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Leap into the Dark: The Cost of Australia's Energy Transition Plan and the Risk of Failure.

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Introduction

The first European settlers arrived in Australia on the eve of the last great energy transition. The motive power of the First Fleet was wind and human muscle. However, the Industrial Revolution that had recently begun in Britain was about to give humans access to a more powerful and efficient source of energy.

The ability to turn energy-dense fossil fuel into usable energy was the key to Australia's rapid growth in prosperity in the space of a century. By the time the Colony of NSW marked a century of settlement in 1878, ocean-going vessels were beginning to be constructed from steel and powered by steam.

Frederick Wolseley was demonstrating a prototype set of mechanical sheers, an Australian invention that would enable Australia to become the dominant supplier of wool to steam-powered woollen mills on the other side of the world.

Preparation was underway for the first export shipment of frozen lamb, a technological breakthrough that would measurably improve British diets and longevity. Australia was joined to Europe by electric telegraph, the first stage in the development of electronic communication that would break the tyranny of distance.

A massive infrastructure investment project that would supply homes, factories and civic spaces with electricity on demand was beginning to be contemplated. Tamworth would become the first town in Australia to be serviced by an electric grid in 1888.

The purpose of this potted history of Australia's industrial and economic progress is to illuminate the scale of the challenge of transitioning to a net-zero emission economy.

The magnitude of the task is seldom acknowledged in the public and political debate. There is a scant appreciation of the technical difficulties of decarbonising our energy supply and limited discussion about the costs.

The following summary of the economic and physical challenges is far from exhaustive.

- The last transition took more than a century to complete. It required constant innovation and an incalculable amount of capital investment.
- Our current net-zero path requires us to abandon fossil fuels entirely in favour of renewable sources of energy, namely wind, solar and water in just 27 years.
- Previous energy transitions adopted sources of energy of greater density and efficiency than the sources they replaced. In this one the process is reversed.
- The last transition gave us more dependable sources of energy that were independent of the weather patterns. A transition to a net-zero economy based purely on renewable energy presents us with the seemingly insurmountable problem of overcoming variability.
- The last transition considerably reduced the demand for land and consequently lifted the pressure on biodiversity. Vast hectares of woodland ceased to be felled solely to produce energy.
- A transition to renewable energy once again makes heavy demands on land. One recent survey[1] estimates that a transition to Zero-2050 that only used land-based renewable generation would require 129,179 sq km of land, an area roughly the size of Victoria.

1 'How to Make Net-Zero Happen', Net Zero Australia, University of Melbourne, July 2023 p.50

- The last energy transition sought greater efficiency by centralising energy production in industrial-scale fossil fuel conversion plants. The proposed transition to renewables decentralises energy production from a few dozen power stations to cottage-scale roof-top generators and hundreds of small, part-time generators distant from population centres.

The net-zero challenge

With the passage of the Climate Change Act in September 2022, Australians became legally committed to transforming the energy system by replacing coal, gas and oil with low-carbon alternatives by 2050.

The legislation, supported by both sides of politics, moves the focus of the energy policy debate away from disputes about climate science to a pragmatic discussion about how best to achieve our goals.

Failure is not an option. Australia is committed to net-zero emissions by 2050 and has the resources and intelligence to achieve its goal. Yet as the Fisher Report[2] found in 2019, the economic impact of pursuing ambitious renewable energy targets is considerable.

Modelling by BAEconomics found that cumulative GNP losses of pursuing Labor's then 45 per cent 2030 target would be between $264 billion and $542 billion depending on the chosen parameters. A rise in the energy price would lead to a minimum 3 per cent reduction in real wages and 167,000 fewer jobs in 2030.

The economic consequences of the Government's current policy are likely to be of a similar order.

In this paper, however, we focus on the direct costs to the National Electricity Market.

Reviewing the current strategy

The Albanese Government has set a greenhouse gas emissions reduction target of 43 per cent below 2005 levels by 2030.

To achieve this target, the Government has adopted a roadmap produced by the Australian Energy Market Operator (AEMO). The roadmap was updated in June 2022 in AEMO's bi-annual Integrated System Plan for the National Energy Market.[3]

The Government has adopted the Step Change scenario described by AEMO as 'rapid consumer-led transformation of the energy sector and coordinated economy-wide action'. The Step Change scenario envisages a fast acceleration in the transition from fossil fuel to clean energy in the NEM rather than building momentum over time, as in the Progressive Change scenario.

The Menzies Research Centre commissioned Sabine Schnittger of Principal Economics to critically review the Government's renewable energy plans. The findings reveal significant risks in adhering to the Government's target.

1. The target requires a significant increase in investment in renewable energy generation, storage and transmission. The AEMO has estimated that the cost of achieving this target would be around $320 billion in net present value (NPV) terms.

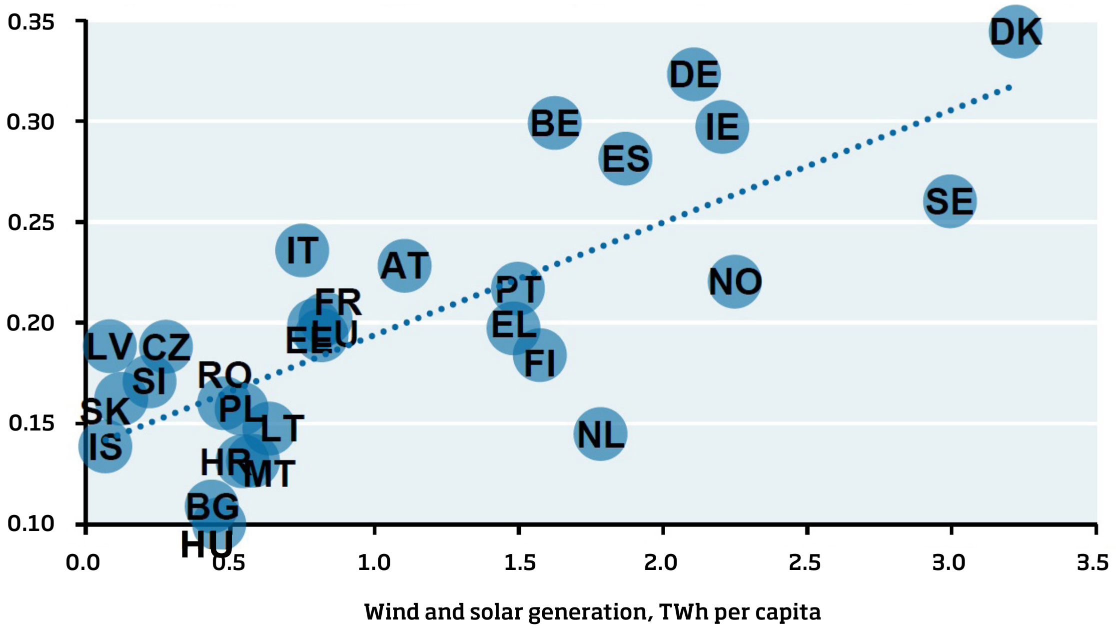
2 'Economic consequences of alternative Australian climate policy approaches', Brian S. Fisher, BAEconomics, Canberra, 2019
3 Integrated System Plan for the National Electricity Market, AEMO, June 2022

2. The target will increase the risk of blackouts. AEMO's own modelling shows that thermal generation capacity will be needed beyond 2050, and that many increasingly pressing system security issues have not been resolved. This is because intermittent renewable energy sources, such as wind and solar, cannot be relied upon to provide baseload power or other system support services. Other independent commentators suggest that AEMO's modelling materially underestimates the risks of outages.
3. The target will lead to higher electricity prices. The cost of building and operating renewable energy projects, the requirement for new transmission lines and the cost of firming impact on system costs. This means that electricity prices will need to rise to cover the cost of the transition to renewables.

These costs will ultimately be carried by the individuals and businesses either as tax-payers or consumers. The result will be substantially higher energy costs for consumers and businesses.

The correlation between the penetration of wind and solar generation and the retail cost of electricity is strong.

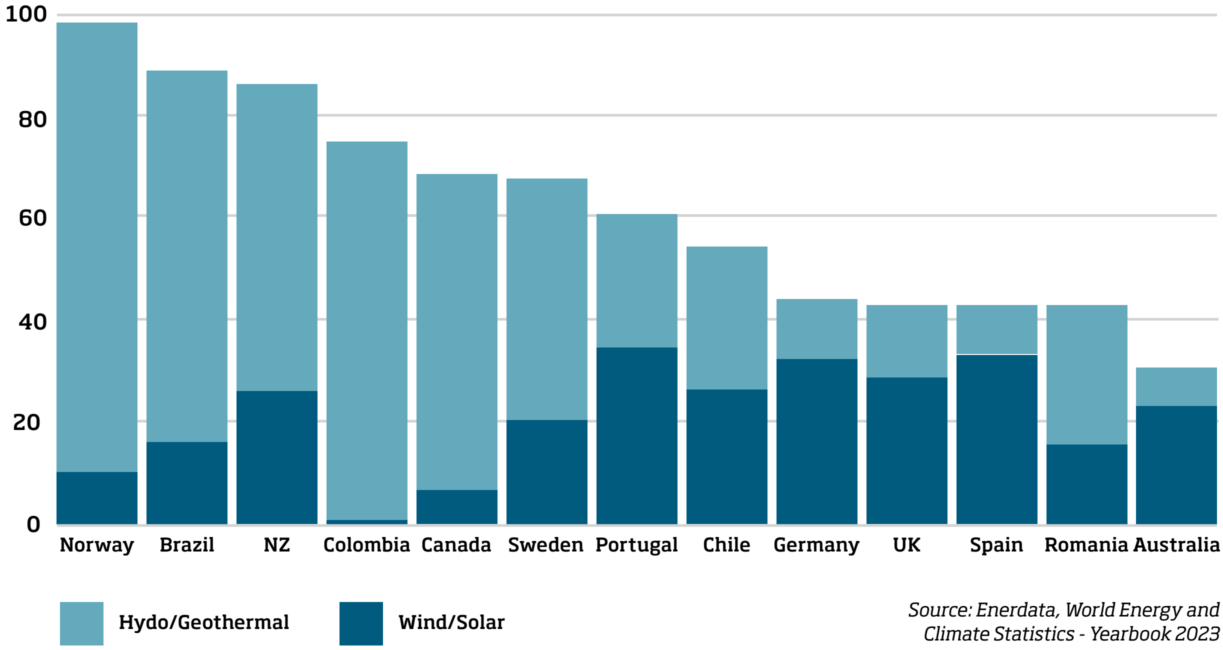
Household electricity prices vs wind and solar penetration in Europe by country, Electricity prices, EU / kWh (H2 2021)



By embarking on this strategy, Australia has taken a leap into the unknown. The scale of investment required to achieve the 82 per cent renewables target is unprecedented. The engineering challenge of incorporating such a large amount of variable renewable energy (VRE) is immense.

No country in the world has achieved anything close to such a concentration without a considerable contribution from nuclear, geo-thermal or hydro generation.

Proportion of renewable energy used for electricity generation, 2022



Source: Enerdata, World Energy and Climate Statistics - Yearbook 2023

Proportion of renewable energy (%)

	Wind	Hydro/Geothermal
Norway	10.2	88.3
Brazil	16.4	72.8
NZ	26.2	60.4
Colombia	0.7	74.4
Canada	6.8	62
Sweden	20.5	48
Portugal	34.8	26.2
Chile	26.5	28.1
Germany	32.5	11.9
UK	29	14.3
Spain	33.2	9.9
Romania	15.7	27.2
Australia	23.2	7.5

The timetable for construction is impossibly tight. The schedule for the withdrawal of baseload coal and gas is out of sync with the timeline for expanding the capacity of renewables. The target will increase the risk of blackouts, as the NEM will only be able to meet reliability objectives with significant investment in storage and other forms of firming capacity.

Meeting the target would require 5000 – 7000 MW of large-scale generation to be added to the grid every year between now and 2030.[4] However, the pace of investment is slowing considerably.

In the third quarter of 2023, just two projects totalling 161 MW gained financial commitment, bringing the total for the year to 509MW.

The Clean Energy Council has revised its rolling quarterly 12-month average by 13 per cent to 608 MW, roughly a tenth of the amount required to meet the Government's target.

Why AEMO's costings are incomplete

The Principal Economics report exposes serious gaps and inconsistencies in AEMO's projected costs. It means that AEMO's estimate of $320 billion (NPV) substantially underestimates the actual figure.

Consumer investment in solar panels and batteries

They do not include the costs incurred by households in installing and maintaining solar photovoltaic (PV) systems and batteries. AEMO's forecast relies on significant uptake of consumer-owned devices to meet the 2030 and 2050 targets.

The Government's target requires a more than four-fold increase in rooftop solar panel capacity from around 15 GW today to more than 37 GW by 2030 and 69 GW by 2050. The total storage capacity of consumer-owned batteries must roughly treble by 2030 to reach a total of 5.5 GW and treble again to reach 14.5 GW by 2050.

At current retail costs, that amounts to an investment cost of $37.8 billion in rooftop solar and $12.9 billion in storage or the equivalent of $5,500 per household.

Costs of incorporating domestic solar into the grid

AEMO's system costs do not include the potential investment required at the sub-transmission and distribution levels to accommodate the projected increase in solar PV systems and batteries.

While a certain amount of distributed generation (such as solar PV systems) can generally be accommodated in a distribution system, the task of regulating local voltages and maintaining power quality becomes harder. When too much distributed generation is added to a particular area, it can lead to difficulties in maintaining stable voltages and power quality, which can impact the proper functioning of equipment, reduce equipment lifespan, and increase fault levels.

Overcoming this problem requires upgrading and expanding the local distribution networks to handle the increased penetration of rooftop solar, adding to the overall costs of transitioning towards a net-zero emissions target.

4 Renewable Projects Quarterly Report Q3 2023, Clean Energy Council

State government expenditure

State governments have committed to separate investment targets in ad hoc announcements independent of the federal government. It is by no means clear how much of this investment has been factored into AEMO's calculations.

The Victorian state government announced in October 2022 it would spend $1 billion to develop its own renewable energy assets. The state proposes to take a controlling 51 per cent stake in a revamped State Energy Commission as a vehicle for direct state investment in renewable energy projects, including onshore and offshore wind and solar.

The Queensland state government has announced a $62 billion renewable energy strategy in which investment will be largely made through state-owned energy entities. It includes grid-scale wind and solar, transmission lines and pumped hydro dams.

Government-run and funded projects typically carry high risk of budget blowouts and less rigorous assessment of financial risks and benefits. It is unclear to what extent future state government liabilities have been factored into AEMO's calculations.

Offshore wind

AEMO'S forecasts do not factor in the cost of offshore wind turbines. Yet the capital costs for offshore wind are rising steeply leading to the cancellation of major projects in the US and Europe.

The levelised cost of electricity of a subsidised US offshore wind project has increased to US$114.20 per megawatt-hour in 2023, up almost 50% from 2021 levels in nominal terms once the increased cost of capital is factored in, according to BloombergNEF calculations.[5]

The CSIRO's 2023 generating cost report found costs rose by 20 per cent on average across all technologies in the year to June 30. It estimated offshore wind costs at between about $85 and $170 per megawatt-hour of output in 2030, compared with as low as about $45 for onshore wind.[6]

The CSIRO's estimates are of limited value since they do not include the associated costs of transmission and firming.

Installation and construction costs will be considerably higher, particularly since Australia needs to gain experience or expertise in this area.

Offshore wind farms require sub-sea cables and offshore substations, which add to the overall project cost. Operations and maintenance costs are considerably higher, and the lifespan of the turbine shorter.

5 'Soaring Costs Stress US Offshore Wind Companies, Ruin Margins', BloombergNEF, August 1, 2023
6 'Surging costs are threatening Gippsland's offshore wind dream', Angela Macdonald-Smith, AFR, July 30, 2023

Green Hydrogen

The Government is committed to transforming Australia into what it calls "a global energy superpower".

The Minister for Climate Change and Energy, Chris Bowen, says large-scale production of renewable hydrogen is critical to achieving that ambition. He has set a goal of transforming Australia into a global hydrogen leader by 2030.

Green Hydrogen is seen as an important contributor to our transition to net zero through use in areas such as industry, transport, grid firming, chemicals and metals production.

The AEMO Integrated System Plan does not fully account for the cost of this investment nor the additional renewable energy requirements. These are not inconsiderable. A study by the Port of Gladstone Corporation, for example, estimates that the proposed Gladstone Hydrogen hub would require 110 GW of renewable generation to produce 4MT of green hydrogen. To meet this demand, AEMO's renewable capacity forecast must be increased by 50 per cent.[7]

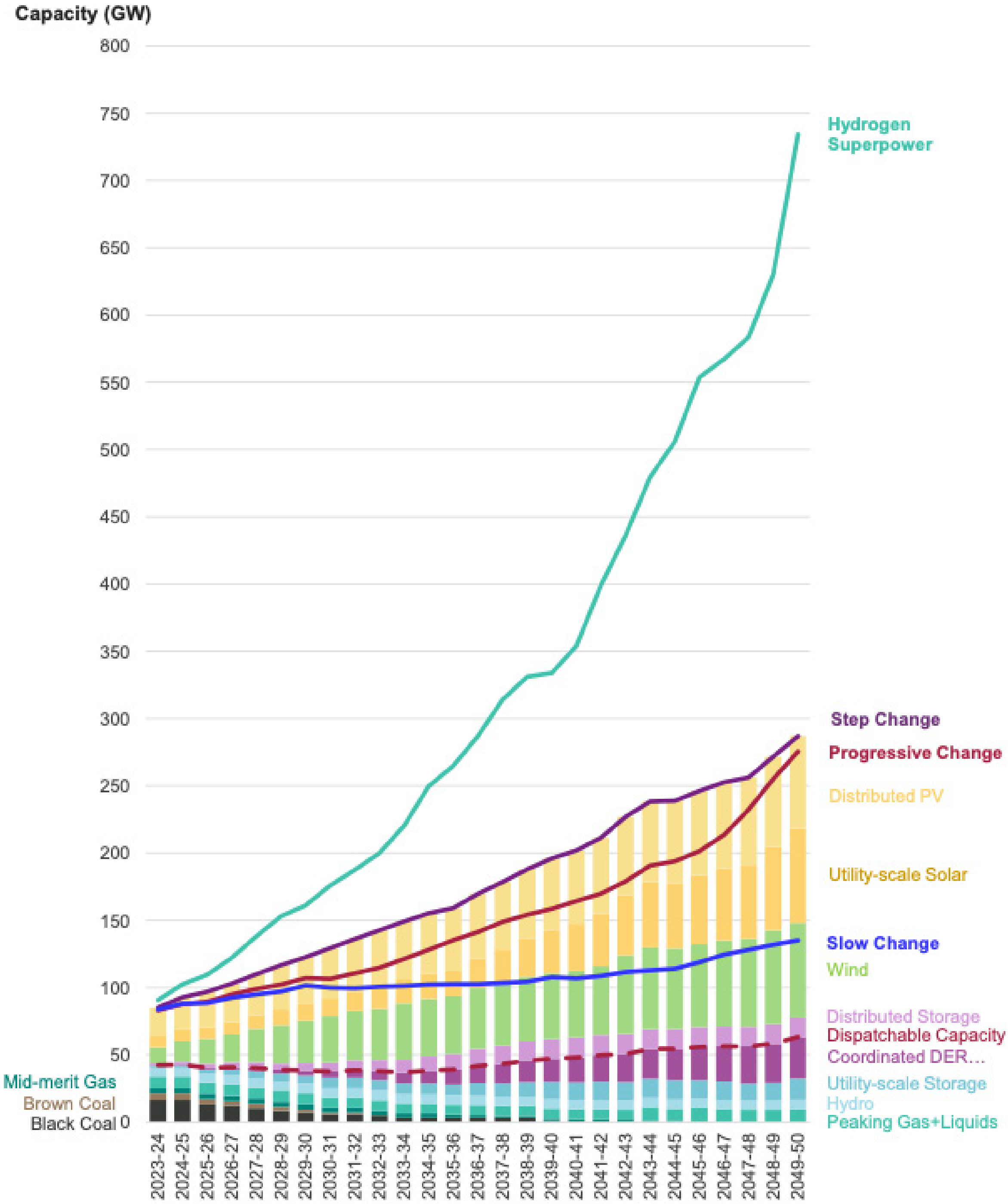
Green Hydrogen is a relatively new technology that has not yet been tested at scale. The technical challenges are not inconsiderable. Relying on green hydrogen as part of our energy future has considerable risks attached.

The production of Green Hydrogen requires a substantial amount of energy and water. AEMO's ISP forecasts the amount of grid-scale wind and solar energy that would be required to achieve hydrogen superpower status by 2050. It forecasts that we will need to add 22 GW of grid-scale solar and 39 GW of wind to the grid by 2050. The Government's target drawn from the step-change scenario will provide only a fraction of that: 5 GW of solar and 22 GW of wind.

On the hydrogen superpower trajectory outlined by AEMO, the renewable energy electricity production target for 2030-31 rises from 83 per cent in the Step Change scenario to 98 per cent.

7 Presentation to the Gladstone Engineering Alliance (GEA) conference by Gladstone Port Corporation CEO Craig Haymes, September 2023

Development opportunities to 2050 in Step Change, and compared to total capacity required in Progressive Change and Hydrogen Superpower



Source: AEMO

The overall capacity of the National Energy Market in 2050 AEMO forecasts will be required to become a hydrogen superpower will be 734 GW, three times the amount in the Step Change scenario.

It follows that demand for land and capital will increase by a similar factor. Yet this has not been factored in to the AEMO forecasts.

Cost blow-outs and delays

Experience suggests that the risk of escalating costs and overruns in renewable energy infrastructure projects is extremely high. A lack of expertise, the use of non-standard technology and design, rent-seeking behaviour, community resistance, and shortages of supply and labour mean that projects of this size and complexity carry considerable risk.

Flyvbjerg's Iron Law of Megaprojects applies: "Over time, the estimated costs of megaprojects tend to increase, while the benefits tend to decrease."[8]

Cost of getting to net zero

The Principal Economics report, however, in combination with other research, permits us to draw the following conclusions with a high degree of confidence:

- The cost of transition to a net-zero emission economy by 2050 will be substantially higher than the $320 billion estimated by AEMO.
- Capital formation on this scale will be a significant challenge.
- The opportunity cost of the allocation of capital to the cost of transition will be high.
- The retail price of energy will continue to rise in the short to medium term as capital costs are absorbed.
- In the absence of rapid technological developments, costs in other heavy emitting sectors, such as heavy manufacturing, agriculture and transport, will increase.
- The flow-on costs in an intricately linked, dynamic economy (e.g. employment, taxation, GDP) will be substantial.

Considering the magnitude of the consequences, the paucity of public discussion and the absence of any serious modelling or cost/benefit analysis is, at minimum, disturbing.

The absence of rigorous analysis of the likelihood of the strategy's success is of equal concern. The Menzies Research Centre's ongoing analysis of the energy system gives us:

- Low confidence that the current strategy will achieve its target of a 43 per cent reduction on 2005-level emissions by 2030.
- Low confidence that the current strategy will achieve its target of a 100 per cent reduction on 2005-level emissions by 2030 without technological advances that are as yet unforeseen.
- High confidence that the forecast investment will be delayed by shortages of capital and material resources.
- High confidence that social licence will be progressively harder to achieve.

8 Flyvbjerg, Bent, 2017, "Introduction: The Iron Law of Megaproject Management", in Bent Flyvbjerg, ed., The Oxford Handbook of Megaproject Management (Oxford: Oxford University Press)

Recent developments

Recent developments in the energy sector reinforce our conclusion that the Government's 2030 target cannot be met. These include:

- A revised completion date for the Snowy 2.0 pumped hydro project of 2029[9]
- Lagging construction of transmission and firming power.[10]
- International subsidy war driving capital away from Australia.[11]
- Forced labour concern in manufacture of Chinese solar panels.[12]
- Difficulties obtaining a social licence.[13]
- A slowdown in projects reaching financial close.[14]
- Cost blowouts and skills shortages.[15]
- Continuing rise in retail energy prices.[16]
- Delays in transmission planning and commencement.[17]

9 "Power worries grow as Snowy 2.0 finish date blows out" AFR May 3
10 "Transition to renewables will be much harder than people think: Broad", AFR March 13, 2023
11 "BHP urges Albanese to catch up to Biden's IRA", March 6, 2023
12 "Solar-Panel Shortage Snarls U.S. Green-Energy Plans" Wall St Journal November 29, 2022
13 "Community hostility to poles and wires a 'great risk' to energy shift", AFR June 2, 2023
14 https://www.cleanenergycouncil.org.au/news/clean-energy-construction-peaks-as-investment-pipeline-battles-headwinds
15 'Qld energy plan 'diabolically difficult' to deliver' AFR October 2, 2022
16 "Power bills to jump by as much as 25 per cent (again), AFR, May 25, 2023
17 " 'A monumental mistake:' Energy experts slam VNI West transmission plans" Renew Economy April 13, 2023.

Need for a Plan B

The Menzies Research Centre recommends:

1. A full review of the current strategy is imperative before further investment decisions are made. We must ascertain if the current policy is affordable and achievable.

   The review should take note of:

   - The impact on the natural environment, farming and biodiversity from industrial-scale renewables.
   - The true cost of transmission and firming of variable renewable energy.
   - The lag between the scheduled withdrawal of coal and gas and the increase in renewable capacity.
   - The technical and engineering challenges of incorporating 82 per cent variable renewable energy into the grid.
   - Accurate modelling of retail energy costs on the current 34 per cent reduction trajectory.

2. An assessment of other clean technology that could offer a quicker, more cost-effective path towards zero emissions.

   In particular, we urge consideration be given to nuclear technology as a potential replacement for baseload coal power from the early 2030s.

Nick Cater
Senior Fellow Menzies Research Centre
April 2024

Implications of the Government's 82 per cent renewables target

By Sabine Schnittger (Principal Economics)

Summary

The Australian Government has committed to reducing emissions by 43 per cent by 2030 and to achieve 'net zero' emissions by 2050. The Government's 'Rewiring the Nation' initiative (budgeted at $20 billion) aims to support these targets by investing in Australia's power grid and thereby lifting the share of renewable generation to 82 per cent by 2030.

The 'Step Change' scenario modelled by the Australian Energy Market Operator (AEMO) in its 2022 Integrated System Plan (ISP) for the East Coast National Electricity Market (NEM) broadly matches the Government's policy objectives. In that scenario, the renewable share of annual generation would increase to around 83 per cent in 2030-31 and to 98 per cent by 2050-51.

Table 1 summarises AEMO's assessment of how the NEM power system should evolve to meet the Government's renewable energy target. Table 1 includes what information can be surmised from the ISP about the costs of achieving the target:

- Around 10,000km of new transmission infrastructure would need to be commissioned. The capital costs of these projects amount to around $14 billion by 2030-31 or around $23 billion by 2050-51 (and doubling the value of the existing regulatory asset base). AEMO presents a 'total network cost' figure of $10.6 billion that is said to be the NPV of an annuity to 2050-51; the derivation of this figure is unclear. Either way, the cost of building and maintaining these investments will mostly fall on electricity customers, but a share will also be borne by taxpayers.
- Additionally, almost 104 GW of renewable generation and storage capacity would be needed by 2030-31 (267 GW by 2050-51), consisting of small-scale and utility scale storage, utility-scale wind and solar generation, and small-scale distributed solar generation. In one of the ISP results worksbooks, AEMO presents a 'total system cost' figure of around $146 billion, which similarly appears to be the NPV of an annuity to 2050-51. Alternatively, a footnote in the ISP suggests that the total spend to develop, operate and maintain the generation, storage and future network investments of the NEM to 2050 would be $320 billion in NPV terms. Again, the cost of these investments would fall on customers and taxpayers. AEMO offers no indication of the implications of this investment program for electricity bills.
- Finally, the increasing share of renewables will create new challenges for system security. AEMO projects that $4 billion would need to be expended to 2035 to maintain system strength. The means of addressing other challenges to system security have not yet been resolved.

Table 1. Implications of the Government's renewable energy target for NEM investment (Step Change scenario)

	Forecast investment & costs	
Transmission	Around 10,000 km of committed, anticipated, actionable and future transmission projects	
	ISP cost estimate	**Capital cost estimate**
	$10.6 billion (2023-24 to 2050-51) (NPV of the equivalent annuity of the transmission capital investment from commissioning to 2050-51)	• $13.8-$14.2 billion by 2030-31 • $22.9-$23.3 billion by 2050-51
NEM system (incl. transmission)	Relative to November 2022: • Closure of ~15.6 GW coal capacity by 2030-31 (~22.7 GW by 2050-51) • Additional utility-scale storage of ~6.8 GW by 2030-31 (~13.8 GW by 2050-51) • Additional wind capacity of ~24.7 GW by 2030-31 (~60 GW by 2050-51) • Additional large solar capacity of ~7.5 GW by 2030-31 (~63.5 GW by 2050-51) • Additional small-scale PV of ~ 19.8 GW by 2030-31 (~51.2 GW by 2050-51) • Small-scale storage of ~11.1 GW by 2030-31 (~45.2 GW by 2050-51)	
	ISP cost estimate	**Alternative ISP cost estimate**
	NPV of the equivalent annuity (as for transmission) of NEM system costs (transmission, generation & storage capacity, maintenance costs, fuel costs, demand side participation): $146.1 billion (2023-24 to 2050-51)	Imputed estimate of NPV cost to develop, operate and maintain the generation, storage and future network investments of the NEM to 2050: $320 billion
System security	Deterioration in system strength: • From 2030-31: Tasmania, SW Victoria • From 2034-35: Central Qld, Southern Qld, Northern NSW, SW Victoria, SA Decline in NEM mainland inertia below the minimum threshold by 2029-30.	
	ISP cost estimate	
	$4 billion to 2035 for system strength	

The system cost estimates presented by AEMO are substantial, but are likely not a complete measure of the incremental costs of achieving the Government's renewable generation target. AEMO's system cost estimates do not appear to include:

- the costs that would be incurred by households who would need to install small-scale PV systems, batteries and other devices in order for the system to be balanced; or
- the costs that would be incurred by distribution network service providers to accommodate the projected uptake in distributed (PV) generation.

Although the ISP Step Change scenario is intended to model the Government's policy settings, there are inconsistencies with Government announcements:

- Given the relatively high cost of this technology, AEMO's projections do not envisage a role for offshore wind generation through to 2050-51.
- Thermal (gas-fired) generation capacity will be required through the forecasting horizon (2050-51) to compensate for intermittent renewable generation and storage limitations.

There are also broader questions that go to the credibility of the modelling of the Step Change scenario:

- A separate assessment of AEMO's modelling suggests that there may be insufficient generation and storage capacity during credible low solar availability and wind drought conditions across south-east Australia beginning in about 2030-31. This may result in increasingly serious outages.
- There is an obvious question as to whether the scale of investment envisaged by AEMO could be achieved in the short timeframe envisaged, given shortages of skilled labour in Australia.
- The cost estimates for new capacity applied in the ISP may be optimistic, given recent reported price increases for wind and solar technologies and the very short timeframe in which these investments are to be commissioned.
- Finally, alternating increments and decrements in storage and renewable capacity year-on-year may raise questions about whether the least-cost system development path identified by AEMO is indeed optimal or least-cost.

1. Government policy settings

The Albanese Government has passed legislation to set an emissions reduction target of 43 per cent from 2005 levels by 2030 and net zero emissions by 2050.[1] The Government's 'Rewiring the Nation' policy is intended to help achieve this target. Rewiring the Nation would facilitate the deployment of large-scale (wind and solar) renewable resources by supporting new investment in transmission infrastructure and the development of renewable energy zones (REZs) where new large-scale renewable capacity would connect to the grid. This policy is projected by the Government to lift the the share of renewable generation to 82 per cent by 2030.[2]

In the October 2022-23 budget, $20 billion was allocated to Rewiring the Nation over four years '*to deliver low cost finance to upgrade, expand and modernise Australia's electricity grid…*'[3] To date, the Australian Government has entered into two agreements under this policy:

- With Tasmania, where a letter of intent has been signed to jointly fund the Marinus Link transmission project via a concessional loan through the Clean Energy Finance Corporation (CEFC) for 80 per cent of project cost.[4] The remaining 20 per cent of costs would take the form of an equity investment shared equally between the Australian Government, Victoria and Tasmania. Further, up to $1 billion of low-cost finance would be directed to Tasmania's 'Battery of the Nation' projects, and low-cost finance would also be made available for the North West Transmission Developments (NWTD).[5]
- With Victoria, to provide $1.5 billion of concessional financing to fund Victorian offshore wind projects and REZs, and a concessional loan of $750 million for the Victoria-New South Wales Interconnector (VNI West) KerangLink.[6]

2. Implications of the Government's 82 per cent renewable share

The press releases announcing Rewiring the Nation initiatives generally refer to potential emissions reductions and job creation opportunities, but offer little insight as to the eventual costs that might fall on consumers and taxpayers. Modelling prepared by Reputex on behalf of the ALP suggests that the increased penetration of renewables under the policy would result in significant reductions in electricity bills, in the order of $378 per year for an average household.[7]

2.1 Transformation of the power system

The forecast reductions in electricity bills that are said to result from achieving the 82 per cent renewable generation target can be contrasted with the very significant costs that would need to be incurred to achieve the 82 per cent renewables target.

1 https://www.pm.gov.au/media/albanese-government-passes-climate-change-bill-house-representatives
2 https://www.minister.industry.gov.au/ministers/husic/media-releases/launch-state-climate-2022-report
3 https://www.dcceew.gov.au/sites/default/files/documents/oct-budget-2022-23-energy-fs.pdf. Other funding for renewable energy initiatives includes $224 million over four years for 400 community batteries, $102 million over four years for community-scale and rooftop solar, $158 million over six years to implement the National Energy Transformation Partnership, and $64 million to support energy storage and electricity grid capacity.
4 The cost of Marinus Link is estimated at around $2.38 billion ±30 per cent for cable 1 and $1.40 billion ±30 per cent for cable 2.
5 https://www.pm.gov.au/media/rewiring-nation-plugs-marinus-link-and-tasmanian-jobs
6 https://www.pm.gov.au/media/rewiring-nation-supercharge-victorian-renewables
7 RepuTex Energy, 2021. The Economic Impact of the ALP's Powering Australia Plan, Summary of modelling results, December.

2.1.1 Transmission

These costs most obviously relate to the costs of installing and maintaining the new transmission infrastructure that the Government wishes to see installed along the east coast of Australia. Much or most of that cost will fall on electricity consumers who would see it reflected in the network component of their electricity bills. A significant share will likely also be borne by taxpayers who underwrite transmission investments (as in the case of Marinus Link as equity investors), or who provide subsidised financing for these investments. In the case of Marinus Link, for instance, the Prime Minister's press release notes that '..*low-cost financing from Rewiring the Nation will reduce the annual costs of Project Marinus to electricity customers by up to half*.'[8]

2.1.2 Generation and storage

The cost of the Government's emissions reduction target also includes the broader costs of rebuilding the power system to achieve the 82 per cent renewable share. These costs include the cost of the renewable generation capacity to achieve the target, as well as the cost of the storage and gas-fired capacity and ancillary services that will be needed to keep the power system operating reliably. In the National Electricity Market (NEM) that operates on the east coast of Australia, investment in new generation capacity has traditionally been the responsibility of the private sector. While transmission investment that has passed through the relevant regulatory review processes is assured cost recovery and a regulated rate of return, that is not the case for generation (and storage) investments. It can nonetheless be assumed that such investments would not occur if the proponents did not expect to recover the costs of these investments and an adequate rate of return from electricity consumers. Further, to the extent that government subsidies will continue to play a role in the future, taxpayers can also be expected to bear a share of these wider system costs. For instance, Victoria has already announced that it proposes to subsidise the development of offshore wind generation to generate around 20 per cent of its energy needs within the decade by offering offtake agreements to developers.[9]

2.1.3 Step Change Scenario

The modelling prepared by the Australian Energy Market Operator (AEMO) to derive its 2022 Integrated System Plan (ISP) offers an indication – albeit with many limitations – of the scale of costs implicit in the 82 per cent renewables target.[10] The 2022 ISP is said to be a 'comprehensive roadmap for the NEM'. The 'Step Change' scenario modelled in the ISP assumes that the share of renewable generation would increase from approximately 28 per cent in 2020-21 to 83 per cent in 2030-31 and therefore broadly matches the Government's policy target. In this scenario:

- the amount of delivered electricity is projected to almost double to 320 terawatt hours (TWh) per year as industry, transport, the services sector and households increasingly rely on electricity as a source of energy;
- 15.6 GW of coal-fired generation is likely to withdraw by 2030-31; and
- by 2050, the share of renewable generation in the NEM is projected to reach 98 per cent.

The following sections describe the high-level results of AEMO's Step Change scenario analysis, focusing on the broad cost implications of the projected transmission and generation/storage investments. It should be noted that the modelling underpinning the derivation of the ISP scenarios is inherently complex and depends

8 https://www.pm.gov.au/media/rewiring-nation-plugs-marinus-link-and-tasmanian-jobs
9 https://www.afr.com/companies/energy/star-of-the-south-warns-offshore-wind-target-at-risk-from-inaction-20220921-p5bjud
10 AEMO, 2022. 2022 Integrated System Plan For the National Electricity Market, June.

on many assumptions and constraints that are imposed to model the power system and how the broader economy is projected to evolve. These constraints include operational limitations that apply to the transmission network, thermal and renewable generators and storage facilities, but also reflect government policy settings. In the case of the Step Change scenario, the decarbonisation target is an economy-wide net zero target before 2050, and a target exceeding a 26-28 per cent reduction by 2030-31.[11] AEMO also applies multi-sectoral modelling to determine emission pathways at a sectoral level and for individual technologies to match economy-wide emission reduction ambitions. AEMO's modelling of the Step Change and other scenarios then encompasses a series of forecasting and planning models that are used to determine an Optimal Development Path (ODP) that is deemed to maximise benefits to consumers. The ODP minimises the discounted total system costs – the sum of generation, storage, transmission and service costs (capital, operation and compliance) annualised across the forecast horizon – subject to the above constraints.[12]

2.2 Transmission investment

Table 2 summarises the timing and costs (where known) of transmission projects described in the 2022 ISP:

- committed projects that have regulatory approval and will proceed with known timing;[13]
- anticipated projects that are highly likely to proceed;
- actionable projects that should immediately commence relevant regulatory processes; and
- future transmission projects that are deemed to benefit customers but are not needed until later in the forecasting horizon.

AEMO does not provide cost estimates for committed and anticipated projects, and these costs have been assembled from referenced regulatory filings. AEMO also does not provide a direct total cost estimate of the transmission investment that it says is needed to decarbonise the NEM, in all about 10,000 km of new network investment. AEMO instead references a 'total network cost' figure of $10,644 billion in NPV terms, noting that this figure "..*does not reflect the full capital investment in network in today's dollars, but rather the NPV of the equivalent annuity calculated from time of commissioning to 2050-51*."[14]

AEMO's annuitised $10.6 billion estimate can be compared with the approximate total capital cost of the transmission investment described in the ISP and summarised in Table 2. On that basis, we estimate the total capital cost of all transmission projects modelled in the 2022 ISP through to 2050-51 to be in the range of $23 billion, of which around 60 per cent or $14 billion would be incurred by 2030-31. To put this figure in context, the combined value of the regulatory asset bases of the NEM transmission networks was $21.7 billion in 2021.[15] The transmission pathway set out in the ISP would then more than double the value of the existing asset base.

11 In addition, state-based renewable energy targets for Queensland, Victoria, Tasmania, and NSW are assumed to be met in all scenarios. Inputs assumptions and scenarios workbook.xlsx

12 AEMO, 2021. ISP Methodology For the Integrated System Plan (ISP), August.

13 AEMO, 2021. ISP Methodology For the Integrated System Plan (ISP), August; AER, 2020. Cost benefit analysis guidelines, Guidelines to make the Integrated System Plan actionable, August.

14 AEMO 2022; Table 4, footnote 55.

15 Australian Energy Regulator, 2021. State of the Energy Market.

Table 2. Timing and capital costs of transmission projects in the 2022 ISP

Project	Timing	Status	Capital cost ($m)
Eyre Peninsula Link	Early-2023	Committed	$280
Queensland to New South Wales Interconnector Minor (QNI Minor)	Mid-2023	Committed	$230
Victoria to New South Wales Interconnector Minor (VNI Minor)	Nov-22	Committed	$45
Northern Queensland REZ (QREZ) Stage 1	Sep-23	Anticipated	$45
Central-West Orana REZ Transmission Link	Mid-2025	Anticipated	n/a
Project EnergyConnect	Jul-26	Anticipated	$457
Western Renewables Link	Jul-26	Anticipated	$737
HumeLink	Jul-26	Actionable	$3,315
New England REZ Transmission Link	Jul-27	Actionable	$1,905 (±50%)
Sydney Ring	Jul-27	Actionable	$880 (±50%) / $2,256 (±50%)
Marinus Link	Jul-29	Actionable	$2,380 (±30%) / $1,402 (±30%)
VNI West (via Kerang)	Jul-31	Actionable	$2,942
Central to Southern Queensland	2028-29	Future	$55
	2038-39		$476
Darling Downs REZ Expansion	2028-29	Future	$43 + BESS contract costs
	2037-38 and 2048-49		$1,160
South East South Australia REZ expansion	2028-29	Future	$57
	2048-49		$949
Gladstone Grid Reinforcement	2030-31	Future	$408
QNI Connect	2032-33	Future	$1,253
Facilitating power to Central Queensland	2033-34	Future	$137
	2044-45		$816
Mid North South Australia REZ expansion	2033-34	Future	$340
	2041-42		$582
South West Victoria REZ Expansion	2033-34	Future	$930
New England REZ Extension	2035-36	Future	$1,237
Far North Queensland REZ Expansion	2038-39	Future	$1,264
Total estimated capital costs			**$22,923 - $23,321**
Estimated capital costs through to 2030-31			**$13,779 - $14,177**
Estimated capital costs 2031-32 through 2050-51			**$9,144**

Notes: The AER guidelines referenced by AEMO state that committed projects meet a number of criteria, including that all consents and approvals have been obtained; construction has commenced or a date has been set; the necessary land has been obtained; the necessary contracts have been signed; and financing arrangements are in place. Anticipated projects have met at least three of the criteria for committed projects. Actionable projects address an identified need specified in an ISP and form part of an ODP. Forecast projects also address an identified need specified in an ISP, and are forecast to be actionable ISP projects in the future.

Sources: https://www.aer.gov.au/networks-pipelines/determinations-access-arrangements/contingent-projects/elec-tranet-%E2%80%93-eyre-peninsula-reinforcement-contingent-project; https://www.aer.gov.au/networks-pipelines/determinations-access-arrangements/contingent-projects/transgrid-expanding-nsw-qld-transmission-transfer-capacity-regulatory-investment-test-transmission-rit-t; https://www.powerlink.com.au/sites/default/files/2021-09/Powerlink%20Queensland%20-%20Developing%20the%20Northern%20QREZ%20-%20Final%20Report.pdf; https://www.powerlink.com.au/sites/default/files/2021-09/Powerlink%20Queensland%20-%20Developing%20the%20Northern%20QREZ%20-%20Final%20Report.pdf; https://majorprojects.planningportal.nsw.gov.au/prweb/PRRestService/mp/01/getContent?AttachRef=PDA-48312206%2120220908T233216.666%20GMT; https://www.aer.gov.au/networks-pipelines/determinations-access-arrangements/contingent-projects/transgrid-and-electranet-%E2%80%93-project-energyconnect-contingent-project; https://aemo.com.au/-/media/files/electricity/nem/planning_and_forecasting/victorian_transmission/2022/aemo--clause-5164z3-analysis--wrl-project--november-2022.pdf?la=en&hash=6C69F-C7AAEB1C36FE0A3F65AC99BB614; Annex 5 2022 ISP.

It is worth commenting on the governance processes around the proposed transmission investment program. Under the NEM Rules, any transmission investment with a value greater than $7 million has to undergo the Regulatory Investment Test for Transmission (RIT-T), which is in turn scrutinised by the Australian Energy Regulator (AER). Only investments that have passed the RIT-T are included in a transmission network service provider's (TNSP's) regulated asset base, which enables the TNSP to recover the cost from consumers. The purpose of the RIT-T is to ensure that only transmission investment that is necessary and delivers the greatest benefit to consumers is commissioned. However, Energy Minister Chris Bowen has already indicated that the RIT-T is no longer 'fit for purpose', and that the Government plans to amend the test. Among other things, the proposed changes would streamline the review process and increase consideration of social and economic factors when making network investment determinations.[16] To date, neither Marinus Link nor VNI West, for which taxpayer funding has been committed, have undergone the RIT-T process.

2.3 Generation and storage investment

The projections in the ISP as regards the generation and storage investment that would be needed to meet the Government's emissions reductions trajectory indicate a very substantial program of investment:

- a nine-fold increase in large-scale renewable (wind and solar) capacity, with capacity trebling from currently around 16 GW to around 48 GW in 2030-31, and again almost trebling to almost 140 GW in 2050-51;
- a more than four-fold increase in distributed PV capacity across households from around 17 GW in small-scale PV capacity to more than 37 GW in 2030-31 and 69 GW in 2050-51;
- accompanying this increase in distributed PV capacity would be substantial growth in small-scale battery storage to more than 45 GW in 2050-51;
- a trebling of 'firming' capacity from non-coal alternatives, namely dispatchable storage, hydroelectric and gas-fired generation:
  - 46 GW / 640 GWh of dispatchable storage by 2050-51, including dispatchable batteries, pumped hydro or alternative storage, including behind-the-meter virtual power plants (VPPs), vehicle-to-grid (V2G) services and other emerging technologies to manage daily and seasonal variations in wind and solar output;
  - 7 GW of existing hydro generation;
  - 10 GW of gas-fired generation, which is said to remain a critical requirement through to 2050-51. Gas-fired generation would be needed to complement battery and pumped hydro generation during peak demand periods, to cover for generation and transmission maintenance, and to provide ancillary services to support system security objectives.

16 https://reneweconomy.com.au/not-fit-for-purpose-labor-vows-to-overhaul-regulatory-process-for-transmission-projects/

The investment program developed by AEMO in the ISP to achieve the Government's emissions reductions ambitions at least cost does not match the Government's stated investment plans:

- The Australian and the Victorian governments have already committed funding for offshore wind projects. Yet, given its high cost, offshore wind generation plays no role in the least-cost development path developed for the ISP Step Change scenario.
- While the Australian Government has expressed its strong support for a net zero emissions target, even the immense investment program outlined in the ISP Step Change scenario would not achieve such a target by 2050-51. Even in the Step Change scenario, around 9.4 GW of thermal (gas and liquids) generation would be required for peaking services through 2050-51 (recognising of course that the associated emissions could be theoretically offset elsewhere in the economy).

2.3.1 AEMO system cost estimates

AEMO offers no direct estimates of the total system cost of the additional generation and storage investment that would be required to achieve the Government's emissions reductions trajectory for the NEM:

- AEMO's 2022 ISP results workbook[17] appears to present a similarly annuitised calculation as for transmission, and reports a 'total system cost' figure of $146.1 billion in NPV terms (2023-24 to 2050-51). That figure includes annuitised transmission investment costs of $10.6 billion in NPV terms, maintenance costs, fuel costs and other items, as well as around $75.6 billion in NPV terms referred to as 'Generator Capital'.[18] We understand that the $75.6 billion figure incorporates the cost of generation and utility-scale storage capital investments.[19]
- An alternative estimate of the total system cost of the Government's preferred emissions trajectory may be gleaned from footnote 4 (p.15) of the ISP. Footnote 4 notes that the network investment identified as actionable is approximately $12.8 billion in today's value (presumably a reference to an NPV calculation), and that this figure constitutes about 4 per cent of the total spend (in NPV terms) for developing, operating and maintaining the planned generation, storage and network investments in the NEM to 2050-51. Footnote 4 therefore suggests a total system cost estimate, including for operations and maintenance, of approximately $320 billion in NPV terms.[20]

2.3.2 System cost estimates

The 'system cost' estimates reported by AEMO are substantial. They give an indication of the scale of investment that would be required to achieve the Government's renewable energy objectives, given how the NEM is configured today.[21] AEMO's estimates nonetheless appear to be incomplete in the sense that they do not represent a comprehensive metric of the costs of achieving the Government's renewables target.

17 2022 Final ISP results workbook - Step Change - Updated Inputs.xlsx

18 These annuitised costs are fixed operational maintenance (FOM) of $37.4 billion, fuel costs (Fuel) of $17.4 billion, variable operational maintenance (VOM) of $4.5 billion) and demand side participation and unserved energy (DSP+USE) of $0.6 billion.

19 Correspondence with AEMO, 20/12/2022.

20 A highly simplified cross-check of the order of magnitude of AEMO's figures would be to consider the projected year-on-year increments in installed wind and solar generator capacity for each REZ in the Step Change scenario scenario. Multiplying these capacity increments with the 'low' generator build costs for large-scale wind and solar generation for each REZ, respectively, gives a total capital cost estimate for the projected new wind and solar capacity of around $50 billion through to 2030-31, and of around $154 billion through to 2050-51. This figure assumes a low cost estimate for renewable capacity, excludes connection, maintenance and fuel costs, and does not include the capital or operating costs of the gas-fired and storage capacity that AEMO predicts will be needed.

21 Additionally, to the extent that most or all of the network investments that have been deployed in the past will remain in network service providers' regulatory asset bases, these will also need to be paid for by electricity customers.

First, as highlighted in a submission in response to the Draft ISP,[22] AEMO's system cost estimates do not include the costs that are projected to be incurred by households. As noted above, the ISP assumes the significant uptake of distributed energy resources (DER): consumer-owned devices such as rooftop PV systems, distributed battery storage, VPPs and EVs that can generate or store electricity as individual units and that, in future, may be used to actively manage energy demand. Electric Power Consulting (EPC) notes that AEMO have not considered the behind the meter costs of solar PV and battery storage in the ISP cost analysis. As such it appears that a significant component of delivered electricity costs that will fall on households have not been considered.[23]

Relatedly, as also noted by EPC, AEMO's analysis stops at the transmission level and does not consider the investment that may be necessary at the sub-transmission and distribution level to accommodate the projected uptake in solar PV and batteries. While a certain amount of distributed generation can generally be accommodated in a given distribution system, beyond a certain point, negative effects appear that relate to difficulties in regulating local voltages or other issues with power quality which may interfere with the operation of equipment, shorten equipment life, and raise fault levels.[24] These types of local investment in distribution networks would then further increase the costs of moving to a net zero emissions target.

2.3.4 Security of supply

Notwithstanding the significant generation build described in the ISP, there are questions as to whether the projected emissions reductions targets can be achieved without significant and unacceptable levels of supply outages or unserved energy (USE). Thus, a separate assessment of AEMO's modelling of the Step Change scenario in the Draft ISP prepared by EPC suggests that the NEM would have insufficient generation and storage capacity during credible low solar PV availability (winter and overcast) and wind drought conditions across south-east Australia beginning in about 2030-31 and increasing thereafter.[25] EPC suggests that in the system trajectory modelled in the ISP, major supply outages would have been experienced across 52 days of the year in 2050-51. They conclude that generation and storage capacity would need to be increased by 40 per cent to fully match supply and demand and eliminate USE. In effect, in a system dominated by intermittent renewable generation, very large levels of resources need to be held in reserve to cope with adverse weather outcomes.

One of the key factors that appears to explain the different USE outcome is a difference in modelled capacity factors, particularly for large-scale wind capacity.[26] AEMO assumes that the capacity factor for wind will increase from 33.6 per cent to around 35.6 per cent in 2030-31 and 2040-41, reflecting the forecast greater geographic diversity of resources. In contrast, EPC's modelling suggests that the capacity factors for wind resources would consistently decline over the modelling horizon, reflecting storage congestion. In Annex 4 to the ISP, AEMO suggests that the system could cope with the types of solar and wind drought conditions referenced by EPC; it is nonetheless noteworthy that it does not seem that AEMO has prepared a sensitivity analysis of this crucial variable.

22 Electric Power Consulting, 2022. Submission on the 2022 Draft AEMO Integrated System Plan, February.

23 Indeed, if these costs were not considered in the overall system cost optimisation, then the optimisation itself is likely to be flawed.

24 Distributed generation effectively reverses the traditional role of distribution networks. Traditionally, distribution systems were designed for diminishing network power at each subsequent lower voltage level. Particularly at lower voltage levels, this 'tapering' can inhibit multi-directional power flows and introduce difficulties in integrating distributed generation. The main impacts of multidirectional power flows relate to the need to reconfigure protection systems, install more complex voltage control, and reconfigure switchgear.

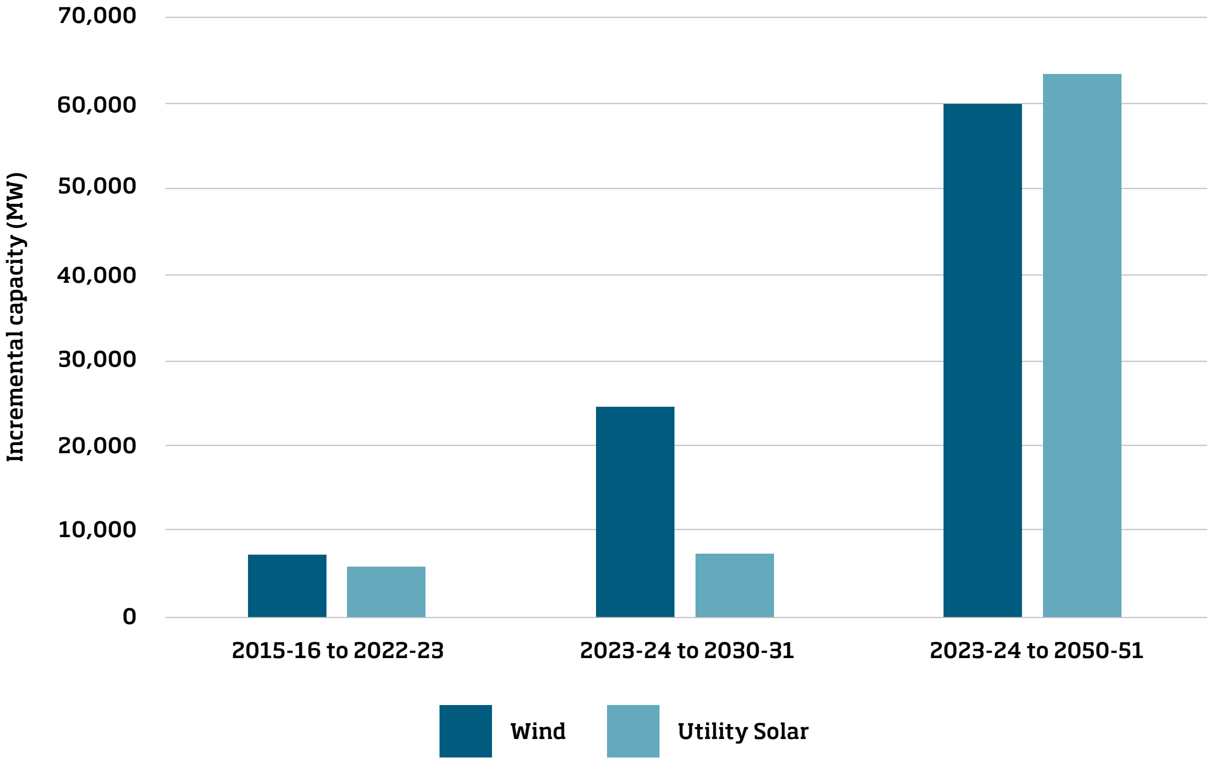
25 Electric Power Consulting, 2022. Submission on the 2022 Draft AEMO Integrated System Plan, 11th February. While this criticism was made of AEMO's Draft Step Change scenario results, the differences in dispatchable capacity between the Draft and the Final results (as reported in the draft and final workbooks) appears minimal.

26 The capacity factor is the ratio of electricity generated as a share of the theoretical maximum electricity generated in a year. The conditions modelled by EPC occurred in June 2017.

2.3.5 Build timetable

Even if the investment and cost figures in the ISP are accepted at face value, there is an obvious question as to whether the scale of investment envisaged by AEMO could be delivered in the timeframe envisaged to achieve the Government's targets. Figure 1 suggests that more than three times as much wind capacity would be commissioned over the next eight years (between 2023-24 and 2030-31), than was put in place over the last eight years (between 2015-16 and 2022-23). Minister Bowen has reportedly said that achieving the Government's 82 per cent renewables target would require the installation of 40 7 MW wind turbines every month until 2030 (noting that no 7 MW turbines have yet been installed in Australia) and 22,000 500W solar panels every day for the next eight years.[27] Acknowledging concerns about the role of China as a critical producer of renewable energy installations and supply shortages of critical minerals, Minister Bowen seemed to suggest that key components could instead be produced in Australia. Indeed, under current Government plans, components for wind turbines and the production of solar panels, battery storage and hydrogen electrolysers will receive up to $3 billion in funding from the newly created National Reconstruction Fund.[28]

Figure 1. Capacity increments – Historical renewables build versus Step Change scenario build



Sources: https://www.aemc.gov.au/data/annual-market-performance-review-2020/nem-generation-capacity-installed-mega-watts-by-fuel-type-2001-2019; https://aemo.com.au/en/energy-systems/electricity/national-electricity-market-nem/nem-forecast-ing-and-planning/forecasting-and-planning-data/generation-information; 2022 Final ISP results workbook - Step Change - Updated Inputs.

27 https://reneweconomy.com.au/the-staggering-numbers-behind-australias-82-per-cent-renewables-target/
28 https://www.industry.gov.au/news/national-reconstruction-fund-diversifying-and-transforming-australias-industry-and-economy

There are many reasons for thinking that an investment program of the scale contemplated by the Government could not be completed within the time available and/or at the contemplated cost:

- Australia does not have a successful track record in mass market manufacturing in general and in the manufacturing of renewable technologies in particular.
- Shortages of skilled labour have intensified over the past year, including for engineers, and for technicians and trades occupations, such as electricians and electrical linesworkers.[29]
- The cost estimates for new capacity applied in the ISP appear dated, given recent reported price increases for wind and solar technologies.[30] While many commentators assume that recent significant price increases are temporary in nature, AEMO's near-term figures may nonetheless be optimistic.[31]
- Finally, there is a time dimension to cost so that costs are typically higher when a given output needs to be produced in a shorter timeframe, reflecting the higher cost of procuring inputs such as labour and materials that are only available in limited supply but need to be obtained in a hurry.

2.3.6 Modelling issues

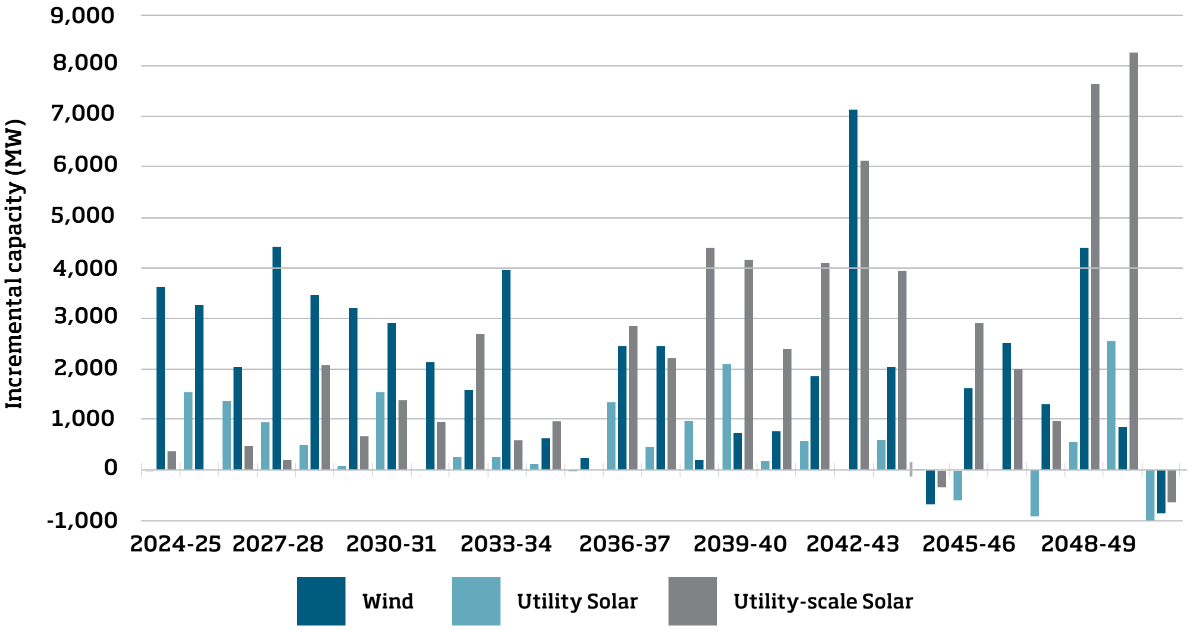
Finally, there appear to be inconsistencies in AEMO's modelled capacity expansion path for storage and renewable resources that would raise questions about whether that path is indeed optimal or least-cost. There are a number of years in which renewable generation and storage capacity declines from one year to the next, and increases again thereafter (Figure 2). At an aggregate (system-wide) level, capacity decrements occur for utility-storage in 2045-46, 2047-48 and 2050-51, and for wind and large-scale solar capacity in 2044-45 and 2050-51. For renewable generation capacity, the increments and decrements appear matched at the REZ level. In the Western Victoria REZ, for instance, wind capacity increases to 2,640 in 2039, falls to 2,448 MW in 2040, increases to 2,970 MW from 2042 to 5,405 MW in 2049, and falls to 4,667 MW thereafter. Similar capacity fluctuations are also observed in Queensland (Darling Downs REZ) and Tasmania (Central Highlands REZ).

29 https://www.nationalskillscommission.gov.au/reports/2022-skills-priority-list-key-findings-report/appendices

30 The assumptions underpinning the ISP assume significant reductions in generator build costs by about half between 2022-23 and 2049-50 for large-scale solar, and by about 20 per cent for wind generation over the same timeframe.

31 https://about.bnef.com/blog/cost-of-new-renewables-temporarily-rises-as-inflation-starts-to-bite/; https://www.fastmarkets.com/insights/wind-power-faces-serious-cost-inflation-and-project-delays-as-raw-materials-prices-rise; https://www.reuters.com/business/energy/eu-wind-targets-under-threat-volatile-costs-2022-11-25/

Figure 2. Modelled capacity increments (decrements) in the Step Change scenario



Source: 2022 Final ISP results workbook - Ste p Change - Updated Inputs.

2.4 System security

Power system security refers to the ability to provide consumers with uninterrupted electricity supplies. Conventional (thermal) power stations provide a number of 'ancillary' services that are crucial for keeping the power system stable and the system secure. Wind and solar generators do not generally provide these services, so that ancillary services need to be provided in some other way as more renewable generation enters the system.

AEMO has explored some aspects of the implications for power system security of the deployment of significant renewable generation that is forecast in the Step Change scenario.[32] System strength refers to the ability of a power system to maintain a stable voltage under normal conditions and to return to a steady state following a system disturbance. AEMO's modelling indicates that system strength is already low in some parts of the NEM, but will deteriorate further in the Step Change scenario from 2030-31 onwards (in the absence of significant transmission investment) in Tasmania and South-West Victoria; from 2034-35, system strength will deteriorate in Central Queensland, Southern Queensland, Northern NSW, South-West Victoria, and South Australia. AEMO's 'high-level' cost estimates (relying on existing and demonstrated technologies) project a cost of $106,000/MW or $4 billion through to 2035 for system strength remediation for the forecast renewable intermittent generation connection in REZs.

A lack of (synchronous) inertia is a second source of concern in a power system dominated by renewables. A lack of inertia reduces the ability of a power system to 'ride through' faults (for instance, an unexpected outage of a generator or of network equipment). AEMO notes that NEM mainland inertia is expected to decline significantly (by about half) by 2029-30 compared to 2024-25, decreasing below the minimum threshold of inertia. In conclusion, AEMO notes that the current inertia framework does not provide for assessing the inertia requirements and shortfalls across the NEM. However, market reforms currently being progressed to value, procure and schedule essential system services, including a Fast Frequency Response (FFR) market may provide some assurance.

32 AEMO, 2022. Appendix 7. Power system security, June.

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