FE-V

Future of Electricity Vietnam

DISCUSSION PAPER

Future Generation

Australian experience and reflections for the Energy Transition in Vietnam

June 2023

Australian Government

About Future of Electricity Vietnam (FE-V)

Australia and Vietnam are neighbours and peers, facing the same regional challenges and sharing the same aspirations for sustainable, secure, and fair electricity services as the basis of prosperity and economic growth. Our power sectors: share many legacy issues on how energy is generated and transmitted; are blessed with high renewable energy (RE) potential and some of the fastest rates of RE deployment in the world; and are undertaking (or have recently undertaken) major structural reforms to the markets, governance arrangements and infrastructure that underpin the sector in order to take advantage of the opportunity presented by a sustainable energy transition.

Future of Electricity Vietnam (FE-V) is a science-to-policy program made up of policy dialogues aimed at leveraging the Australian experience in energy transition to support Vietnam in exploring practical and feasible interventions for a decarbonised, reliable and affordable power system.

Recognising 50 years of diplomatic relations between Australia and Vietnam, FE-V is an initiative of the Australian Embassy in Hanoi bringing Australian and Vietnamese experts together to share experiences and to co-develop knowledge products of prioritised topics relating to 5 main dimensions of the power sector (generation, fuels, consumption, grid and market) with the Central Economic Commission of the Communist Party of Vietnam (CEC), a strategic dialogue partner. The FE-V initiative is divided into two phases. The first phase focuses on providing high-level inputs for an energy transition strategy, including a review of the 3-year implementation of Resolution 55 which CEC is carrying out.

FE-V is delivered by Australia's Partnerships for Infrastructure (P4I) and the Australia - Mekong Partnership for Environmental Resources & Energy Systems (AMPERES) together with the Australian National University (ANU) and Commonwealth Scientific Industrial Research Organisation (CSIRO). P4I is an Australian Government initiative partnering with Southeast Asia to drive sustainable, inclusive, and resilient growth through quality infrastructure. Led by the Australian Department of Foreign Affairs and Trade, P4I is implemented by EY, Adam Smith International, The Asia Foundation and Ninti One.

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Photo: Workers install solar panels for a project in Binh Thuan Province – Ngoc Ha, Vietnam News Agency.

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AMPERES

Partnerships for INFRASTRUCTURE

CSIRO

Australian National University

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List of Abbreviations

Abbreviation	Full name
AEMO	Australian Energy Market Operator
AER	Australian Energy Regulator
ANU	Australian National University
ASEAN	Association of Southeast Asian Nations
BESS	Battery Energy Storage Systems
CEC	Central Economics Committee
COD	Commercial Operation Date
DPPA	Direct Power Purchase Agreement
ECMC	Energy and Climate Change Ministerial Council
EPTC	Electric Power Trading Company
EREA	Electricity and Renewable Energy Authority
EVN	Vietnam Electricity Group
FCAS	Frequency Control and Ancillary Services
FiTs	Feed-in Tariffs
HILT	Heavy Industry Low-carbon Transition
HVDC	High Voltage, Direct Current
ISP	Integrated System Plan
LCOE	Levelised Cost of Electricity
LGCs	Large-scale Generation Certificates
LNG	Liquefied Natural Gas
MOF	Ministry of Finance
MOIT	Ministry of Industry and Trade
NEM	National Electricity Market
PPAs	Power Purchase Agreements
RET	Renewable Energy Target
VRE	Variable Renewable Energy
WEM	Western Electricity Market

The term "WEM" used across five discussion papers may differ in full-name definitions. Some authors perceived its full name as "Western Electricity Market", while others called it "Wholesale Electricity Market". After internal discussion, we have come to a consensus that the term "WEM" could mean both "Western Electricity Market" and "Wholesale Electricity Market". Note that the market operated in Western Australia enables wholesale electricity sales between generators and retailers, and so is itself a wholesale electricity market. In all discussion papers, we retained the full-text definitions in the text and the abbreviation list according to each author's usage.

A. Thematic Setting

A1 - Overview

Australia is a major energy producer and exporter and has one of the longest electricity systems (extending for 5,000 kms) that is undergoing the world's fastest decarbonisation transition to renewable generation[1]. In 2020-21, electricity generation in Australia produced ~266 terawatt hours (TWh)[2] of electrical energy from all sources, of which 17% was generated outside the electricity sector by industry and households (7% from small-scale solar). The two major electricity sector markets (comprising 97% of electricity demand[3]) are the National Electricity Market (the NEM – servicing Queensland, New South Wales, the Australian Capital Territory, Victoria, Tasmania and South Australia), and the Western Electricity Market (the WEM – in Western Australia). Under the Australian constitution, each state and territory is responsible for its own electricity system, but is linked by major interconnectors across state borders.

The NEM and the WEM are administered by the Australian Energy Market Operator (AEMO[4]), an independent system operator that is majority-owned by all Australian governments except the Northern Territory. Under the constitution, energy is a state government responsibility, so the coordination of the electricity sector is achieved through negotiations between state, territory and federal governments through the Energy and Climate Change Ministerial Council (ECMC[5]).

The NEM supplies ~204 TWh to 10.7 million customers while the WEM supplies ~20 TWh to 1.1 million customers[6]. The total electricity generating capacity of the NEM is ~65GW (~6 GW for the WEM), of which 14 GW is distributed solar – collectively the largest generator in the NEM. In 2022[7], renewables (hydro ~8%, wind ~13%, solar ~6% and rooftop solar ~9%) comprised ~36% of energy generation in the NEM. At some times renewables have exceeded 60% of generation[3] (and as much as 75% for the whole month of December 2021 in South Australia[7] which has only a weak interconnection with the rest of the NEM). Fossil fuels (black and brown coal ~58%, gas ~6%)[7] comprise the remainder of generation in the NEM.

[1] International Energy Agency (2023) *Australia 2023 Energy Policy Review*, https://www.iea.org/reports/australia-2023. Accessed April 2023.
[2] Department of Climate Change, Energy, the Environment and Water (DCCEEW) (2022) *Australian Energy Update 2022*, https://www.energy.gov.au/publications/australian-energy-update-2022. Accessed April 2023.
[3] Clarke D and Graham P (2022), Australian Electricity Transitions 1900 to 2050: What will it take for Australia to transition to a net-zero electricity system by 2050? CSIRO, Australia, https://doi.org/10.25919/wy2n-7x38
[4] AEMO (2023) https://aemo.com.au/. Accessed April 2023.
[5] DCCEEW (2023) Energy and Climate Change Ministerial Council. https://www.energy.gov.au/government-priorities/energy-and-climate-change-ministerial-council. Accessed April 2023.
[6] AEMO National Electricity Market fact sheet (2021) https://aemo.com.au/en/learn/energy-explained/fact-sheets. Accessed April 2023.
[7] Australian National University (ANU) (2023) Australian Energy Emissions Monitor https://iceds.anu.edu.au/research/research-initiatives/australian-energy-emissions-monitor. Accessed April 2023.

There are many alternative options for countries to achieve decarbonisation of the electricity sector and subsequent electrification of all other sectors of the economy[8]. Apart from the present dominant trio of solar photovoltaic, wind and hydroelectric generation, other forms of potential renewable generation include offshore wind, solar thermal, geothermal, wave and tidal power. However, so far only a few of these have reached pilot stage in Australia, and have yet to be demonstrated to be commercially competitive with photovoltaics, wind and existing hydro (new hydro is unlikely because of social and environmental constraints on this dry continent). Nuclear (fission) power is also prohibited by Federal legislation[9], including nuclear fusion[10] which may become a prospective energy source later this century.

In addition, there is virtual electricity generation (or generation replacement that reduces the need for generation on particular timescales), which comprises three types:

- Energy storage (including utility-scale and behind-the-meter batteries, and pumped hydro[11]), all requiring an electricity generator to energise them, but which can release the stored energy on demand as a virtual generator;
- Demand response (on request from the retailer to the customer to reduce consumption), which is effectively a form of instantaneous generation replacement; and
- Energy efficiency, which similarly can reduce demand once implemented, although not instantaneously.

All of these are presently being used in Australia at various levels to supplement physical generation (see issue 4, section B4 for more details).

The current generation mix in Australia is largely the result of the introduction over time of price discovery policies at different levels of government which have enabled different generation technologies to compete for a role in the market. However, these policies have been largely uncoordinated between the states, and between state and federal governments. At a federal level, there have been many changes in policy as a result of successive changes in government. This policy uncertainty – particularly at the federal level – has hindered the progress and raised the cost of the energy transition as discussed in section A2.

The various policies that have been introduced to support the energy transition in Australia have included state government feed-in tariffs and reverse auctions (with contracts-for-difference), the federal

[8] Baldwin KGH, Howden M, Smith MH, Hussey K and Dawson PJ (2021) *Transitioning to a Prosperous, Resilient and Carbon-Free Economy: a Guide for Decision Makers*, Cambridge University Press. https://doi.org/10.1017/9781316389553
[9] Australian Government (1999) *Environment Protection and Biodiversity Conservation Act 1999*, *https://www.legislation.gov.au/Details/C2022C00214*. Accessed April 2023
[10] ABC News (2022) *Nuclear fusion 'breakthrough': How scientists achieved it, and what it means for clean energy*, https://www.abc.net.au/news/science/2022-12-14/nuclear-fusion-reaction-net-gain-clean-energy-explainer/101765634. Accessed April 2023
[11] Blakers A, Stocks M, Lu B and Cheng C (2021) A review of pumped hydro energy storage, *Progress in Energy*, 3(2), 022003 https://doi.org/10.1088/2516-1083/abeb5b

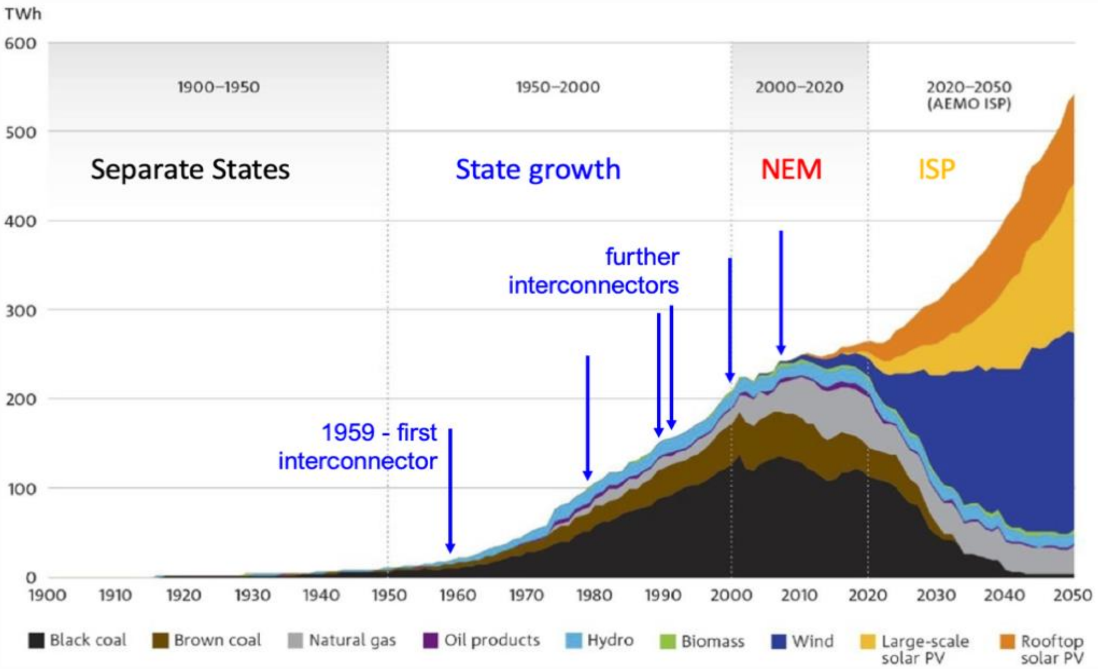
government's Renewable Energy Target[12], and open pool (or spot) markets for electricity in the NEM and WEM. Spot markets in particular have enabled generators with competitive Levelised Cost of Electricity[13] (LCOE) to bid successfully into the NEM, or alternatively to undertake Power Purchase Agreements (PPAs) to supply electricity under long term contracts (up to 20 years or so) with individual customers.

Other issues which have affected the uptake of particular types of generators include grid connection availability (often an issue for remote renewables or offshore wind), water usage, displacement of other land use (e.g. agriculture), social licence and connection time.

A2 - Evolution of the Theme

Australia started electricity generation in the early 1900's using separate municipal and state-based networks (Figure 1). Gradually as the economy and the electricity network grew significantly from around 1950, the first interconnectors between the states were established to capture the economies of a larger, more diverse system. The mix of generation was dominated by abundant coal resources with some hydroelectricity from the Snowy Hydro Scheme which commenced generating in 1955[14], and was later joined by the exploitation of discoveries of vast quantities of natural gas.

Figure 1 | Generated and projected energy in the NEM States and Territories, 1900 – 2050[3].



[12] DCCEEW (2023) Renewable Energy Target scheme https://www.dcceew.gov.au/energy/renewable/target-scheme. Accessed April 2023.
[13] CSIRO (2023) GenCost: annual electricity cost estimates for Australia, https://www.csiro.au/en/research/technology-space/energy/energy-data-modelling/gencost-2021-22. Accessed April 2023.
[14] Snowy Hydro (2023) The Snowy Scheme https://www.snowyhydro.com.au/generation/the-snowy-scheme/. Accessed April 2023.

In response to perceived inefficiencies and price increases, in the 1990s the states commenced transforming their previous public electricity commissions into transmission monopolies and multiple generation, distribution and retail businesses – many of them privatised. This period also saw the opening up of competition between generators in early wholesale markets, before the eventual establishment of the NEM in December 1998 (adding Queensland in 2001 and Tasmania in 2006), and the WEM in September 2006[3].

Over the last few decades since the introduction of the NEM and the WEM, and despite considerable federal government policy uncertainty (apart from the RET) going back more than 15 years, the evolution of electricity generation in Australia has followed a path largely driven in recent times by the sheer economics of renewable generation. After overcoming the increased cost of finance arising from state and federal government policy uncertainty, solar and wind are now the cheapest form of renewable generation, and are expected to reach 50% in the NEM[15] by the middle of the decade.

As the imperative to address climate change has increased – particularly with the simultaneous need to replace the aging fleet of fossil fuel power stations – so has the need for central planning of the energy transition. This has largely been the responsibility of AEMO which in 2018 produced the nation's first Integrated System Plan (ISP)[16] that lays out the future development of the entire electricity system, including (amongst other elements) the projected need for new generation, transmission and storage. AEMO is now planning for 100% peak renewable electricity generation on any particular day to occur by 2025[3], and plans to have the systems in place to cope with this in the near future. The proposed shift in the generation mix to a net zero economy by 2050 is shown in Figure 1, which indicates the projections of AEMO's ISP from 2020 onwards.

As a result of this rapid uptake of renewables, Australia is now leading the global energy transition with the fastest per capita rate of solar and wind installation[17] in the world, especially if the enhanced capacity factor of Australia's higher solar resource is taken into account (almost double that of many high-latitude countries). Figure 2 shows the renewable watts per person installed each year between 2018 and 2021 indicating Australia's leading role. The current Australian Government policy aims for 82% renewable electricity by 2030[18] in order to reach its overall 43% emissions reduction target from a 2005 baseline (with electricity now ~33% of emissions). Now that Australia has greater federal policy certainty, this target should be

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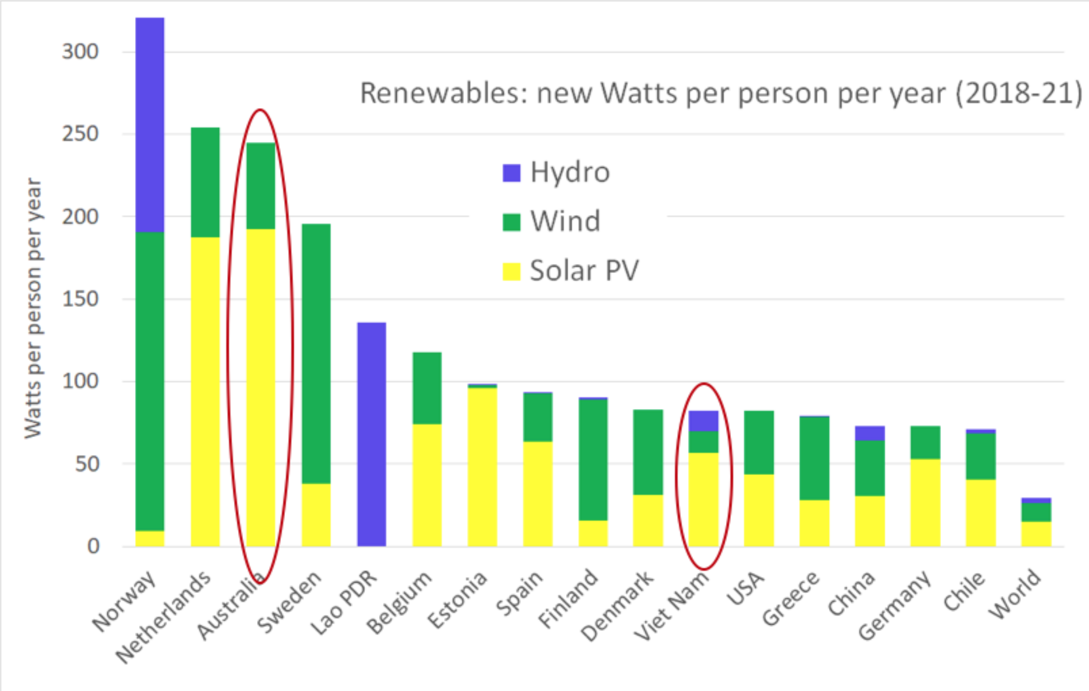
[15] Baldwin K, Blakers A and Stocks M (2018) At its current rate, Australia is on track for 50% renewable electricity in 2025, *The Conversation*, September 10, 2018. https://theconversation.com/at-its-current-rate-australia-is-on-track-for-50-renewable-electricity-in-2025-102903. Accessed April 2023.
[16] AEMO (2022) Integrated System Plan (ISP) https://aemo.com.au/en/energy-systems/major-publications/integrated-system-plan-isp. Accessed April 2023.
[17] Stocks M, Blakers A and Baldwin K (2019) Australia is the runaway global leader in building new renewable energy, *The Conversation*, September 25, 2019. https://theconversation.com/australia-is-the-runaway-global-leader-in-building-new-renewable-energy-123694. Accessed April 2023.
[18] Clean Energy Regulator (CER) (2023) State of Total Renewables, https://www.cleanenergyregulator.gov.au/Infohub/Markets/Pages/qcmr/december-quarter-2022/State-of-Total-Renewables.aspx. Accessed April 2023.

achievable with just a 50% increase in the current rate of renewable energy installation[18] if demand remains at current levels (see also Issue 1, section B4).

Figure 2 | Installed renewable electricity capacity (W) per person per year by source type. International capacity data from the International Renewable Energy Agency. Australian data from the Clean Energy Regulator



Guided by the AEMO ISP, the States are now making their own decisions on how to best achieve their own ambitious emissions reductions plans, with the result that some earlier market-based decisions from the introduction of the NEM are being reversed. This includes returning some generation to public ownership, and directing transmission construction to remove bottlenecks in the construction of new geographic zones for renewable generation. New markets are also having to be designed, such as a capacity market for firmed renewable energy[19] (including storage), and an environmental National Electricity Law objective[20].

A3 - Importance of the theme to the Australian electricity service industry

Given that responsibility for energy is given to the States under the Australian constitution, there has always been a tension between the directions set by the federal government and planning by the states. As outlined in the 2017 Independent Review into the Future Security

[19] DCCEEW (2022) Capacity Investment Scheme to power Australian energy market transformation, https://www.energy.gov.au/news-media/news/capacity-investment-scheme-power-australian-energy-market-transformation. Accessed April 2023.
[20] AEMC (2023) *National Energy Objectives* https://www.aemc.gov.au/regulation/neo. Accessed April 2023.

of the National Electricity Market (the Finkel Review[21]), there are also tensions in solving the energy trilemma: between the environment, security and affordability. The 'climate wars[22]' at federal government level over the past 15 years have seen the (progressive) Labor party pushing for action on the energy transition, while the (conservative) Coalition party has blocked many of the reforms (including a price on carbon) needed to make the energy transition more rapid and effective. As a result, the environmental component in the energy trilemma has not been addressed until recently when the current federal government required that an environmental component be introduced into the national energy objectives[23].

The policy vacuum at the federal level (apart from the Renewable Energy Target which was downgraded in 2015[24]) has meant that states and territories have often followed their own policies to encourage renewable energy generation and meet their own emissions reductions targets. An exemplar is the Australian Capital Territory, which has been able to achieve 100% renewable electricity in 2020[25] using a reverse auction (contract-for-difference) scheme[26], a very successful price discovery mechanism that has had widespread application in many countries[27]. However, the race for renewables has not been without its mistakes, with over-generous state and territory feed-in tariffs for rooftop solar[28] causing market distortions that have diverted funds from potentially more efficient ways of enhancing uptake of renewables, while subsidising those households which have the capacity to pay the up-front costs[29].

Previous coordinating bodies have recognised the growing need for governance change, as was recommended by the Finkel Review. In order to address stresses on the NEM due to rapid technology change, rising costs, and policy uncertainty on how to deal with electricity emissions, and prompted by the electricity blackout in South Australia in 2016[30], the Finkel Review made 50

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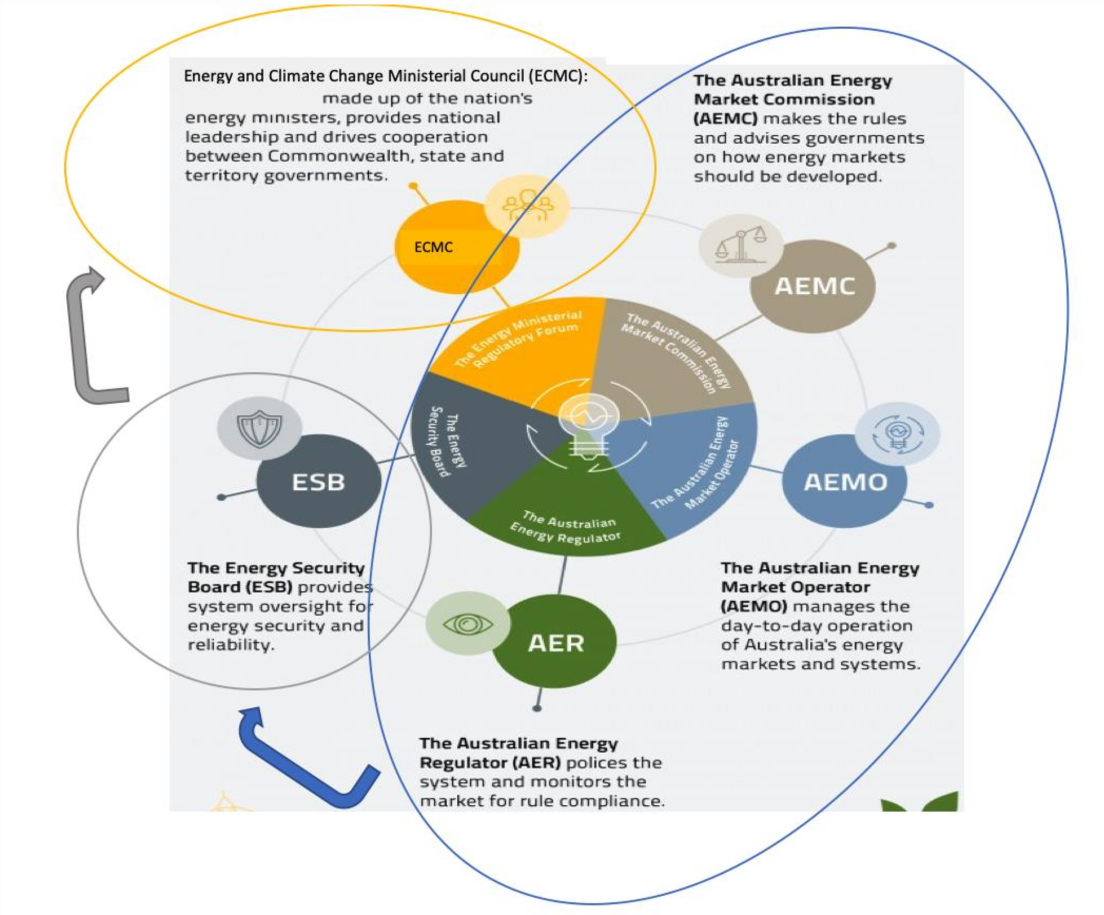
[21] DCCEEW (2017) Independent Review into the Future Security of the National Electricity Market – Blueprint for the Future, https://www.energy.gov.au/publications/independent-review-future-security-national-electricity-market-blueprint-future. Accessed April 2023.
[22] Pearse, R (2022) 3 lessons from Australia's 'climate wars' and how we can finally achieve better climate policy, *The Conversation*, 19 July, 2022. https://theconversation.com/3-lessons-from-australias-climate-wars-and-how-we-can-finally-achieve-better-climate-policy-187000. Accessed April 2023.
[23] DCCEEW (2022) Consultation on proposed legislative changes to incorporate an emissions reduction objective into the national energy objectives https://www.energy.gov.au/government-priorities/energy-and-climate-change-ministerial-council/priorities/national-energy-transformation-partnership/consultation-proposed-legislative-changes-incorporate-emissions-reduction-objective-national-energy-objectives. Accessed April 2023.
[24] CER (2022) About the Renewable Energy Target: History of the scheme https://www.cleanenergyregulator.gov.au/RET/About-the-Renewable-Energy-Target/History-of-the-scheme. Accessed April 2023.
[25] ACT Government (2023) What the ACT Government is doing https://www.climatechoices.act.gov.au/energy/what-the-act-government-is-doing. Accessed April 2023.
[26] Buckman G, Sibley J and Ward, M (2019) The large-scale feed-in tariff reverse auction scheme in the Australian Capital Territory 2012, to 2016, *Renewable Energy*, 132, 176-185. https://doi.org/10.1016/j.renene.2018.08.011
[27] Auctions for Renewable Energy Support II (2023) http://aures2project.eu/. Accessed April 2023.
[28] Nelson, T, Simshauser, P and Nelson, J (2012) Queensland solar feed-in tariffs and the merit-order effect: economic benefit, or regressive taxation and wealth transfers? *Griffith Research Online* https://core.ac.uk/download/pdf/159509033.pdf. Accessed April 2023.
[29] Poruschi, L, Ambrey, CL and Smart, JCR (2018) Revisiting feed-in tariffs in Australia: A review, *Renewable and Sustainable Energy Reviews*, 82(1), 260-270. https://doi.org/10.1016/j.rser.2017.09.027
[30] Australian Energy Market Commission (AEMC) (2019) Review of the System Black Event in South Australia on 28 September 2016, https://www.aemc.gov.au/markets-reviews-advice/review-of-the-system-black-event-in-south-australi. Accessed April 2023.

recommendations. All but one was adopted – the need for carbon pricing – reflecting the 'climate wars' over the carbon price introduced by a previous federal Labor Government that lasted 2 years from July 2012. The carbon price had an observable effect on reducing the carbon intensity of the electricity sector[31] (see also Issue 1, section B2) until rescinded by the following Coalition Government in July 2014.

The remaining recommendations of the Finkel Review had significant implications for generation. Stronger governance was recommended, including establishing an Energy Security Board (ESB) to coordinate three key agencies: the Australian Energy Market Commission (AEMC); the independent Australian Energy Regulator (AER); and AEMO. The ESB now reports to the ECMC (Figure 3).

Figure 3 | Governance of the Australian energy sector (adapted from Stanwell[32]).



There was also a call by the Review to establish a national emissions reduction trajectory, which has now been achieved by the present federal government's 82% renewables target by 2030, with net-zero

[31] O' Gorman, M and Jotzo F. (2014) Impact of the Carbon Price on Australia's Electricity Demand, Supply and Emissions, *Centre for Climate & Energy Policy working papers, Crawford School of Public Policy, ANU*. https://ccep.crawford.anu.edu.au/sites/default/fil ... 2014-07/ccep1411.pdf.
[32] Stanwell Corporation (2023) What's Watt: What is the Energy Security Board and why is it important? https://whatswatt.com.au/what-is-the-energy-security-board-and-why-is-it-important/. Accessed April 2023.

emissions for the whole economy by 2050[33]. The aim of establishing a trajectory was to reduce government policy uncertainty in order to accelerate and lower the cost of the energy transition.

Generators were also required to provide three years notice of exiting, and a generator reliability obligation for minimum dispatchable capacity was introduced (now replaced by the proposed capacity market for firmed renewable energy). Also included were calls to: enhance virtual generation from demand response, energy efficiency, and rooftop solar; develop plans for renewable energy zones (REZs) and associated transmission infrastructure (now called the AEMO ISP); and, create a strategic plan for the NEM.

While complex, the present electricity governance model reflects the realities of the Australian constitution and the need for collaboration. However, given past federal government policy uncertainty, this cooperation has been under strain, with many state governments taking their own paths to procure generation and storage, or provide publicly-owned power generation.

Whether this will change with the new federal Labor Government's proposed inclusion of environmental objectives in the National Electricity Law[23], the proposed firmed renewable capacity market, and the impetus provided by the Rewiring the Nation[34] policy, remains to be seen. This is also in the context of consumers now being able to choose their own retail providers (particularly with regard to renewable electricity) and participate in generation/storage/demand response much more than previously. All these factors will contribute to determining the future rate of Australia's energy transition.

A4 - List of key issues

Based on the Australian experience, and on the development of the energy transition in many countries including Vietnam, we have grouped the key topics for discussion under the following five issues:

1. Price discovery to accelerate renewable generation
2. Integrated system planning
3. Managing variable renewable electricity generation
4. Virtual generation and energy storage
5. Electricity trade

A5 - Relevance to Vietnam

It would be useful to consider the Finkel Review as equivalent to Resolution 55, since each set out a rationale and targets for development of power and energy. They also cover similar topics. Furthermore, they each outline an implementation plan intended to mobilize government and the private sector. We therefore think it is

[33] Australian Government (2022) *The Climate Change Act 2022* https://www.legislation.gov.au/Details/C2022A00037 Accessed April 2023.
[34] DCCEEW (2022) Rewiring the Nation supports its first two transmission projects https://www.energy.gov.au/news-media/news/rewiring-nation-supports-its-first-two-transmission-projects. Accessed April 2023.

useful to review the institutional structure of Australia's response to power sector development with respect to the implementation of Resolution 55.

In both cases, we see a clear structure for governance. In the case of Resolution 55, we see a structure that includes the state, government and the Fatherland Front. However, Decision 140/NQ-CP largely reduced implementation to a single ministry, MOIT, that has its own interests in the power and energy sector. In practice, this means that opinions on implementation of Resolution 55 are not as diverse as they should be, and furthermore, only the CEC is left to monitor implementation. This becomes very clear in the long delays for completion of PDP8. PDP8 itself again places primary responsibility for the implementation with MOIT.

A6 - Recommendations to Vietnam

We recommend that:

1. The CEC take a careful look at the structure of implementation of the Finkel report and consider how this could inform the structure of responsibilities in the implementation section of Resolution 55. The Australian experience with renewable energy targets may also be useful for Vietnam, including creating national target programs for renewable energy.
2. Whatever policy decisions are taken forward, avoid government policy uncertainty which acts as a barrier for investment in new generation.
3. Price discovery mechanisms be applied to reveal the changing price of generation as learning rates evolve, thereby providing a least-cost approach to the energy transition. This can be achieved through internationally validated mechanisms like, for example, reverse auctions with contract-for-difference which can enable price discovery before the development of fully-fledged spot markets. We note that in PDP8 there is a requirement to research and develop an auction mechanism, which is consistent with our recommendation.
4. The CEC investigate options for carbon pricing in the electricity sector as a least-cost way of supporting price discovery. We note that PDP8 does not consider carbon pricing.
5. Policy approaches for transitioning to renewable generation be laid over the top of existing generation rather than mandating the closure of incumbent fossil fuel generators, to enable competition e.g. in the wholesale market, that then allows the energy transition to play out.
6. A holistic approach to the energy transition be undertaken, including planning across the entire system to enable the interplay between transmission, distribution, generation and storage to be managed effectively, efficiently and at least cost.

B. Issues Exploration

Issue 1 - Price discovery to accelerate renewable generation

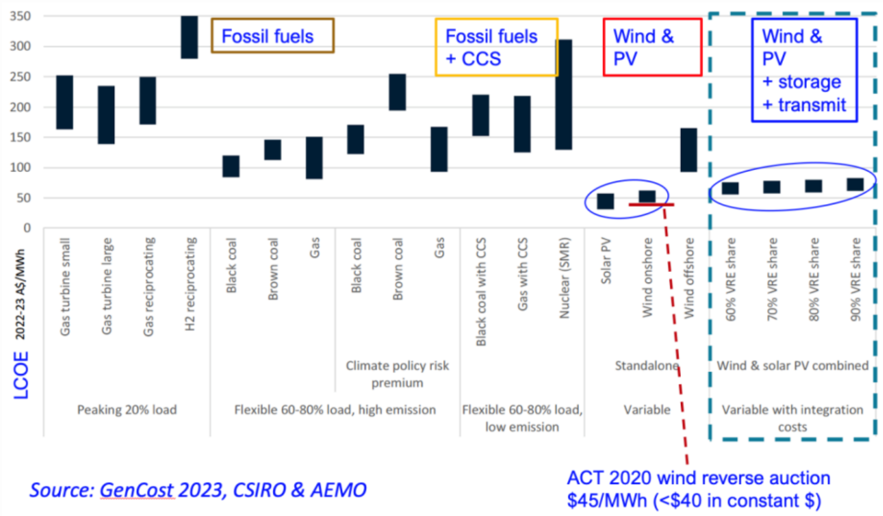
B1 - Problem context

The future electricity generation mix will be determined by, amongst other factors, the availability of energy resources, geography, social context and geopolitical considerations. However, chief amongst these is the cost of electricity generation – typically expressed as the Levelised Cost of Electricity (LCOE) where the investment cost (including the cost of finance), fuel costs and maintenance costs are amortised over the lifetime of the generator.

The issue here is how to determine these costs – particularly the investment cost – at a particular time and geographic location. In order to do this, some form of price discovery is needed to verify the cost of a particular form of energy generation.

An example of an LCOE analysis is shown in Figure 4, which presents the LCOE for electricity generation by source in Australia, as provided by the GenCost 2022-2023[35] study (created by AEMO and Australia's chief scientific research agency, CSIRO). The data inputs for this study are largely empirical, being derived either from price discovery as energy from the various sources is purchased in Australia, or adapted to the Australian context from energy costs elsewhere.

Figure 4 | LCOE for various electricity generator types in Australia for 2030[35].



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[35] Graham P, Hayward J, Foster J and Havas L (2022) *GenCost 2022-23 Consultation Draft*, CSIRO, Australia https://doi.org/10.25919/hjha-3y57

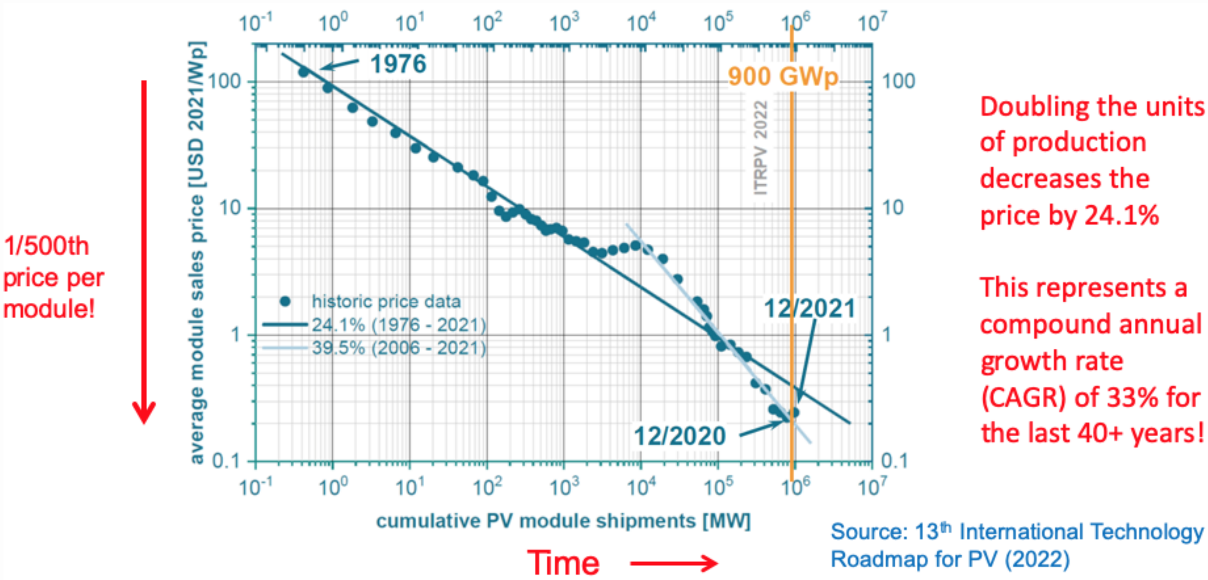
The dominant cost competitiveness of solar and onshore wind is apparent, even allowing for the additional storage, transmission and gas peaking required to ensure system reliability as the level of VRE approaches 100%. A recent onshore wind reverse auction in the Australian Capital Territory[36] returned a strike price in the contract-for-difference that was below $45/MWh, which given the 10-year duration of the contract is similar to an LCOE. Allowing for inflation over the contract period, this represents a wind electricity generation price in constant dollars of <$40/MWh - even cheaper than the lowest value in the GenCost projections for 2030.

Photovoltaics and onshore wind are now the cheapest form of electricity generation in Australia, and for this reason solar and wind comprise the overwhelming majority of new generating capacity installed. This is largely due to the sheer economics of solar and wind, complemented by the federal government's Renewable Energy Target (RET) and other State/Territory policies, but *in spite of* the general federal government policy uncertainty over the past 15 years.

B2 - Strategic setting

The key issue in a least-cost approach to the energy transition is: how do you enable price discovery for the changing costs of generation as the learning rate for different technologies evolves rapidly over time? Figure 5 shows the learning rate for solar PV modules: an extremely rapid cost reduction – by a factor of 500 over 45 years!

Figure 5 | Learning rate for solar PV modules (US$/watt) vs. number of modules produced



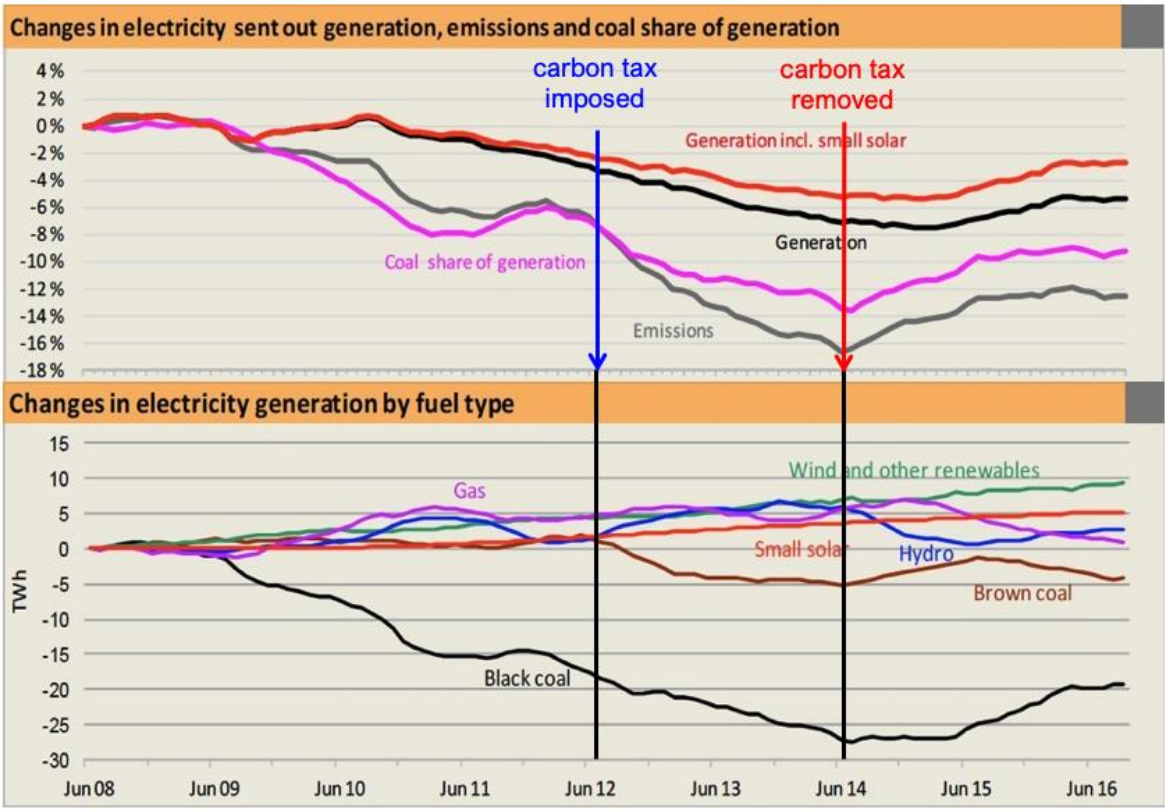
[36] ACT Government (2020) *BIG batteries part of Canberra's next renewable energy plan*, https://www.cmtedd.act.gov.au/open_government/inform/act_government_media_releases/barr/2020/big-batteries-part-of-canberras-next-renewable-energy-plan. Accessed April 2023.

As the competitiveness of technologies can change rapidly with time, continuous opportunities for price discovery are needed to enable the cheapest technologies to be adopted. An important element in comparing generation prices is the inclusion of the cost of negative externalities, especially environmental costs such as greenhouse gas emissions causing climate change. Ideally, an economy-wide carbon price would enable such comparison (see e.g. the fossil fuel generation prices with a climate risk premium in Figure 4).

Unfortunately in Australia, a carbon price only existed for two years from July 1st, 2012, when introduced by the federal Labor Government at that time, before being repealed by the federal Coalition Government in July 2014. These changes contributed significantly to climate and energy policy uncertainty which increased the cost of finance for new generating capacity, a problem recognised by the Finkel Review which offered several options for carbon pricing in the electricity sector. None of these were accepted by the Coalition Government – thereby contributing to even greater policy uncertainty.

Nevertheless, the carbon price had a noticeable effect on electricity generation. Figure 6 shows both the emissions and the generation mix in the NEM from 2008 to 2016. During this period both demand and emissions were generally in decline due to a combination of a shift away from manufacturing, uptake of behind-the-meter rooftop solar (red curve), responses to price rises and improved energy efficiency. However, a noticeable decrease in emissions occurred[31] that was directly attributable to the introduction of the carbon tax, as evidenced by the rapid decline in brown coal generation which was the most heavily-emitting generator. Following removal of the carbon tax, brown coal generation immediately increased, with a concomitant increase in electricity emissions, thereby demonstrating the effectiveness of carbon pricing.

Figure 6 | NEM generation and emissions by generator type showing effect of the carbon tax



Source: Pitt and Sherry, October 2016

Subsequent to the removal of the carbon price, the only federal support for renewable generation was provided by the Renewable Energy Target[24], originally implemented in 2001 by a previous federal Coalition Government. Under this scheme, Large-scale Generation Certificates (LGCs[37] are created for every megawatt hour (MWh) of electrical energy produced by a renewable energy generator, and these certificates can be traded with companies who may wish to surrender the LGCs to demonstrate their use of renewable energy. Recently LGC prices[38] exceeding AU$70 have been realised (despite the fact that the RET objective was met early in 2019[39]), as LGCs continue being issued until 2030. Like carbon pricing, the RET supports renewable energy generation – but is not a direct form of price discovery.

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[37] CER (2022) *2020 Large-scale generation certificates.* https://www.cleanenergyregulator.gov.au/RET/Scheme-participants-and-industry/Power-stations/Large-scale-generation-certificates. Accessed April 2023.
[38] CER (2023) *Quarterly Carbon Market Reports Q4 contents 2.1 Large-scale generation certificates (LGCs)* https://www.cleanenergyregulator.gov.au/Infohub/Markets/Pages/qcmr/december-quarter-2022/Large-scale-generation-certificates-(LGCs).aspx. Accessed April 2023.
[39] CER (2019) *2020 Large-scale Renewable Energy Target capacity achieved.* https://www.cleanenergyregulator.gov.au/About/Pages/News%20and%20updates/NewsItem.aspx?ItemId=683&ListId=19b4efbb-6f5d-4637-94c4-121c1f96fcfe. Accessed April 2023.

B3 - Solutions

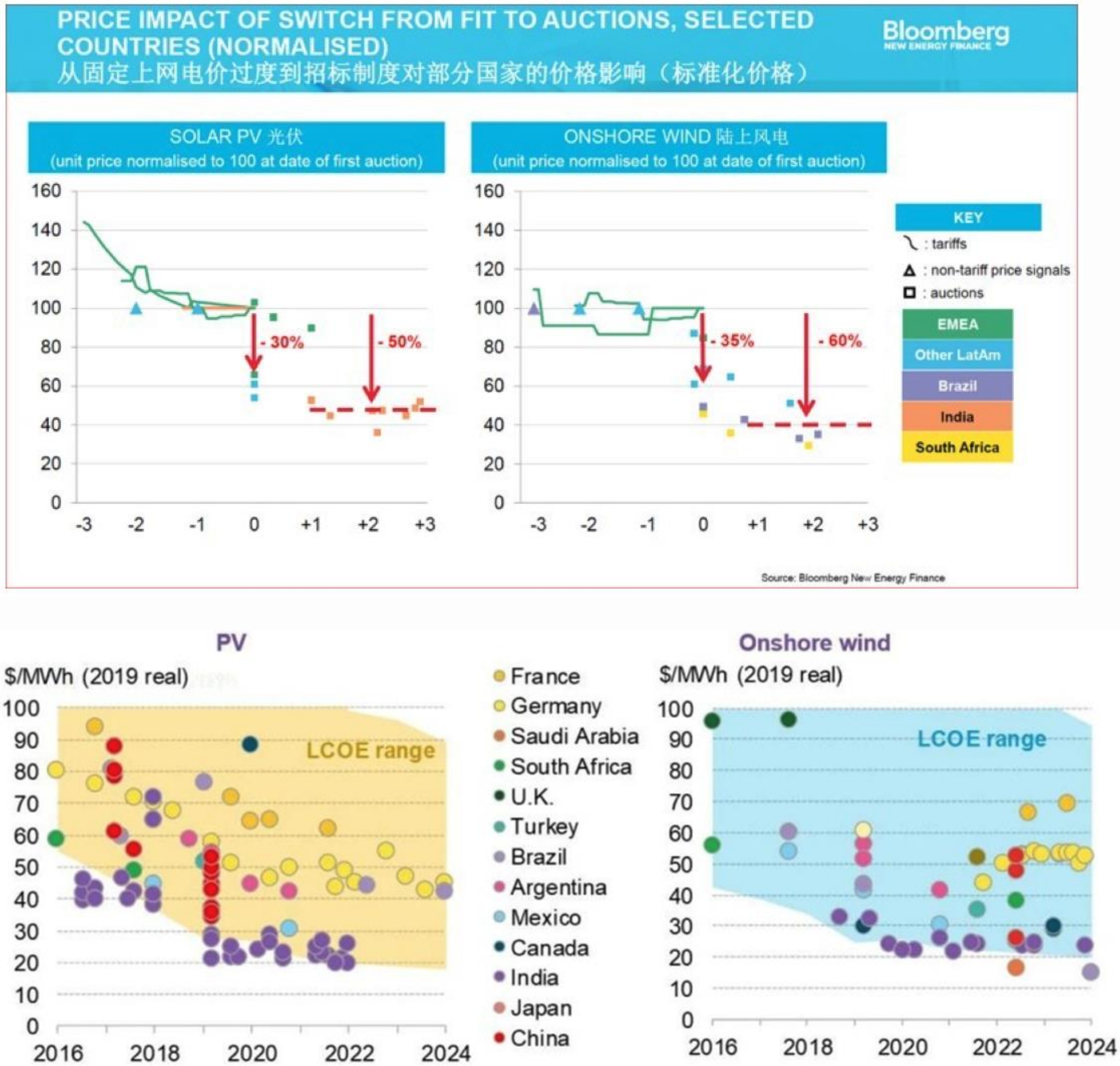
A range of price discovery mechanisms exists, and ultimately, energy generators who trade into an open pool, energy-only, merit-order market such as the Australian NEM reveal their prices instantaneously over the bid period (currently 5 minutes – see Markets discussion paper). However, such markets often take time to develop and require sufficient generating market participants to provide competition, supported by a strong regulatory framework.

In Australia, a number of other mechanisms for price discovery have been used to accelerate renewable energy generation outside the open-pool market in the NEM. This can provide an entry point for generators into the electricity system before entering full-scale competition in the open-pool market. These mechanisms include:

- Power Purchase Agreements (PPAs): Generators contract directly with large companies for supply of renewable electricity, whether by tendering, negotiation or other mechanisms.
- Feed-in Tariffs (FiTs): Usually applied to rooftop solar generation, many state and territory governments offered (often generous[28]) FiTs at a fixed price to 'prosumers'[40] to sell their solar generation back into the grid. This is a crude form of price discovery since if the tariff is set too high, too many generators might be rewarded, or if it is set too low, then too few generators may be encouraged to supply. A number of different FiTs might be required to set the right balance, and adverse social consequences[29] may also eventuate.
- Reverse Auctions: Unlike auctions where buyers bid, in a reverse auction the seller bids. This mechanism was pioneered by the ACT Government[26] and later adopted by other states. Using a contract-for-difference[41] approach, the customer is guaranteed a fixed ('strike') price by the generator, which when below the market rate provides a return for the difference from the generator to the customer, and when above the market rate provides a return from the customer to the generator to match the strike price.

[40] Consumers who also produce electricity from rooftop solar.
[41] ACT Government (2023) *Large-scale feed-in tariffs and reverse auctions* https://www.climatechoices.act.gov.au/policy-programs/large-scale-feed-in-tariffs-and-reverse-auctions. Accessed April 2023.

Figure 7 | (Top) Comparison of reverse auctions with FiTs and other price signals. (Bottom) International data from reverse auctions showing price discovery vs. time for solar and wind. (adapted from Bloomberg New Energy Finance[42])

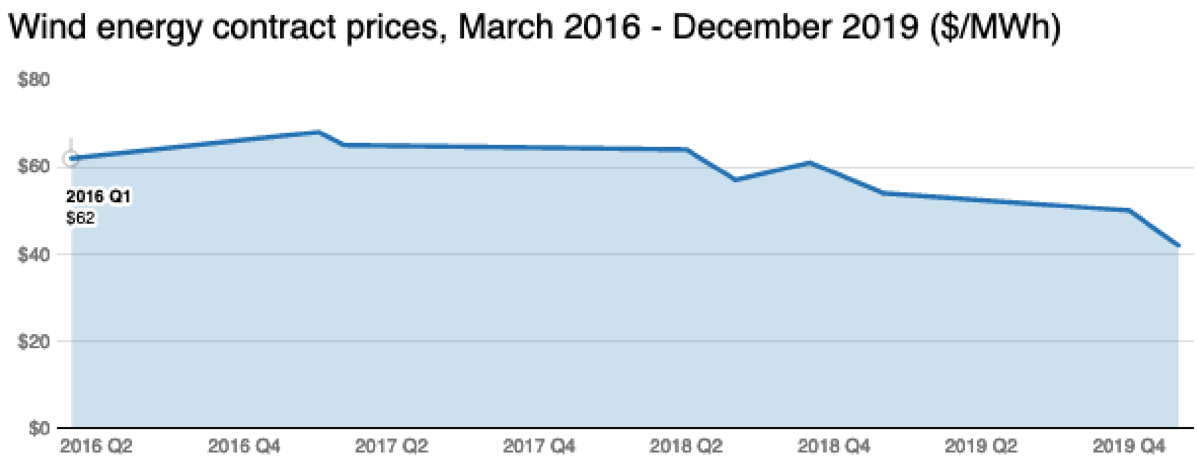


Reverse auctions have generally been regarded as the most efficient form of price discovery[27], and Figure 7 shows data from Bloomberg New Energy Finance[42] that indicates the effectiveness of reverse auctions over FiTs in price discovery for a range of countries (with a downward effect on prices being demonstrated). Indeed, this has been the experience in Australia, and Figure 8 shows the price discovery that arose from wind reverse auctions[43], which reveals the decline in wind

[42] Bloomberg New Energy Finance (2021) *Renewable Energy Auctions* https://www.bloomberg.com/netzeropathfinders/best-practices/renewable-energy-auctions/. Accessed April 2023.
[43] Baldwin, K (2017) Renewables will be cheaper than coal in the future. Here are the numbers, *The Conversation*, 27 September, 2017 https://theconversation.com/renewables-will-be-cheaper-than-coal-in-the-future-here-are-the-numbers-84433.

generation costs discovered by reverse auctions over the indicated period.

Figure 8 | Wind reverse auction prices[44] in constant dollars showing price discovery



Long-term wind auction contract prices, as per projected wind farm completion (power switch on) date. Wind table constant prices, expressed in March 2016 dollars, assuming 3% inflation. The graph shows a gradual decline in wind energy contract prices, consistent with improvements in technology and economies of scale. Sources: ACT Wind Auction I: Jacobs Wind Auction Review, August 2015. ACT Wind Auction II: AECOM ACT Wind Auction II Review, 2016. ACT Next Generation Renewables: 200 MW Next Generation Renewables Auction fact-sheet. AGL and Origin Energy: Renew Economy, 8 May 2017, "Origin stuns industry with record low price for 530MW wind farm".

Source: Compiled by Ken Baldwin, Australian National University

B4 - Expert reflection on Australian experience

As a result of a combination of the federal RET and various price discovery mechanisms implemented by the states and territories, Australia has installed on average ~6 GW renewable generating capacity each year, for the last 5 years[18] (Figure 9). This represents an increase in the share of renewable generation of 4% annually, roughly evenly shared among rooftop solar, utility scale solar and utility scale wind. Australia has the highest level of rooftop solar penetration in the world, with 30% of households (more than 3 million in total) having installed rooftop solar[45]. Australia is currently installing around ~3GW of rooftop solar capacity *each year* (Fig. B6). This is to be compared with the PDP8 estimated increase in rooftop solar in Vietnam of only 2.6 GW during all of 2023 – 2030.

Note that prior to 2018, there was very little uptake of utility solar and wind, principally due to federal government policy uncertainty. An increase of the installation rate for solar and wind of 6% annually will be needed to meet the new federal government target of 82% renewables by 2030.

Given the recent flat consumer demand, ~6 GW new renewables is equivalent in energy terms to removing two major

[44] DCCEEW (2023) Solar PV and Batteries. https://www.energy.gov.au/households/solar-pv-and-batteries Accessed April 2023.

(~1 GW) fossil fuel power stations from the generating mix each year (assuming an average renewable-to-fossil capacity factor ratio of 1:3). The NEM schedule of generator installations and retirements by generator type for the period up until 2019 is shown in Figure 9.

So starting with a dominantly fossil fuel electricity sector (84% in 2016/7 to 73% in 2021/22[2]), the Australian energy transition is proceeding at the fastest rate of any country[17]. This is in spite of federal government policy uncertainty, apart from the presence of the RET (achieved early in 2019) and other uncoordinated state government programs. Price discovery in the mechanisms indicated above and in the NEM open-pool market have played an important role in this rapid uptake, which has revealed the rapidly decreasing costs of solar and wind, combined with Australia's excellent solar and wind resources.

While federal policy support for this rapid energy transition has been imperfect, there was still sufficient price discovery in the system through a range of mechanisms to allow the competitive economics of wind and solar to be revealed, and enable this world-leading status to be achieved.

Figure 9 | Renewable energy capacity installed (columns), total NEM operational demand (excluding self-consumed demand from rooftop PV - line) and renewable energy annual contribution (percentages)
Source: Clean Energy Regulator.

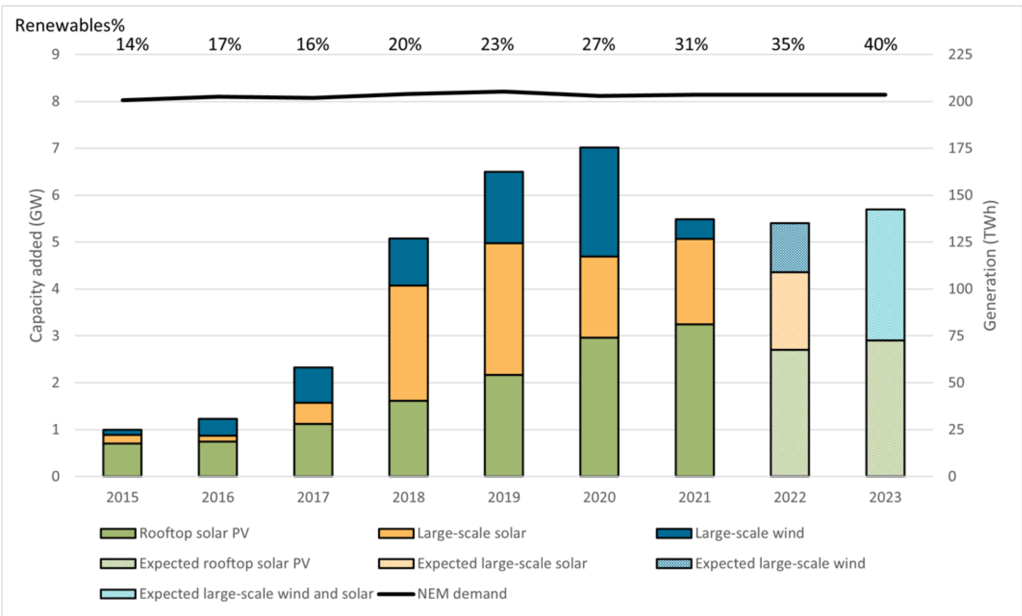
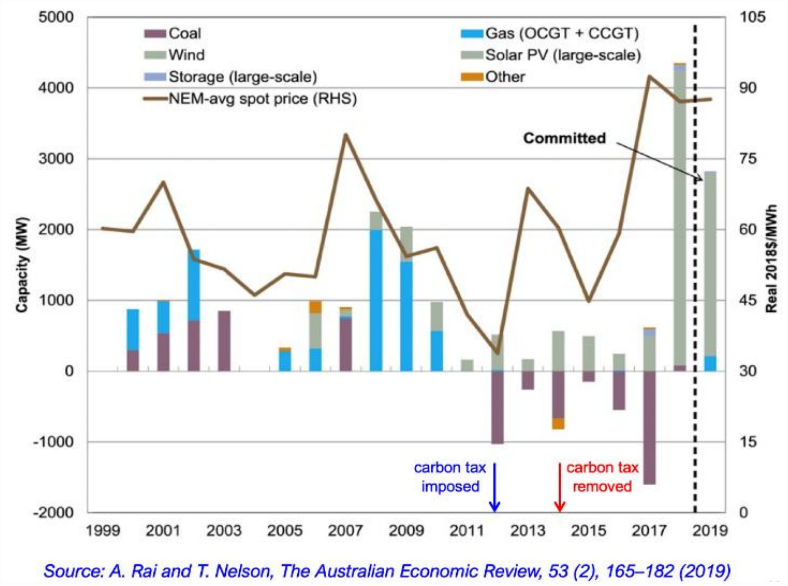


Figure 10 | Generator installation/retirement by type from the beginning of the NEM to 2019[46].



B5 - Expert reflection on Vietnamese significance

In the Australian case, we see the expansion of renewable energy sources despite federal policy uncertainty on the role and value of renewable energy in the national energy market. In part this was due to actions carried out by states and territories, in particular with respect to residential rooftop solar. However, the sheer economics of renewable energy meant that despite policy uncertainty, wind and solar developed rapidly. Therefore, price transparency was a key element in this transition.

1. Price discovery mechanisms reveal the changing price of generation to both consumers and regulators as learning rates evolve, thereby providing a least-cost approach to the energy transition.

2. Feed in Tariffs can be used to support policy, especially in building out knowledge, expertise, and supply chains, but have limited value over the longer term because, as a renewable energy sector learns, the LCOE will decline, while FiTs are generally fixed over a longer period of time. FiTs, therefore, are a limited form of price discovery.

3. Open pool markets, in which load dispatch centres prioritize the lowest cost providers on a continuous basis, can operate efficiently if providers compete on the basis of price. In Vietnam, there are currently 108 power plants directly participating in the open pool, spot

[46] Rai, A and Nelson T (2019) Australia's National Electricity Market after Twenty Years, *The Australian Economic Review* 53(2), 165 – 182, https://onlinelibrary.wiley.com/toc/14678462/2020/53/2. Accessed April 2023.

market, with a total installed capacity of 30,837 MW, equal to about 38.8% of the total capacity of the national power system. Many of these are small and medium scale hydropower facilities. Many of the larger facilities, and the majority of renewables, provide wholesale power to a single buyer, the Electric Power Trading Company (EPTC), under specific power purchase agreements through regional Generation Companies, or Gencos. The Gencos deliver power to the EPTC under contracts for difference. The EPTC then sells power to regional power companies in a retail market. This structure limits the capacity of markets to drive down prices primarily due to the prevalence of contracted prices and limited trading ranges. Transition to a wholesale power market will require both regulatory changes related to pricing and renegotiation of contracts with power suppliers. This is a long term process that has already begun, but needs to be accelerated. PDP8 is silent on the timescale needed to expand the wholesale electricity market.

4. In Australia, solar and wind are now the cheapest form of electricity generation, and for this reason they comprise the vast majority of the new generating capacity installed. The CEC needs to understand why the LCOEs for these power sources in Vietnam are much higher than the Australian case. The declining cost of solar panels is global. Given that the cost of panels is the major factor behind the declining levelized cost of photovoltaics, the CEC needs to ask what other factors affect price in Vietnam. Feed in Tariffs are an obvious factor, but they are not the only factor. From the investor perspective, high FiTs, initially starting at $0.0936 USD per kWH, compensated for lack of a bankable PPA, high administrative cost for investment licensing and project permits, and unofficial facilitation fees. The business community has argued that lower FiTs, even no FiTs, are acceptable if time to market is reasonable and EVN shares operations risk. This would mean, in practical terms, standardized PPAs that limit curtailment and standardized permitting processes that reduce time to Commercial Operation Date (COD). The result would be lower cost to investors and lower cost to power consumers.

5. Reverse Auctions, which have been successful tools for price discovery in Australia, will require revision of laws related to procurement in Vietnam. Current laws reflect a normal bidding process in which a seller puts up an item and buyers place bids until the item goes to the highest bidder. In a reverse auction, sellers bid for the prices at which they are willing to sell their goods and services, with buyers selecting the lowest price. The

research and development of schemes for reverse auctions proposed in PDP8 will be essential to enable price discovery for all forms of electricity generation as an adjunct on the way to expanding the wholesale electricity market.

6. Inclusion of the cost of negative externalities, especially environmental costs such as greenhouse gas emissions causing climate change, is an important element in comparing generation prices. Ideally, an economy-wide carbon price would enable such comparison. This has been politically impossible in Australia. Vietnam, along with other countries with open economies, see trade barriers being erected through Carbon Border Adjustment Mechanisms. The best response, and one that keeps those fees and taxes in country, is to create national emissions trading and carbon taxation systems. Decree-06/2022/ND-CP on Greenhouse Gas Emissions and Ozone layer Protection authorizes creation of an Emissions Trading System in Vietnam. The MOF is also researching the feasibility of creating a Carbon Tax. The World Bank has suggested that a tax of $12 USD per ton of CO_2 would be equivalent to the weighted average cost of the Environmental Protection Tax on coal, gasoline, and diesel. If the cost of these taxes over time can be built into the LCOE for generation by source, the actual cost of coal thermal power and LNG to power relative to renewable sources would become more transparent- – thereby enhancing price discovery. Revenue from the sale of Emissions Allowances and Carbon Taxes could also be used to finance the transition to a lower carbon economy.

7. The current proposal for creation of Direct Power Purchase Agreements in Vietnam is equivalent to Australia's contracts for difference. It is a Virtual PPA that does not require buyers and sellers of power to be near each other because no power is actually transmitted between them. The buyer is not buying actual power but rather the rights to that power. There are thus no transmission charges. Under the draft mechanism, eligible suppliers would include those that have not met conditions for application of FiTs. These "transitional RE suppliers" can negotiate better contracts with buyers than those offered by EVN. Unfortunately, even under these conditions, the cost to buyers is not attractive relative to their current cost for power as EVN has also imposed a transmission charge on these contracts for difference. The DPPA pilot needs to move forward as a learning process, especially as a test of pricing mechanisms, but a final mechanism will need to address reasons for the relatively high cost.

Issue 2 - Integrated system planning

B1 - Problem context

The rapid rate of renewable energy generation uptake has not been without its problems in Australia. In the distribution network, high levels of rooftop solar generation have created capacity issues with networks not designed for high levels of two-way flow[47]. At times of low demand and high sunshine, curtailment of rooftop solar to balance the system[48] is sometimes required, leading to dissatisfaction from prosumers. In the transmission network, similar problems with congestion[49] have occurred, along with bottlenecks in regulatory processes which delay connection of utility-scale renewables to transmission networks which are often close to capacity. (For more details on these issues, see the Grid discussion paper.)

Furthermore, despite the current and previous coordination arrangements between states and territories which by-and-large have proceeded with their own renewable generation policies independently from the federal government, there has not until recently been nationwide planning[50] of generation location around the country. This is particularly important given the scale of the NEM, which stretches over 5,000 kms and has 40,000 kms of poles and wires. This geographic feature can be used to advantage to reduce the variability of solar and wind, as somewhere it will be windy, and with shifting cloud cover during the day, somewhere it will be sunny.

In order to provide an holistic approach to the energy transition over the entire electricity sector, central planning is required. Such an approach will allow the interplay between transmission, distribution, generation and storage to be planned effectively, efficiently and at least cost. This is what led to the AEMO Integrated System Plan (ISP)[16].

B2 - Strategic setting

Overall responsibility for ensuring reliability of the electricity system lies with AEMO, who have developed a number of mechanisms to deal with variable renewable electricity (VRE) as explained later under issue 3. There are a number of options to ensure system balancing available to authorities once renewables begin to dominate the generation mix:

[47] Energy Networks Australia (2019) Energy Insider: Solar saturation: sooner than we thought https://www.energynetworks.com.au/news/energy-insider/solar-saturation-sooner-than-we-thought/. Accessed April 2023.
[48] AEMO (2021) Solar PV curtailment initiative by SA Government supports the NEM https://aemo.com.au/en/newsroom/media-release/solar-pv-curtailment-initiative-by-sa-government-supports-the-nem. Accessed April 2023.
[49] Clean Energy Council (2023) Congestion Relief Market is key to fixing grid congestion https://www.cleanenergycouncil.org.au/news/access-reform-explainer. Accessed April 2023.
[50] DCCEEW (2022) National Energy Transformation Partnership https://www.energy.gov.au/government-priorities/energy-and-climate-change-ministerial-council/priorities/national-energy-transformation-partnership. Accessed April 2023.

- Overbuilding renewable generation capacity
- Electricity storage (see also issue 4 here)
- Demand response
- Load following by other generators including hydro (fast), thermal power stations (slow)
- Expansion of transmission to exploit geographic advantage (see Grid discussion paper)

Of these, generation capacity overbuild is a key tool, and is closely linked to transmission network expansion.

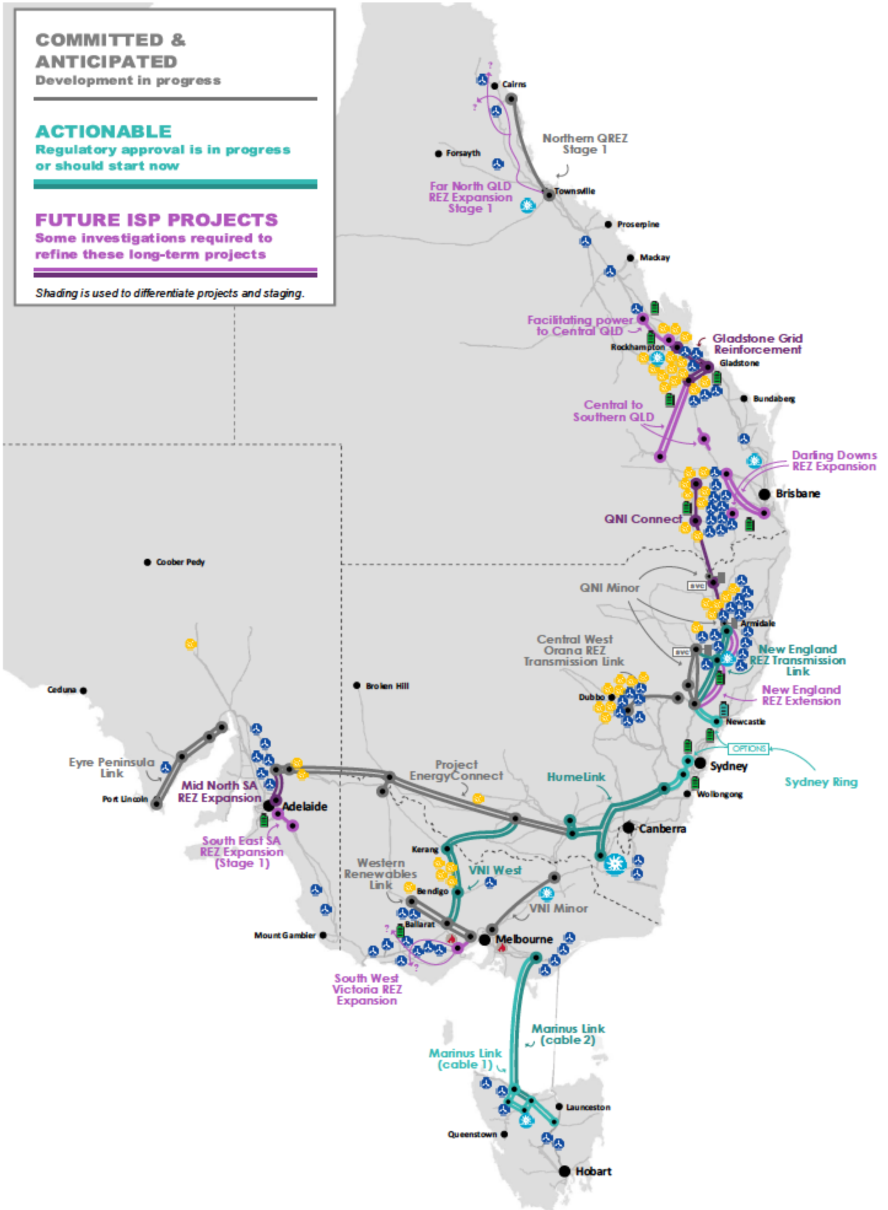
Even at current levels of renewable generation in the NEM (now approaching 40%), it is important to plan for location of new renewable generation, particularly given the problems outlined above. To achieve this, the AEMO ISP, developed following a recommendation of the Finkel Review, is updated every two years (now preparing for its fourth edition[51]).

B3 - Solutions

The ISP has developed the concept of Renewable Energy Zones (REZs) shown graphically in Figure 11. The location of the zones is designed to tap into the best renewable energy resources, and positions the wind/solar farms as close as possible to the major load centres on the coast so as to maximise the use of available and planned transmission lines (colour coded by priority in the figure). In addition, storage and support services in various forms (batteries, pumped hydro, synchronous condensers etc.) are shown by the appropriate symbols.

[51] AEMO (2023) 2024 Integrated System Plan (ISP) https://aemo.com.au/energy-systems/major-publications/integrated-system-plan-isp/2024-integrated-system-plan-isp. Accessed April 2023.

Figure 11 | Map of the 2022 AEMO Integrated System Plan for the NEM: solar (yellow) and wind (blue) Renewable Energy Zones; pumped hydro (aqua); utility scale batteries (green); synchronous condensers (red); 10,000 kms of new transmission prioritised by colour.



The REZ concept also helps minimise the cost and delays of land acquisition for transmission lines, and helps reduce the possibility of congestion and regulatory delays for connection. Furthermore, there is an opportunity to maximise the utilisation of storage – either located at the REZ or near the load source – given that localised, shared storage makes better use of the available storage capacity.

B4 - Expert reflection on Australian experience

Prior to the Finkel Review, there was only limited planning for the development of new renewable energy generation sources between the states and territories. In terms of optimising the national benefit of investment in new renewable generators, the AEMO ISP represents a significant step forward.

Some states such as Victoria[52] and New South Wales[53] have more recently articulated their own REZs and are developing their own generation plans. Other states including Queensland[54] and Victoria[55] have announced plans for public ownership of new renewable generators which may provide greater planning certainty for the development of REZs.

Whether under the stewardship of the national AEMO ISP, or under the aggressive acceleration of renewable energy generation capacity by the individual states and territories, the development of REZs represents a resurgence of *central planning* aimed at improving the effectiveness, economics and efficiency of the energy transition.

B5 - Expert reflection on Vietnamese significance

1. An integrated system plan with priority projects identified is part of PDP8. The priority projects are in specific locations with current or planned grid access. This is the primary means of staging development of power sources. Developers are eager to get projects listed as a way of indicating project feasibility to potential investors. However, the system encourages lack of transparency in the selection of projects as it allows for developers to bargain with officials and against each other for inclusion in the list. It also lacks flexibility in allocating sites to least cost sources. Developers prefer this process as it gives them a degree of certainty within their own project cycle but the social cost is in lack of transparency leading to inefficient selection of projects. A more flexible system with price transparency such as provided by reverse auctions is preferable for these reasons.

2. The creation of Renewable Energy Zones with access to the grid may be a means of gradually changing this process. Creation of REZs, rather than projects, can be used to promote more transparent bidding processes, including reverse auctions for offshore wind.

[52] Victorian Government (2023) Renewable Energy Zones https://www.energy.vic.gov.au/renewable-energy/renewable-energy-zones. Accessed April 2023.
[53] New South Wales Government (2023) Renewable Energy Zones https://www.energyco.nsw.gov.au/renewable-energy-zones. Accessed April 2023.
[54] Queensland Government (2022) Queensland wind farm precinct to dwarf all others https://statements.qld.gov.au/statements/96683. Accessed April 2023.
[55] Victorian Government (2023) State Electricity Commission of Victoria https://www.vic.gov.au/state-electricity-commission-victoria. Accessed April 2023.

Issue 3 - Managing variable renewable electricity generation

B1 - Problem context

As VRE generation approaches or exceeds 50% of the generation in the electricity system, strategies are needed to ensure that supply reliably meets demand given the intrinsic fluctuations in solar and wind output. In Australia in 2021, VRE has exceeded 60% in the NEM and the WEM on occasions[3]. In South Australia which has the highest VRE penetration, in December 2022 there were 10 consecutive days over which the average production of wind and solar accounted for 100 per cent of local demand[56].

Further, traditional thermal and hydroelectric generation provide inbuilt inertia which helps maintain frequency in the system – something that is not inherently a property of solar and wind generation. Additional strategies are needed to ensure frequency and voltage stability in a dominantly renewable electricity system.

B2 - Strategic setting

The responsibility for ensuring system reliability of supply, and stability of frequency and voltage, rests with AEMO. As the energy transition evolves and VRE increases, these issues are progressively addressed as key elements of the Integrated System Plan.

The Renewable Integration Study[57] is a part of the ISP aimed at maintaining system security. In addition to the reliability standard[58] that guarantees supply for 99.998% of the year, the frequency range has to be maintained within the normal operating frequency band from 49.85Hz to 50.15Hz. To achieve this, there are eight Frequency Control and Ancillary Services (FCAS)[59] markets operated by AEMO.

B3 - Solutions

As indicated before, various strategies can be used to address reliability:

- Overbuilding renewable generation capacity
- Electricity storage

[56] Renew Economy (2022) *South Australia's remarkable 100 per cent renewables run extends to over 10 days* https://reneweconomy.com.au/south-australias-remarkable-100-per-cent-renewables-run-extends-to-over-10-days/. Accessed April 2024.
[57] AEMO (2020) Renewable Integration Study (RIS) https://aemo.com.au/energy-systems/major-publications/renewable-integration-study-ris. Accessed April 2023.
[58] AEMC (2023) Reliability https://www.aemc.gov.au/energy-system/electricity/electricity-system/reliability. Accessed April 2023.
[59] AEMO (2023) Ancillary Services https://aemo.com.au/en/energy-systems/electricity/national-electricity-market-nem/system-operations/ancillary-services. Accessed April 2024.

- Demand response
- Load following by other generators including hydro (fast), thermal power stations (slow)
- Expansion of transmission to exploit geographic advantage

Figure 12 | Levelised cost of storage + transmission as a function of VRE penetration

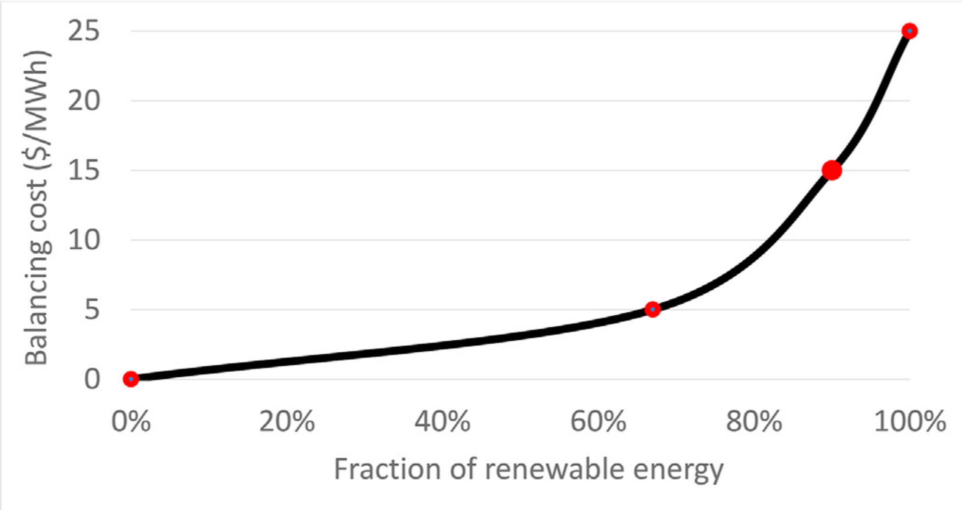


Figure 12 shows ANU calculations[60] for the added LCOE arising from additional storage (mainly pumped hydro), transmission and curtailment of overbuilt supply. These calculations are consistent with the values obtained in the CSIRO/AEMO Gencost study[13] (Figure 4), which show that even with this additional cost of balancing, solar and wind are still the cheapest form of new electricity generation.

To address voltage and frequency stability, a similarly wide-ranging suite of strategies can be employed (see Grids discussion paper):

- Smart inverters that interface solar and wind farms with the AC network provide grid support functions and ride-through capabilities
- Batteries which can respond rapidly on millisecond timescales
- Synchronous condensers, capacitors and other control devices

B4 - Expert reflection on Australian experience

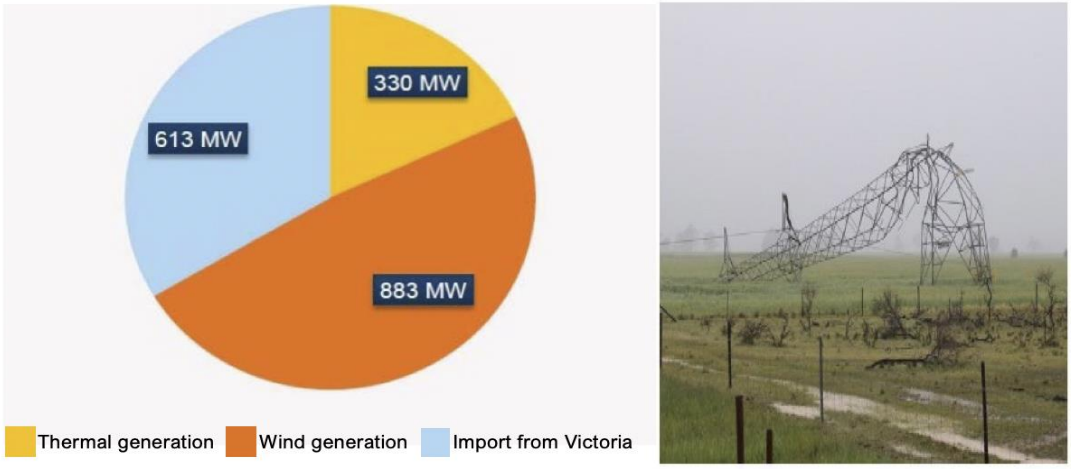
One of the key drivers for the Finkel Review[21] into the Future Security of the National Electricity Market was the blackout of the South Australian electricity system that occurred in 2016. As articulated by the AER:

[60] Blakers A, Stocks M, Lu, B and Cheng C (2021) The observed cost of high penetration solar and wind electricity, Energy, 233, 121150 https://doi.org/10.1016/j.energy.2021.121150.

"It was triggered by severe weather that damaged transmission and distribution assets, which was followed by reduced wind farm output and a loss of synchronism that caused the loss of the Heywood Interconnector. The subsequent imbalance in supply and demand resulted in the remaining electricity generation in SA shutting down. Most supplies were restored in 8 hours, however the wholesale market in SA was suspended for 13 days.[61]"

Figure 13 indicates that around half the generation prior to the blackout was provided by wind farms, with a weak interconnection from Victoria (which was under repair) providing most of the remaining support along with a small amount of thermal generation. Overly sensitive settings on the wind farm inverters took them offline when several transmission lines collapsed.

Figure 13 | Energy generation prior to the South Australian blackout and transmission damage



The following recommendations from the Finkel Review (amongst others) followed as a direct consequence of the blackout:

"A package of Energy Security Obligations should be adopted. By mid-2018 the Australian Energy Market Commission should:

- Require transmission network service providers to provide and maintain a sufficient level of inertia for each region or sub-region, including a portion that could be substituted by fast frequency response services.

- Require new generators to have fast frequency response capability.

[61] AER (2018) *Investigation report into South Australia's 2016 state-wide blackout* https://www.aer.gov.au/wholesale-markets/compliance-reporting/investigation-report-into-south-australias-2016-state-wide-blackout. Accessed April 2023.

- Review and update the connection standards in their entirety:
  - The updated connection standards should address system strength, reactive power and voltage control capabilities, the performance of generators during and subsequent to contingency events, and active power control capabilities.
  - To be approved for connection, new generators must fully disclose any software or physical parameters that could affect security or reliability.
  - Thereafter, a comprehensive review of the connection standards should be undertaken every three years."

One of the responses of the South Australian Government was to immediately purchase the world's largest battery[62] (100 MW) at that time. Since then, the battery has not only supported VRE capacity, but has also provided significant FCAS services.

As a result of the Finkel Review, many recommendations have been implemented which help manage the introduction of VRE generators into the grid, which has continued to operate reliably even in states with high VRE penetration such as South Australia.

B5 - Expert reflection on Vietnamese significance

Vietnam does not currently have regulations or standards for the inclusion of battery energy storage systems (BESS) in a grid connected facility or in the grid itself. For this reason, battery energy storage is not included in near term power sector plans. Several studies have been completed that show the value of BESS in promoting grid stability and offtake from variable sources. The common refrain within MOIT is that BESS is too expensive. Like similar statements regarding renewable energy, cost needs to be interrogated through price discovery mechanisms. BESS is one storage option that could improve integration of renewable energy into the grid. Development of regulations and standards should not be difficult: examples of BESS integration are now global. Vietnam does not represent a case where the economics of battery storage are unique.

Moving forward quickly on regulations and standards related to inclusion of BESS and other forms of electricity storage including pumped hydro will unlock access to renewable energy currently lost to curtailment and increase grid stability as more variable sources are brought online. Australia's Capacity Investment Scheme (CIS) will provide the national framework to

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[62] Hornsdale Power Reserve (2023) Overview https://hornsdalepowerreserve.com.au/. Accessed April 2023.

drive new *dispatchable* renewable capacity. Dispatchable renewable capacity requires developers to install electricity storage – whether BESS, pumped hydro, compressed air or other forms of storage. These kinds of agreements for dispatchable renewable capacity may be a means for Vietnam to integrate solar into grids without overloading systems or forcing curtailment during peak renewable capacity periods. Such a policy can be overlaid on the existing power network without requiring any change in policy for existing electricity markets, in order to seamlessly smooth the energy transition.

Issue 4 - Virtual generation and energy storage

B1 - Problem context

As indicated in Issue 3, one of the crucial tools for balancing VRE is virtual electricity generation (or generation replacement) which comprises three main types:

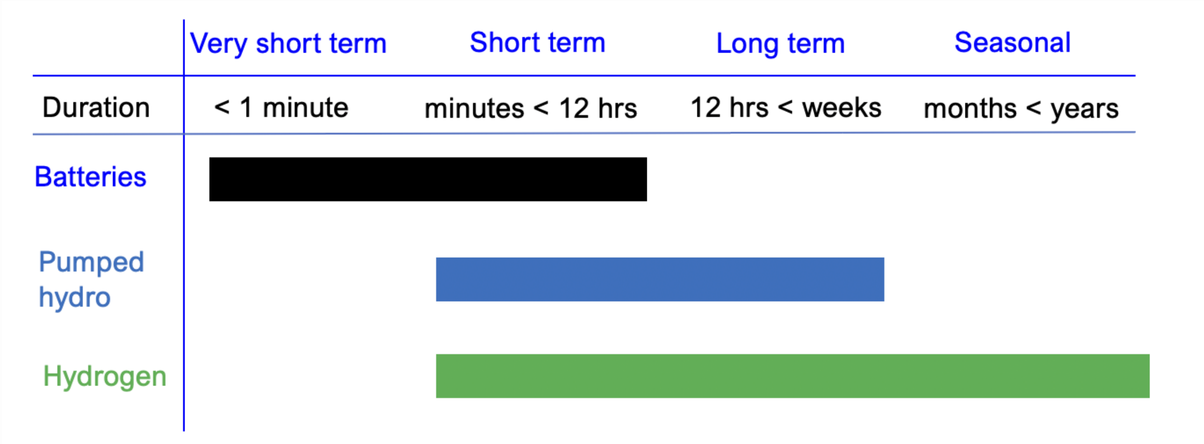
- Electricity storage[63] including utility-scale and behind-the-meter batteries, pumped hydro[11] (both on- and off-river), hydrogen/hydrogen derivatives (e.g. ammonia) and other technologies, all of which require a generator source to energise them, but which can release the stored energy on demand as a virtual generator;
- Demand response to requests for reducing consumption – effectively instantaneous generation replacement. Using sophisticated software that connects load sources within the customer's network to a communication link with the retailer, network service provider or market operator, loads can be switched on and off over timescales as short as fractions of a second following requests by the retailer. These requests can either be accepted automatically by prior arrangement, or by a decision-making algorithm based on the customer's needs and in response to price signals e.g. time-of-use electricity tariffs. Further, export of electricity from behind-the-meter rooftop solar generation or from household batteries (including electric vehicle batteries) can be controlled in a similar fashion, driven by the economics of balancing energy export with self-consumption (see a commercial example: Reposit[64]).
- Energy efficiency, which similarly can reduce demand, although not instantaneously. Energy efficiency will not

[63] Koohi-Fayegh S and Rosen MA (2019) A review of energy storage types, applications and recent developments, *Journal of Energy storage*, 27, 101047 https://doi.org/10.1016/j.est.2019.101047.
[64] Reposit (2023) Guaranteed $0 Electricity Bills https://repositpower.com/. Accessed April 2023.

be addressed here as it is not a flexible virtual generator, but can effectively replace what has traditionally been called 'baseload generation' (see Demand and Consumption discussion paper).

The ability to deliver or replace energy generation when required over timescales ranging from seconds to months is an essential feature of a dominantly renewable energy generating system. Figure 14 shows the key timeframes and the applicability of the three main types of energy storage: batteries, pumped hydro and hydrogen. Pumped hydro has the potential to be used seasonally[65], but only when energy and water storage are guaranteed to be complementary and/or when there is continual availability of excess electricity for pumping.

Figure 14 | Timescales for the three main types of energy storage



The remainder of the discussion will consider energy storage only (since energy efficiency and demand response are covered under Theme 5, Demand and Consumption), although similar considerations over mainly short time-scales (<12 hours) also apply to demand response.

B2 - Strategic setting

As countries plan for zero-emissions future electricity systems, comprehensive analysis of the energy balancing requirements is needed to address potential energy shortfalls over all timescales. Such analysis underpins the AEMO ISP discussed above, where the geographic location of energy storage systems is planned to complement both local generation e.g. in renewable energy zones, and local loads e.g. neighbourhood or utility-scale batteries.

An example of seasonal energy balancing requirements is shown in Fig. B12 from the Council of European Energy

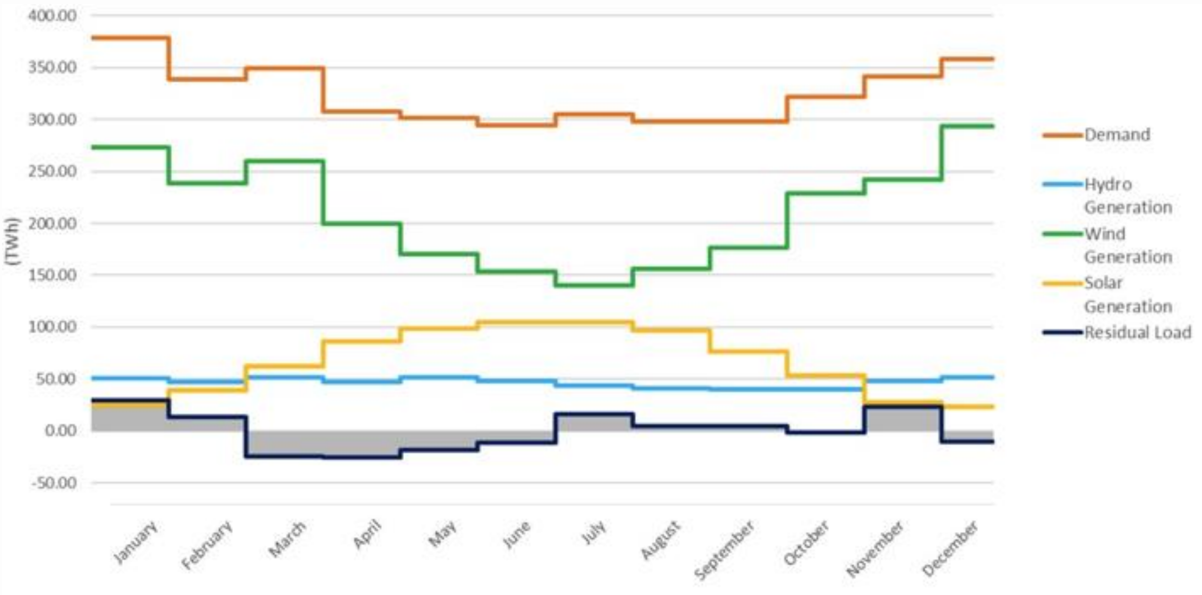
[65] Hunt JD, Byers E, Wada Y, Parkinson S, Gernaat DEHJ, Langan S, van Vuuren DP and Riahi K (2020) Global resource potential of seasonal pumped hydropower storage for energy and water storage https://doi.org/10.1038/s41467-020-14555-y.

Regulators 100% Renewable Energy Systems 2040 scenario[66]. As shown in the figure, supply from solar, wind and hydro is unable to meet demand at all times of the year, particularly in the winter months (November – February) with a predicted seasonal shortfall of 75 – 94 TWh (~3% of annual energy generation). To address this seasonal energy shortfall, the report concludes:

"It might then be cheaper and thus more efficient to store in the long-term green gases to use in the wintertime instead of pure natural gas".

Green gases refers to net-zero hydrogen e.g. as made using renewable electricity and electrolysis, or biogas which can be net-carbon neutral over a usage cycle.

Figure 15 | Council of European Energy Regulators 100% Renewable Energy Systems 2040 scenario showing residual loads arising from seasonal generation shortfall of renewables



B3 - Solutions

The main form of energy storage for electricity generation worldwide is provided by pumped hydro which constitutes 95% of global electrical storage power and 99% of global storage electrical energy[11]. Batteries[67] are the next largest contributor with rapidly increasing deployment, and have the advantage of being rapidly scalable. Hydrogen[68] has the potential to contribute to seasonal storage in the future but currently is only

[66] Council of European Energy Regulators (2021) *CEER White Paper on Long-Term Storage* https://www.ceer.eu/list-of-publications#. Accessed April 2023.
[67] IEA (2020) Batteries and hydrogen technology: keys for a clean energy future https://www.iea.org/articles/batteries-and-hydrogen-technology-keys-for-a-clean-energy-future. Accessed April 2023.
[68] National Renewable Energy Laboratory (NREL) (2020) Answer to Energy Storage Problem Could Be Hydrogen https://www.nrel.gov/news/program/2020/answer-to-energy-storage-problem-could-be-hydrogen.html. Access April 2023.

present at pilot demonstration level. Other forms of storage[69] such as compressed air, flywheels, and gravity storage are possible, but very rarely contribute to current electricity systems. Note that heat storage will also be an important source of energy storage for decarbonisation across the economy, but is limited to heating and cooling applications as thermodynamic considerations mean that it is inefficient to re-convert heat into electricity.

B4 - Expert reflection on Australian experience

Especially because Australia is an isolated island nation, it has to rely on virtual generators to balance VRE because it cannot import electricity from neighbouring countries.

Note, however, that unlike many other countries, seasonal storage is *not* needed in Australia because wind and solar often offer complementary daily and seasonal profiles. Furthermore, Australia's vast and cheap wind and solar resources – combined with the option of traditional seasonal hydroelectricity generation – means that it is more cost-effective to "overbuild" renewables, and invest in more storage and transmission, in order to provide system reliability as VRE approaches 100%. As stated in the 2022 AEMO ISP[16]:

"building enough VRE to meet the energy needs of winter is likely to be more efficient, on estimated technology costs, than building less VRE but more seasonal storage.[16]"
That isn't to say that seasonal storage is not required in some other countries, whose seasonal variability is such that there is insufficient renewables to balance the demand profile at different times of year e.g. between the wet season and the dry season.

The status of major existing and planned energy storage projects in Australia that can be used to address VRE balancing on shorter than seasonal timescales is shown in the table below.

Table 1 | The status of major existing and planned energy storage projects in Australia.

Location	Technology	Power GW	Energy GWh	Comments
Tumut 3[14]	Pumped hydro	1.8	60	Existing
Bendeela[70]	Pumped hydro	0.2	<1	Existing

[69] IEA (2022) Energy Storage https://www.iea.org/fuels-and-technologies/energy-storage. Accessed April 2023.
[70] Origin (2023) Shoalhaven proposed expansion https://www.originenergy.com.au/about/who-we-are/what-we-do/generation/shoalhaven-proposed-expansion/ Accessed April 2023.

Wivenhoe[71]	Pumped hydro	0.6	6	Existing
Snowy 2.0[72]	Pumped hydro	2.0	350	Under construction
Kidston[73]	Pumped hydro	0.3	2	Under construction
Battery of the Nation[74], **Tasmania**	Pumped hydro	0.6-2.5	6-25	Detailed planning
Utility[75] **combined**	Batteries	2.0	2	Existing
Household[76] **combined**	Batteries	-	1	Existing
EV combined	Batteries	-	1	Existing

As can be seen, pumped hydro is the dominant form of existing energy storage being used in Australia, and construction of Snowy 2.0 is already underway to expand this by connecting two existing reservoirs in the Snowy Mountains hydroelectricity scheme. Although batteries provide only a small fraction of energy storage presently, the 2022 AEMO ISP states that:

"dispatchable batteries, pumped hydro or alternative storage … manage daily and seasonal variations in the output from fast-growing solar and wind generation. By 2050, the ISP modelling recognises that VPPs, vehicle-to-grid (V2G) services and other emerging technologies will provide approximately 31 GW of dispatchable storage capacity, and utility-scale battery and pumped hydro storage 16 GW.[16]*"*

By comparison, PDP8 estimates that 30.65-45.55 GW of pumped hydro storage and utility scale batteries will be required, with no mention of the role of virtual power plants (VPPs), V2G or other emerging technologies.

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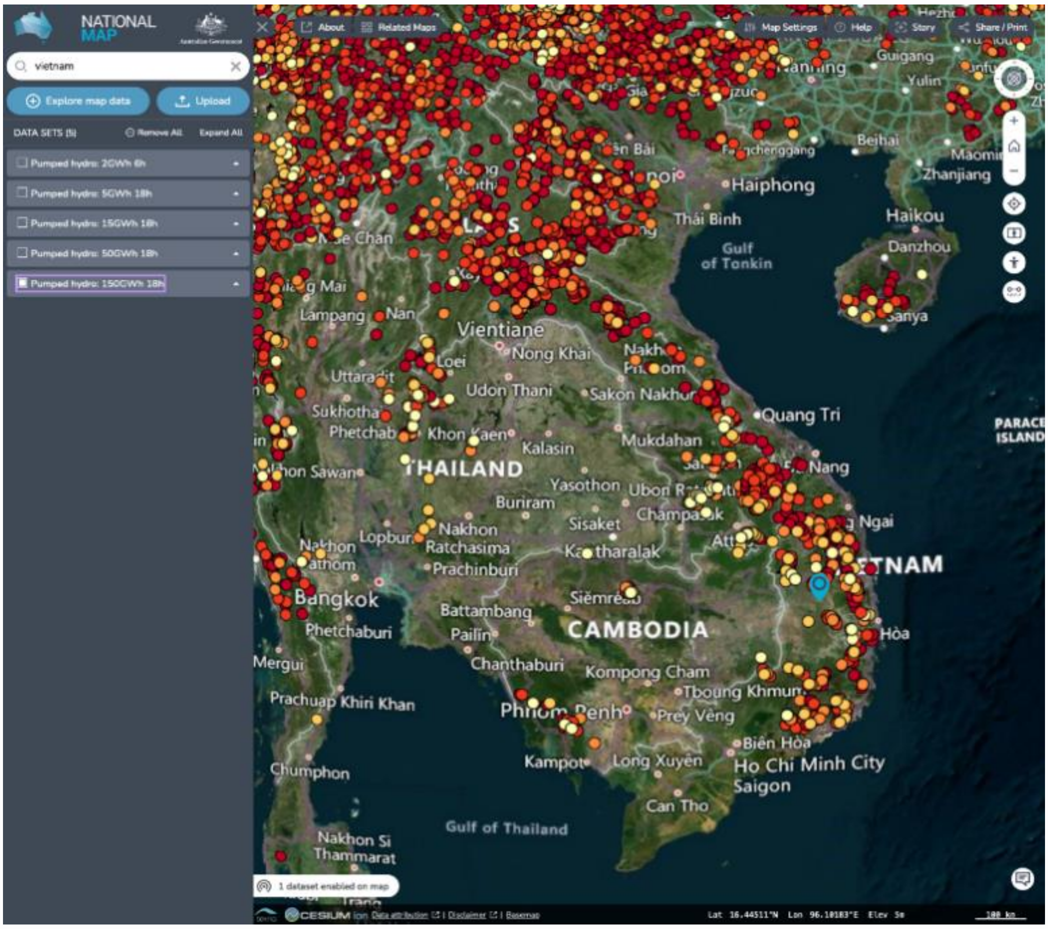
[71] Cleanco Queensland (2023) Major overhaul to keep Wivenhoe pumping https://www.cleancoqld.com.au/major-overhaul-to-keep-wivenhoe-pumping/. Accessed April 2023.
[72] Snowy Hydro (2023) Snowy 2.0 https://www.snowyhydro.com.au/snowy-20/about/. Accessed April 2023.
[73] Genex (2023) 250MW Kidston Pumped Storage Hydro Project https://genexpower.com.au/250mw-kidston-pumped-storage-hydro-project/. Accessed April 2023.
[74] Tasmanian Government (2023) Battery of the Nation https://www.stategrowth.tas.gov.au/recfit/major_investment_projects/battery_of_the_nation. Accessed April 2023.
[75] Clean Energy Council (CEC) (2020) Investors Backing Big Batteries https://www.cleanenergycouncil.org.au/news/investors-backing-big-batteries. Accessed April 2023.
[76] CEC (2023) Energy storage https://www.cleanenergycouncil.org.au/resources/technologies/energy-storage. Accessed April 2023.

B5 - Expert reflection on Vietnamese significance

The 100% Renewable Energy group[77] at the Australian National University has created a pumped hydro atlas of the world that includes all prospective sites for off-river, pumped hydro development outside those locations that are unavailable due to national parks, agricultural production, urban areas and other land use constraints.

An example is shown in Figure 16 for the ASEAN region, which indicates the many sites available for pumped hydro storage exceeding 150 GWh and 18 hours of storage at that power rating[78]. As is typical of many countries in the region, Vietnam's off-river, pumped hydro storage capability greatly exceeds that required to support a 100% renewable energy electricity sector[79].

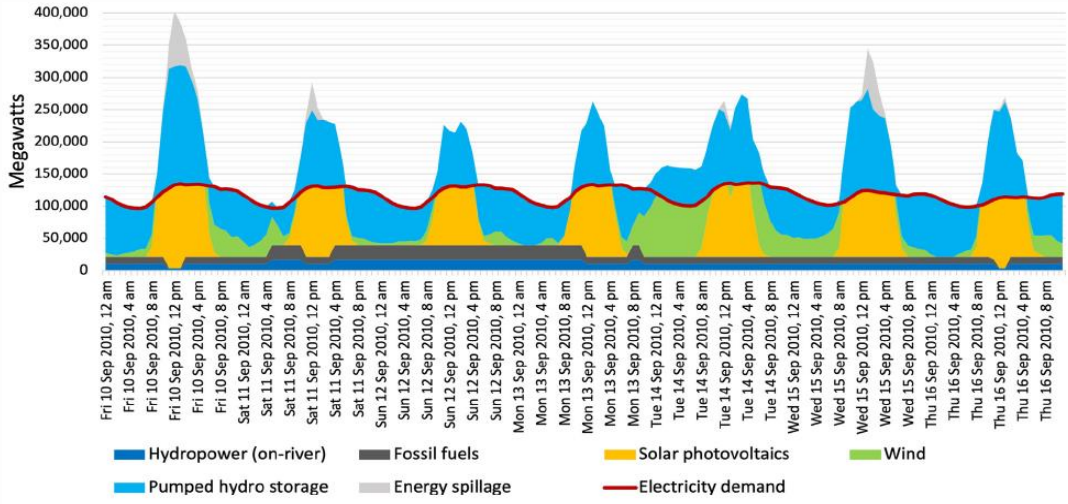
Figure 16 | ANU atlas of off-river pumped hydro sites exceeding 150 GWh and 18 hours of storage in the ASEAN region[77].



[77] ANU (2023) 100% Renewable Energy Group https://re100.eng.anu.edu.au/. Accessed April 2023.
[78] https://www.nationalmap.gov.au/#share=s-py9ofDCNEwqsrfGGkptS5dJ9wSq. Accessed April 2023.
[79] Stocks M, Stocks R, Lu B, Cheng C and Blakers A (2020) Global Atlas of Closed-Loop Pumped Hydro Energy Storage, *Joule*, https://doi.org/10.1016/j.joule.2020.11.015.

In a related ANU study[80], the potential significance of pumped hydro storage in Vietnam is illustrated in the predicted scenario shown in Figure 17, which is a snapshot of daily energy consumption patterns matched by largely renewable generation supported by pumped hydro storage (light blue). By capturing excess generation (mainly from solar) in the middle of the day, pumped hydro storage can help satisfy demand at other times when solar is not available.

Figure 17 | Diurnal electricity demand and generation in a high electricity consumption scenario for a "stressful" week with low availability of renewable energy supply in Vietnam[79].



In relation to other storage issues in Vietnam:

1. Lithium battery storage, Vanadium Redox Flow Batteries, flywheels, hydrogen storage, pumped hydropower, and compressed air are all included in the current technology catalogue prepared by EREA. The catalogue provides input to power system modelling.

2. Discussions in Vietnam have focused on the use of current hydropower dams for pumped storage. In this context, some offshore wind developers have proposed pumping at night, when demand is low, for use during the day, when hydropower is generally the lowest cost source. The limitations to this option are environmental. In central Vietnam, where seasonal rainfall patterns tend to be more extreme, many rivers run very low during dry seasons as upstream hydropower dam operators conserve as much water as possible for power generation. Climate change projections for central Vietnam, where many hydropower plants are located,

[80] Lu B, Blakers A, Stocks M and Do TN (2021) Low-cost, low-emission 100% renewable electricity in Southeast Asia supported by pumped hydro storage, *Energy*, 236, 121387 https://doi.org/10.1016/j.energy.2021.121387

suggest more pronounced seasonality and less rain. These conditions would also apply to off-river pumped storage, but to a significantly lesser extent because it is a closed system. Given Vietnam's significant potential pumped hydro resources, greater consideration could be given to off-river, pumped hydro storage to complement BESS for longer storage durations (>12 hours).

3. Further, given the increased seasonal variability for conventional hydro-electricity arising from climate change, hydrogen as a solution to *seasonal* energy storage (on timeframes of many months) should also be considered.

Issue 5 - Electricity trade

B1 - Problem context

Electricity trade between jurisdictions can assist with balancing electricity generation and demand, enabling investment savings through the use of shared infrastructure and complementary generation. The geographic advantage for renewable generation can be exploited in various ways:

- Transit of the sun from east to west can be used to provide time-shifted generation for load centres at different longitudes
- Changing cloud patterns can be mitigated by exploiting solar generation in lower-cloud regions
- Shifting wind patterns can be used to exploit temporal wind availability.

In addition, energy storage facilities can be located optimally near generators or load centres, and pumped hydro that uses existing large reservoirs can be used effectively as a large battery to support other geographic regions e.g., Tasmania's "battery of the nation" project.

B2 - Strategic setting

An example of such a potential regional electricity trading network is shown in Figure 18 which indicates a possible configuration[79] for a high voltage, direct current (HVDC) transmission backbone for southeast Asia, with projected links to Australia, India and China.

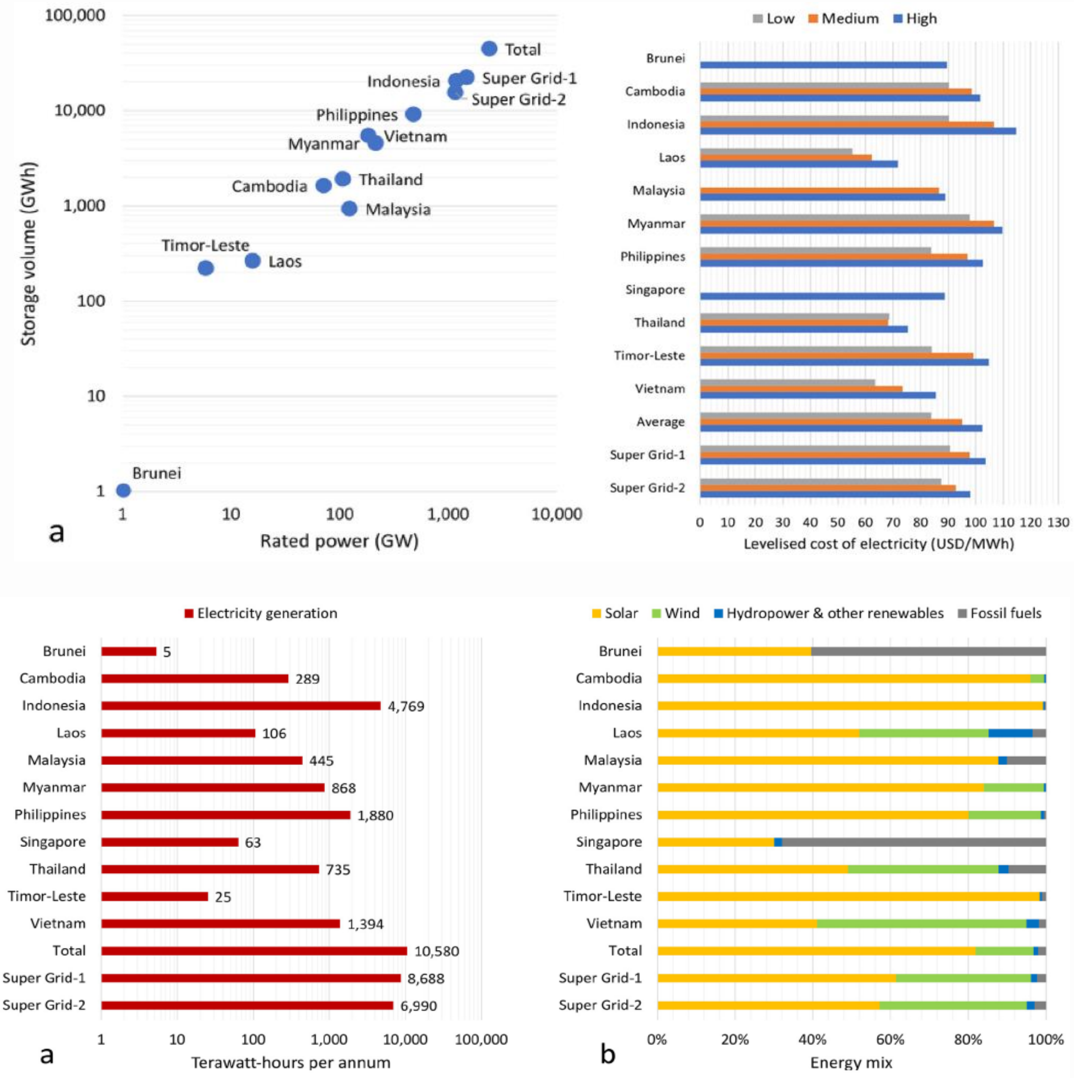
Figure 18 | One possible configuration79[79] for a southeast Asia HVDC Super Grid

This configuration has been examined by researchers at ANU to establish the potential investment savings for generation and storage infrastructure, which more than compensate for the additional HVDC transmission investment required to exploit geographic advantage.

B3 - Solutions

The results of this study are shown in Figure 19 below. The individual generation characteristics for each country are shown, together with their average/total, plus the total using the Super Grid scenario for (1) SE Asia only, and (2) additional links (arrows in map).

Figure 19 | (clockwise, bottom left) Results for electricity generation, storage and LCOE, and changes in the generation mix (all except LCOE use the high electricity consumption scenario[79]



In all cases, the advantages of sharing generation and storage using either of the Super Grid options is apparent. In the high electricity consumption scenario, less storage investment is required, the LCOE is similar (Super Grid 1) or reduced (Super Grid 2) despite the vast increase in transmission costs, while the total electrical energy generation required is less – resulting in substantial economic savings.

As can be seen from the energy mix graph, the Super Grid scenarios move from a strong reliance on domestic solar when each country is considered individually, to a greater proportion of wind when using shared resources. Much of the wind generation comes from Vietnam[81], with other contributions from Laos and Thailand. This aligns with the aim to develop offshore

[81] For more on the prospects of offshore wind in Vietnam, see Do TN, Burke PJ, Hughes L and Thi TD (2022) Policy options for offshore wind power in Vietnam, *Marine Policy*, 141, 105080 https://doi.org/10.1016/j.marpol.2022.105080

wind in PDP8, although the ambition by 2030 is relatively small, with only 5-10 GW capacity anticipated for electricity export, and 5-8 GW for imports (from Laos).

In relation to the land area required for these studies, the paper notes:

"there is large potential for floating solar photovoltaics to be deployed in inland reservoirs and the territorial waters, and "Agrivoltaics" … allows co-location of large amounts of solar photovoltaics with agriculture. In comparison, the land spanned by wind turbines is large in Vietnam and the Philippines, especially in the high electricity consumption scenario, although the area actually alienated for towers and access roads is only a small fraction. The development of offshore wind provides access to a much larger wind resource."

B4 - Expert reflection on Australian experience

Although Australia is unable to trade with neighbouring countries, the states and territories in the NEM effectively form an electricity trading network with time-varying regional spot market pricing[82] (see Markets discussion paper). Constraints on electricity trading between States – such as were experienced in the South Australian blackout mentioned in Issue 3 – can have catastrophic effects when other sources of generation are suddenly removed, in that case as the result of an extreme weather event.

Under the AEMO ISP, the connecting high voltage transmission linkages will be strengthened, with the result that greater sharing of VRE will be possible. It will be particularly important to augment the present weak interconnection between South Australia and the NEM given the significant solar and wind resources in that State, which currently has the highest percentage of renewable energy generation. The addition of significant storage through Snowy 2.0[71] and the Tasmanian 'Battery of the Nation[73] will further augment the capacity to support growing levels of VRE.

Australia is already a major energy export powerhouse for fossil fuels. Its energy production is more than three times the country's total energy supply[1], with exports of fossil fuels dominated by coal and natural gas. However, Australia has a significant opportunity to transition to renewable energy exports by harnessing its vast solar and wind resources. At the ANU, the Grand Challenge program *Zero-Carbon Energy for the Asia-*

[82] AEMO (2023) Dispatch overview https://aemo.com.au/en/energy-systems/electricity/national-electricity-market-nem/data-nem/data-dashboard-nem. Accessed April 2023.

Pacific[83] has investigated the prospects for renewable exports of:

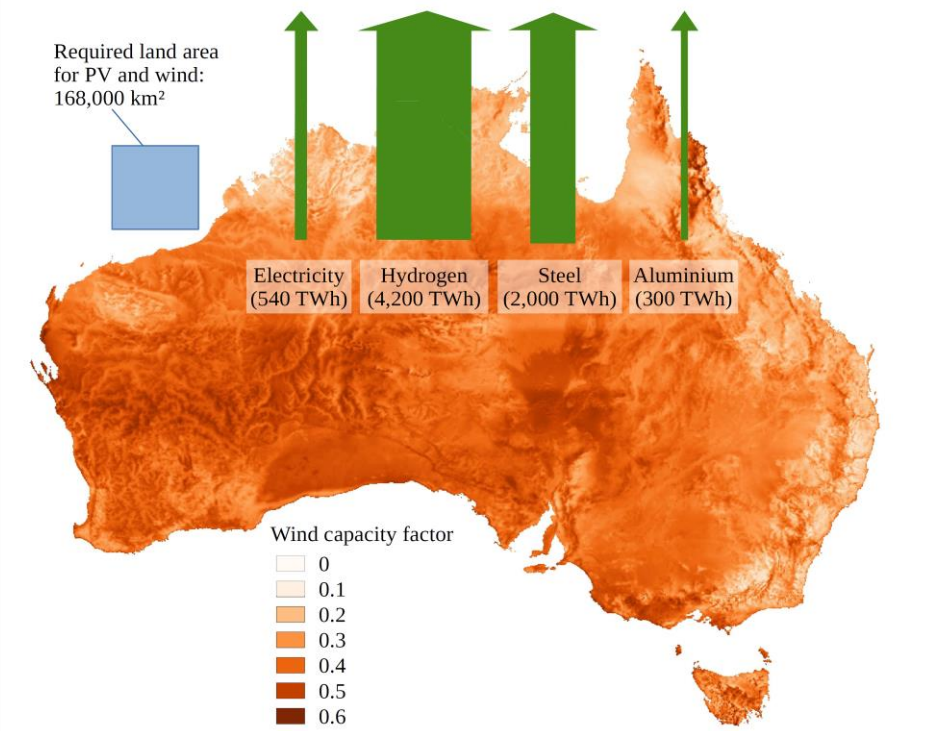
- Electricity through HVDC undersea cables, such as proposed by Sun Cable[84]
- Hydrogen and hydrogen derivatives such as ammonia, as proposed e.g. by the Australian Renewable Energy Hub[85], amongst many other proposed export facilities
- Manufactured products such as green steel (made with green hydrogen and renewable electricity), as is being studied in the Heavy Industry Low-carbon Transition (HILT) Cooperative Research Centre[86].

The ANU Grand Challenge project has calculated the potential to export all three renewable energy products (Figure 20)[87] using two business-as-usual assumptions:

1. Australia continues to export the same amount of energy (in joules) as presently, with 20% being exported as renewable electricity, and 80% as green hydrogen.
2. Australia continues to mine the same amount of iron ore and aluminium ore as presently but converts it into green steel and green aluminium exports using green hydrogen and renewable electricity.

[83] ANU (2023) Zero-Carbon Energy for the Asia-Pacific initiative (ZCEAP) https://iceds.anu.edu.au/research/research-initiatives/zero-carbon-energy-asia-pacific-initiative-zceap. Accessed April 2023.
[84] Sun Cable (2023) https://suncable.energy/. Accessed April 2023.
[85] BP Australia (2023) Renewable Energy Hub in Australia https://www.bp.com/en_au/australia/home/who-we-are/reimagining-energy/decarbonizing-australias-energy-system/renewable-energy-hub-in-australia.html. Accessed April 2023.
[86] HILTCRC (2023) De-Risking Decarbonisation for Heavy Industry https://hiltcrc.com.au/. Accessed April 2023.
[87] Burke PJ, Beck FJ, Aisbett FJ, Baldwin KGH, Stocks M, Pye J, Venkataraman M, Hunt J and Bai X (2022) Contributing to regional decarbonization: Australia's potential to supply zero-carbon commodities to the Asia-Pacific, *Energy*, 248, 123563 https://doi.org/10.1016/j.energy.2022.123563.

Figure 20 | Wind capacity factor map of Australia, with the renewable electricity requirements for the renewable-energy based exports shown using the two business-as-usual assumptions



The figure above shows the amount of green electrical energy per annum (TWh) required for each export using these two assumptions, and which total over 7,000 TWh of electrical generation each year. This is ~27 times the current total electrical energy generation from all sources in Australia (266 TWh p.a.). The land area required (assuming 50% solar and 50% wind) is also shown and represents ~2% of the continental land area – or slightly more than the land area devoted to forestry.

These very large numbers underline both the challenges and the opportunities for renewable energy export trade with southeast Asia.

B5 - Expert reflection on Vietnamese significance

Regional grid integration has been a topic of discussion for more than 20 years. The primary barrier is grid stability. As a result, power imported to Vietnam has tended to come from discrete sources through direct wire. There have also been security concerns related to the integration of the power dispatch system. These will eventually be resolved as regional systems integration plays a greater role in load sharing. Vietnam already has a load sharing agreement with Cambodia and purchases power from Laos and China. The latter has been a crucial source of power to compensate for coal thermal generators who could not meet their commitments under the strain of recent high prices of coal. PDP8 also recognises the significance of regional electricity trade, but the ambition for 2030 is relatively small, and does not consider the opportunity for off-river pumped hydro storage to complement electricity generation across borders. More research into the benefits of regional electricity trade (such as outlined in the recently published policy brief referenced here[88]) could reveal opportunities for even higher ambition.

[88] Do TN, Burke PJ and Lu B (2023) Harnessing solar and wind for sustainable cross-border electricity trade in the Greater Mekong Subregion, *Frontiers in Environmental Science*, 11, 1188335, https://doi.org/10.3389/fenvs.2023.1188335.

FE–V

Future of Electricity
Vietnam

A science – to – policy initiative of the Australian Embassy in Hanoi, in consultation with the Central Economic Commission of the Communist Party of Vietnam

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