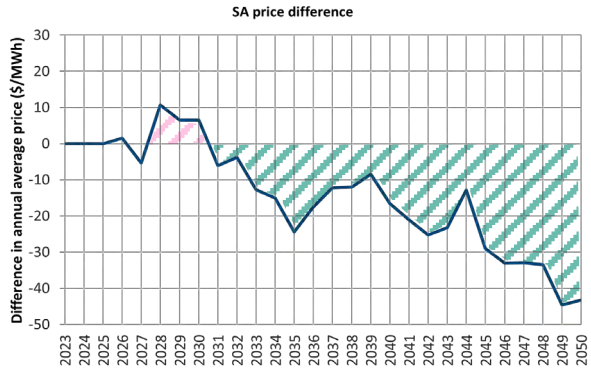
Annual average wholesale spot prices are expected to increase in the short term under the 1.5°C Investor Credible scenario, as existing gas generators run more frequently in support of accelerated coal closures. In comparison to Baringa's bankable case, lower wholesale prices are expected from the early 2030s across all NEM regions, underpinned by greater renewable penetration as well as more government coordination to support the 1.5°C pathway.









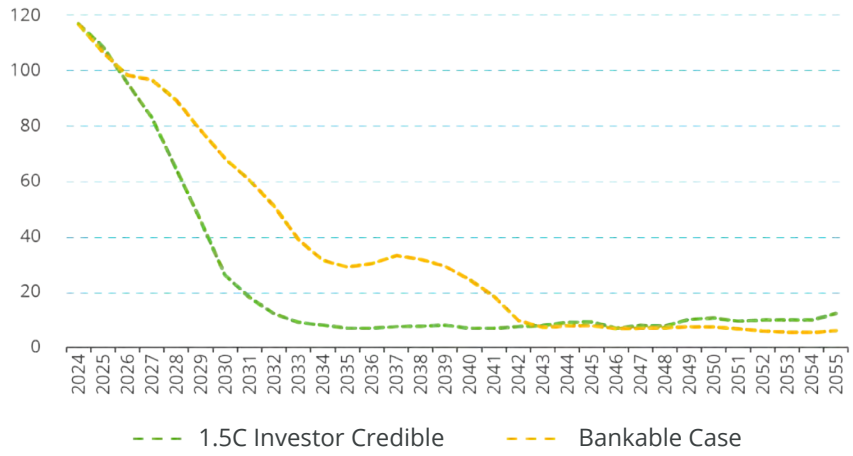


- Comparison between projected annual average wholesale spot prices under the 1.5°C Aligned Case with those under the bankable base case reveal higher prices in the late 2020s and early 2030s as coal exits and existing gas generators are required to run more frequently.
- From the early 2030s, the 1.5°C Aligned Case delivers lower wholesale spot prices, relative to the base case.

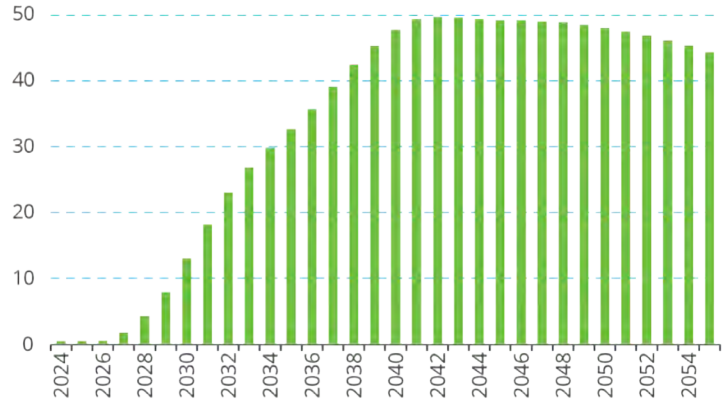
The social benefit of emission reductions

The 1.5°C Investor Credible scenario reduces emissions by more than 348 Mt compared to Baringa's Bankable Case. This equates to a benefit of $43 billion using the ACT Government's social cost of carbon.

Total emissions by year (Mt CO2)



Cumulative value of CO2 reductions(AUD Billions)



Policy Recommendations

Electricity sector needs a carbon budget

A nationally agreed carbon budget for the electricity sector is an important first step that will help state governments and market bodies steer the energy transition. Meeting carbon reduction targets will be challenging without the introduction of carbon targets across industry sectors and clear policies aligned with the ambition.

Recent state government announcements for stronger renewable energy targets are positive, but investors still face uncertainty until these targets are legislated and backed with clear implementation strategies.

Transition needs national coordination

We expect the current trend of accelerated coal closures to continue as these plants struggle to remain competitive against renewable energy, with ageing infrastructure becoming less reliable and more costly to maintain, but this will take too long and eat the carbon budget as the window closes. It offers a pathway to net zero, but not one that is 1.5°C aligned.

Decarbonising the NEM in line with staying below 1.5°C will require brown coal closures to be completed by 2029, with all coal generation offline by 2033. Governments must also ensure the right types of investment in new generation, storage and network assets are made in the right places and at the right time.

The scale and pace of coal closures will require national coordination to ensure the reliability, security and affordability of electricity as the mix of generation, storage and network assets changes in each NEM region. Coordination of closures will also play a vital role in transitioning coal industry workers, local communities and regional economies.

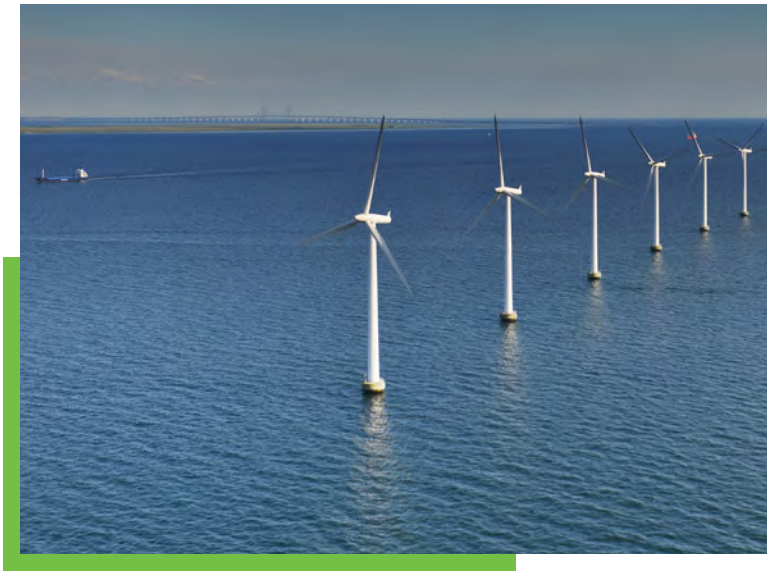
Investment in long duration storage

Long duration storage provides capacity during infrequent renewable energy droughts, making it a core component of system reliability and security. But the limited periods in which this technology will be required, and the associated risk of low revenues, weaken the commercial case for development.

We anticipate government support will be required to deliver the scale of long duration storage in the timeframe required to accelerate energy transition. Baringa's modelling finds market economics alone cannot deliver the volumes needed, which may mean governments need to commit to projects up to 10 years ahead of when they would be required in the market to ensure they are developed in time.

The 1.5°C Investor Credible scenario has a total installed 'deep storage' or 'long duration' dispatchable capacity (8hrs or greater) of about 20 GW by 2055. It also has 16 GW of flexible capacity that has been modelled as open combustion gas turbines but could be delivered through green technology like hydrogen turbines. This takes total long duration dispatchable capacity needs to 36 GW.

Governments are already committing to new capacity, including Snowy Hydro 2.0, long duration pumped hydro in Queensland, and Tasmania's Battery of the Nation, but at least 12 GW more deep storage is still needed.



Support for offshore wind development

Given the availability and quality of onshore resource, offshore wind is not currently economic in the NEM without subsidy. It is unlikely to be cost-competitive until the 2040s. We expect Victoria will be the first to build offshore wind capacity, with government support closing the economic gap.

Despite the relative economics favouring onshore new build, the significant social license and supply chain challenges associated with onshore generation and network build may justify bringing more offshore wind into the system with government support. A single project will generate gigawatts of power, reducing delivery risks and providing a level of certainty.

On the downside, more complex site assessment and approval processes mean much longer project development timeframes. The ISP assumes a total lead time of nine years for offshore wind, but it is worth noting that it has taken about 12 years in the UK. Australian governments are making efforts to enable coordination that should reduce these timeframes.

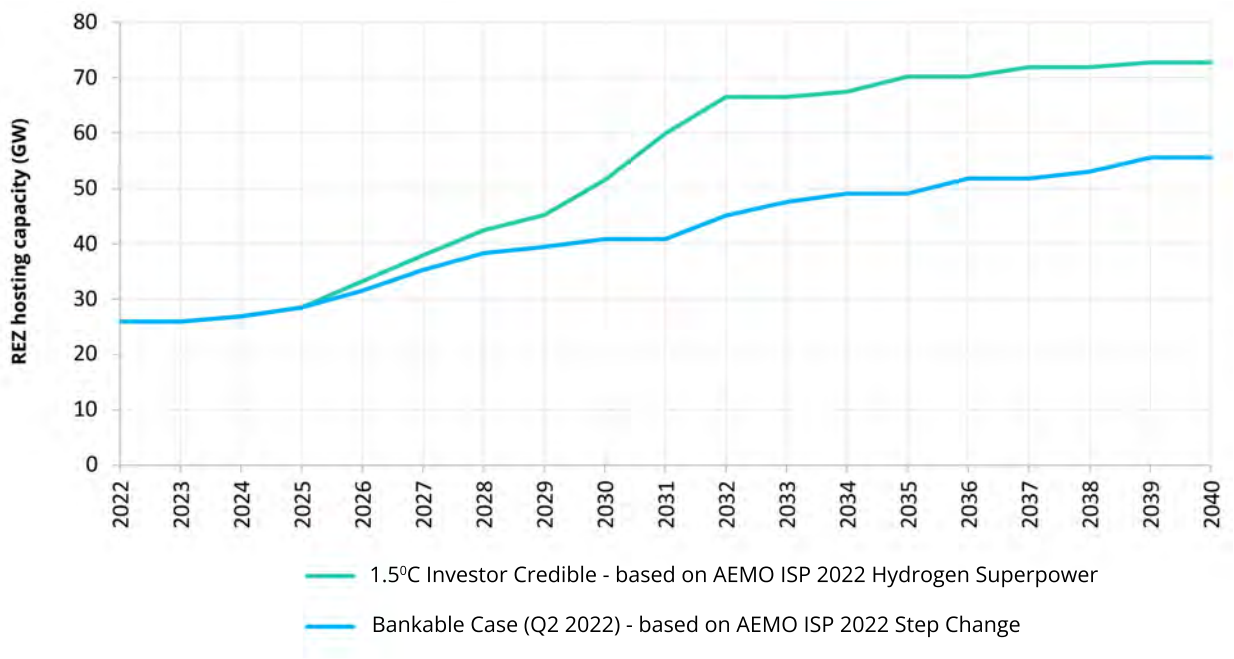
Governments will need to make near-term commitments in order to see offshore wind farms commissioned in the late 2020s and early 2030s.

Accelerating network infrastructure build

The 1.5°C Investor Credible scenario assumes that the network infrastructure identified in the AEMO ISP 2022 Hydrogen Superpower scenario is developed, with the timing accelerated compared with the AEMO Step Change scenario to accommodate the necessary new generation and storage infrastructure in each region.

Renewable Energy Zone build needs to be accelerated from the mid-2020s to accommodate new generation. Some of the 'future projects' identified in the 2022 ISP need to be included as 'actionable projects' to hasten approval and development.

Major new network infrastructure is expected to take approximately six years to plan, approve, develop and commission. Government must ensure that the regulatory framework is able to accommodate the fast-tracked consideration and approval of multiple projects in parallel.



Skills, supply chains and communities

Decarbonising the NEM in line with staying below 1.5°C commitments will require the development of network, generation and storage infrastructure at scale. Practical delivery will be challenging when so many other economies are looking to decarbonise at the same time.

Australian governments recently agreed to explore options for aggregating renewable energy and storage projects to identify supply chain coordination and onshore manufacturing opportunities.

Communities will also need to be engaged in and prepared for the transition. Those with coal generation infrastructure will need to be supported through employment and economic transition. Others impacted by future network, generation and storage development will want to ensure that this benefits the community rather than conflicting with its interests. Consideration should be given to vulnerable groups most impacted by short-term increases in electricity prices, noting that they are modelled to decline significantly in the medium to long term.

Next Steps

Governments

To ensure there is a coordinated effort between the Commonwealth, state and territory governments, we are calling for the 1.5°C goal to be incorporated into the National Energy Transformation Partnership (NETP).

We need policy settings that will help unlock the $421 billion of private investment required. This may include a commitment to open discussions with gentailers on developing policy that supports the orderly transition away from coal in line with achieving 1.5°C aligned outcomes.

Following an announcement through the NETP, we are calling on governments to develop a suite of policies aimed at achieving a 1.5°C aligned trajectory. These may include:

- **Increasing renewable energy targets**
- **Coordinating coal closures**
- **Supporting long-duration storage**
- **Fast-tracking offshore wind**
- **Accelerating the development of network infrastructure**
- **Skills and supply chain coordination and development**
- **Best-practice community engagement and social licence**

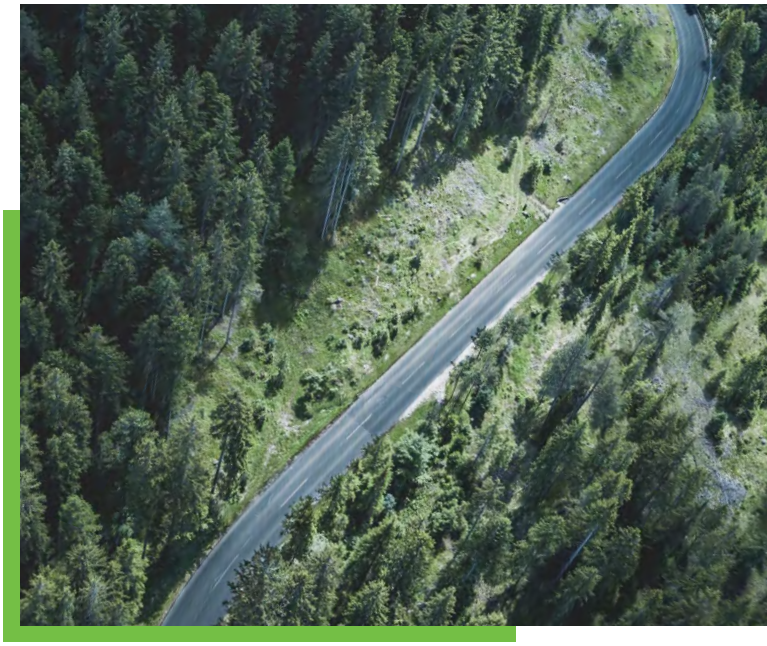
Gentailers

The Baringa 1.5°C Investor Credible scenario presents a feasible pathway to building the generation, storage and network capacity required to replace coal and facilitate rapid electrification, whilst maintaining investable and affordable wholesale prices.

We are calling on gentailers to work closely with governments through the NETP on a coordinated approach that supports the orderly transition away from coal in line with achieving 1.5°C aligned outcomes.

This may include negotiation on policies that leverage site specific advantages such as access to the grid or renewable resources to accelerate the repurposing of coal fired-power power stations and associated transmission infrastructure into clean energy hubs.

There is no time to lose in seizing these energy transition opportunities. The key to protecting shareholder value and maintaining market share lies in renewable generation and storage capability investment. Gentailers must make effective use of their existing transmission infrastructure and transition their workforce to supporting a clean energy future.



Market Bodies

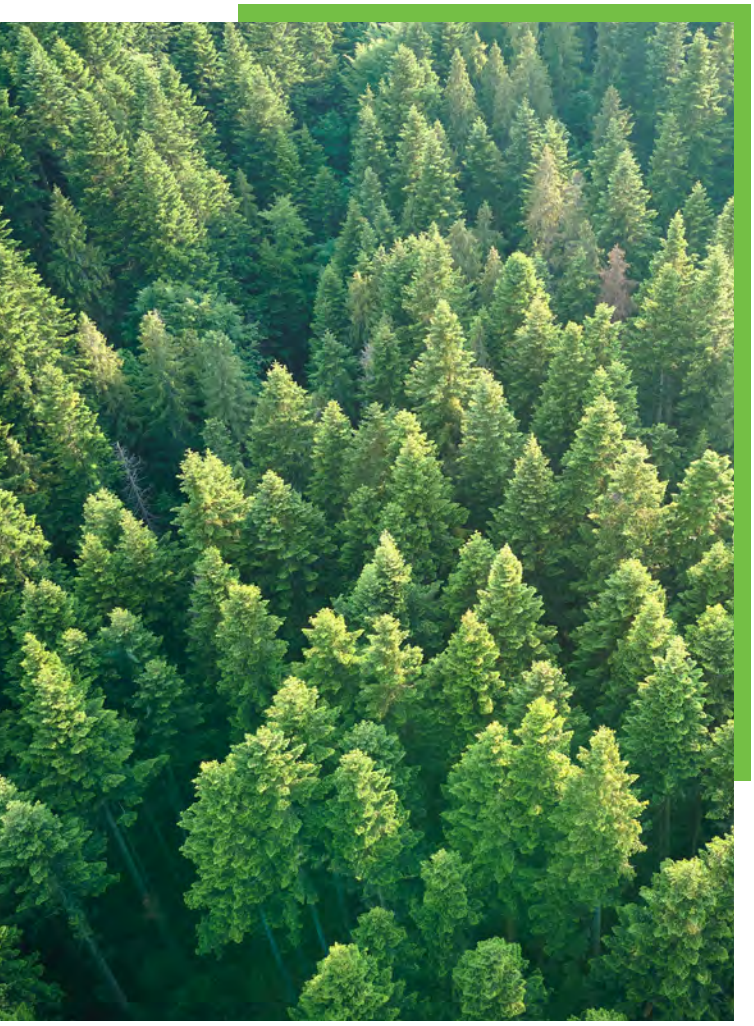
We advocate for the Commonwealth, state and territory governments to announce policies aligned with our 1.5°C Investor Credible scenario. These announcements will have a trickle-down effect through the three energy market bodies as part of the amended National Energy Objective (NEO).

We call on market bodies to base their work on Baringa's 1.5°C Investor Credible scenario before the NEO is passed. To ensure there is no delay in the transition, we are calling on AEMO to include this scenario in the next ISP.

Investors

We are calling on investors to start planning for a credible 1.5°C aligned pathway and to start using Baringa's 1.5°C Investor Credible scenario. They also have a significant role to play in educating market bodies and governments around the importance of a credible 1.5°C scenario in unlocking the $421 billion required to decarbonise the NEM in line with Paris Agreement commitments.

About This Report



The Clean Energy Investor Group was formed in 2019 to respond to the increasing market volatility and risks faced by investors in utility-scale renewable energy projects in Australia. CEIG advocates on behalf of investors on the policy and market design needed to help unlock low-cost capital for Australia's clean energy transition.

CEIG acknowledges the support of Boundless Earth to present this report to key stakeholders.

The report is based on the 'Decarbonising Australia: Accelerating our energy transition with a credible 1.5°C scenario' commissioned by Boundless Earth. The research and modelling was completed by Baringa in November 2022.

Boundless Earth's mission is to ensure Australia is on track to become a renewable energy superpower by 2030. Boundless Earth is a non-profit which deploys philanthropy, investment and direct advocacy to achieve its goal.

Baringa Partners is building the world's most trusted consulting firm by putting people first, creating impact that lasts and solving the toughest challenges. Every client we work with gets a hand-picked team eager to share their deep experience and geeky enthusiasm for their specialist subjects. We build working relationships that last for decades because we're in it for the long haul.

Methodology

Key input assumptions

Baringa has taken a top-down and bottom-up approach to the development of a credible 1.5C pathway. It started with a top-down approach, applying an indicative carbon budget for NEM regions that aligned with a 1.5°C economy-wide carbon budget, drawn from CSIRO and ClimateWorks multisectoral modelling undertaken in 2021[1]. It also applied a 43% reduction by 2030 and Net Zero by 2050 commitments as constraints. It assumed the proposed emission reductions from non-electricity sectors were achievable.[2]

For the bottom-up approach, Baringa developed an independent NEM carbon trajectory using iterative modelling incorporating a credible view on coal closures, new generation build, and future electricity demand to align with the top-down applied constraints. This resulted in a marginally higher carbon output for the NEM than the 2021 CSIRO and ClimateWorks modelling, but overall it is aligned with a 1.5°C carbon budget.

Other key input assumptions used in the iterative modelling included policy assumptions from Baringa's current bankable case, which is widely used by investors:

[1] Baringa notes that CSIRO/ClimateWorks released updated economy-wide analysis after this work was completed – the 2022 Hydrogen Export scenario. Although economy-wide emissions halved in this scenario compared to CSIRO/ClimateWorks' 2021 work, the carbon budget for the NEM did not change. Baringa considers its 1.5°C Investor Credible scenario remains relevant for policymakers. To enhance the scenario's accuracy, Baringa would include additional business demand from reduction in industry emissions. This would likely result in a faster deployment of renewables but the main messages from this report would remain unaffected.

[2] Baringa notes that all of the economy-wide 1.5°C scenarios include significant negative emissions technologies, such as sequestration. If these negative emissions are not achieved, the NEM carbon budget would need to be reduced significantly to align with a 1.5°C pathway.

Driver	Assumption	Current bankable base case
Policy	Carbon price	None.
	Emissions reduction policy	Federal Govt Net Zero by 2050 commitment implemented via incorporation of AEMO 2022 Final ISP Step Change.
	Integrated System Plan	New interconnection and transmission implemented as per 2022 Final ISP optimal development path.
	State-based renewable targets	First 2-3 rounds of VRET and QRET auctions proceed. Partial achievement of VIC offshore wind targets (full capacity not assumed, given no legislation or policy detail). 12 GW of new renewables capacity assumed to enter in NSW as per legislation (GWh equivalent).
	Green value	LGC value until legislated 2030 end date, then voluntary demand drives enduring value.
Capacity mix	Coal plant retirements	Pre-2030: Retire coal plant at end of 50-year life (subject to economic test), or earlier if there is a public announcement or significant adverse economics up to 2030. Post-2030: Retirement at the earlier of expected retirement and 45-year life.
	Gas plant retirements	Aligned with AEMO assumptions.
	Technology costs	Baringa internal cost assumptions.
Demand	Demand and peak demand	AEMO Central (ESOO 2020) transitioned to AEMO Step Change case (ISP 2022 Final) by 2030
	Rooftop solar and residential storage	AEMO Step Change (2022 Final ISP)
	Electric vehicle (EVs)	AEMO Step Change (2022 Final ISP)
	Hydrogen	AEMO Step Change (2022 Final ISP), adjusted to smooth peaks
	Electrification (business and residential)	AEMO Step Change (2022 Final ISP)
Commodity prices	Gas prices	LNG netback prices (latest ACCC LNG netback series, transition to JKM future prices then US Henry Hub prices)
	Coal prices	Asian coal export price for 'uncontracted' plant (Japan coal prices less transport costs)

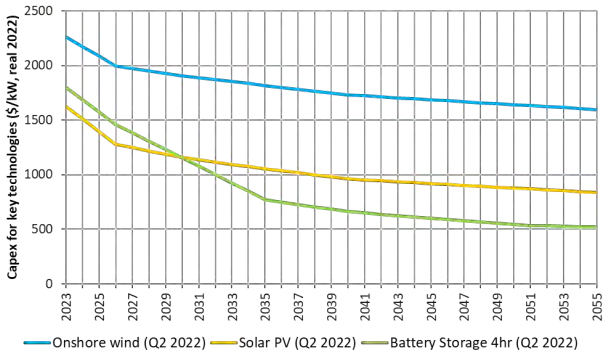
Assumption	Source
PV uptake	AEMO ISP 2022: Step Change
BtM battery uptake	AEMO ISP 2022: Step Change
EV uptake	AEMO ISP 2022: Strong Electrification
Electrification	Residential - 2022 ESOO – Hydrogen Superpower
	Business - 2022 ESOO – Hydrogen Superpower
	Underlying demand - ISP 2022 – Hydrogen Superpower
Volume of domestic H_2 demand	ISP 2022 – Hydrogen Superpower
Volume of export H_2 demand	AU H_2 strategy targeted deployment
Transmission Network Buildout	ISP 2022 base – if constrained we select other projects to bring in

Technology cost assumptions are a major driver of new investment in the model for standalone wind and solar as well as hybrid systems after 2025.

Baringa's cost assumptions are based on a database of global cost elements such as panels, turbines and battery cells, as well as local cost elements like grid costs. This is regularly benchmarked against data seen in due diligence work. Baringa has reviewed and updated its short-term capital expenditure predictions. Learning rates are reasonably aligned to AEMO ISP assumptions in the long term.

The cost of capital is assumed to decrease to 6% post-2040 as new policies de-risk renewable investment.

Technology costs



Our methodology

- Our cost assumptions are based on an internal Baringa database of global cost elements (eg. panels, turbines, battery cells) and local cost elements (e.g. BOP, grid costs), which is regularly benchmarked against data seen in our DD work.
- We note these assumed cost reductions are smaller than those experienced in the past 5 years. Learning rates are reasonably closely aligned to AEMO ISP assumptions in the long term.
- Post-2050 technology cost assumptions use linear extrapolation of the year-2050 technology cost, based on the average annual rate of decline in costs over the preceding 10 years.
- We assume the cost of capital decreases to 6% in the long term (post 2040) as new policies de-risk renewable investment.

Technology costs (2023): indicative average for merchant projects (i.e. no long-term PPA)

Technology	All-in capex ($/kW)	Opex ($/kW/yr.)	Load factor (%)^	Equity hurdle rate (% nominal)	Gearing (%)	Cost of debt (% nominal)	WACC (pre-tax real)	LCOE/LCOS ($/MWh)
Onshore wind	2,260	46	36 – 40%	14.8%	40%	4.0%	8.3%	$72-80/MWh
Solar PV (AC)	1,622	20	23 – 27%	14.8%	40%	4.0%	8.3%	$71-84/MWh
Battery Storage 4hr	1,564	19	17%	14.8%	40%	4.0%	8.3%	$125/MWh

Overview of our NEM model

Our model produces half-hourly wholesale prices for each NEM region.

Key Inputs

- Scenario inputs – Policy, fuel prices, technology costs, demand, behind-the-meter deployment, plant retirement
- AEMO plant-level database – Installed capacity, efficiencies, operating costs, operating constraints
- Investment decision model for new build capacity
- Cross-regional interconnector capacity
- Detailed half-hourly wind and solar profiles

Model Engine

- Half-hourly dispatch, least-cost optimisation framework using the PLEXOS platform
- Optimisation of operational constraints including start costs, ramp rates, heat rates
- Maintenance scheduling and unplanned outages

Key Outputs

- Half-hourly wholesale electricity prices by NEM region
- Generation schedules
- Generation weighted-average prices
- Asset energy revenues and gross margins
- Carbon emissions
- Interconnector flows (imports/exports)

Bidding behaviour

Prices are set by the running costs of the marginal plant (SRMC), plus the impact of plant bidding above SRMC in periods of system scarcity to extract additional 'scarcity rent' revenue.

- The system short run marginal cost (SRMC) is the marginal cost of the marginal generation unit in each half hour
- Plant with lower SRMCs than the marginal generation unit will earn 'infra-marginal rent' profit, which is the difference between their SRMC and system SRMC or 'shadow price'
- Scarcity rent is added to the system SRMC to calculate final hourly wholesale prices:
- We treat scarcity rent as a function of half-hourly capacity margin, where tighter capacity margin equals higher scarcity rent
- This reflects the scarcity value of power on a half-hourly basis, which is important in determining a return on capital in an energy-only market
- We correlate scarcity rent to the capacity margin, underpinned by historic bidding behaviour, but it is the result of many inter-related factors

Defining a credible coal closure schedule

The coal closure methodology in our 1.5°C Investor Credible scenario considers emissions intensity, plant life, reliability and security, build out replacement capacity and affordability in determining the schedule.

Brown coal is closed as a priority, given these generators have the highest emissions intensity, and other generator closures are sequenced within each state based on technical life, with newer generators closing later.

Coal closure schedule

Plant	State	Capacity (MW)	Comm.	Bankable Case (Q2 2022)	1.5°C Aligned Case	Accelerated closure
Liddell	NSW	2,020	1972	Apr-23	Apr-23	-
Eraring	NSW	2,880	1982	Aug-25	Aug-25	-
Yallourn West	VIC	1,435	1973-82	Jun-28	Jun-26, Jun-27	~2 years
Gladstone	QLD	1,680	1976	Jun-26	Jun-26	-
Vales Point B	NSW	1,320	1978	Jun-26, Jun-27	Jun-26, Jun-27	-
Loy Yang A	VIC	2,265	1984-88	Jun-31, Jun-33	Jun-27, Jun-28	~5 years
Tarong	QLD	1,400	1986	Jun-30, Jun-31	Jun-27, Jun-28	~3 years
Callide B	QLD	700	1988	Jun-28	Jun-28	-
Bayswater	NSW	2,740	1985	Jun-30, Jun-33	Jun-28, Jun-29	~4 years
Loy Yang B	VIC	1,120	1993-96	Jun-40, Jun-41	Jun-29	~12 years
Callide C	QLD	840	2001	Jun-41, Jun-42	Jun-29	~13 years
Tarong North	QLD	450	2003	Jun-31	Jun-29	~2 years
Stanwell	QLD	1,460	1996	Jun-40, Jun-41	Jun-30, Jun-31	~10 years
Kogan Creek	QLD	744	2007	Jun-37	Jun-30	~7 years
Mount Piper	NSW	1,390	1993	Jun-39	Jun-31, Jun-32	~8 years
Millmerran	QLD	852	2002	Jun-41, Jun-42	Jun-32, Jun-33	~9 years

*Year means the plant closes within the financial year. Where there are two years, plant units are closed over both years.