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Renewable electricity policy for Australia

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Abstract

Australia has one of the highest per capita emissions of greenhouse gases in the world. If Australia is to stay within its share of the remaining, diminishing, global carbon budget for stabilising Earth's temperature increase at 2°C or less, a necessary (but not sufficient) requirement is to transition its electricity system rapidly to 100% renewables by 2030 or soon afterwards. A future ecologically sustainable energy system will be mostly electrical, with most heat and transport being provided by electricity instead of liquid and gaseous fossil fuels. Although a carbon price is rejected by both major political parties at present, several simple and affordable policies, to be implemented by a future federal government and existing state governments, could assist the market to accelerate the renewable electricity transition. These policies include incentives for dispatchable renewables and other forms of storage, funding for a few key transmission links and an industry-funded incentive for the retirement of the most polluting coal-fired power stations. When the point is reached where variable renewables begin to contribute the majority of electricity generation in Australia, additional policies will be needed to overcome more complex barriers involving electricity market design, education and training of professionals and tradespeople, and industry policy.

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1. Introduction

A substantial majority of Australians is concerned about climate change (73%) and agrees that the Government needs to implement a plan to ensure the orderly closure of old coal plants and their replacement with clean energy (70%) within the next 20 years (67%).[1] Furthermore, an overwhelming majority (84%) of Australians support the statement that "the government should focus on renewables, even if this means we may need to invest more in infrastructure to make the system more reliable".[2]

Yet the Liberal National Coalition (LNC) Federal Government continues to promote coal, has a very weak greenhouse gas target (26-28% reduction) for 2030, has discarded its very weak renewable energy target (26% of electricity) for 2030, has no policies capable of driving a transition to a predominantly renewable energy future and still has legislation, stalled in the Senate, to undermine existing policies, namely to close the Australian Renewable Energy Agency (ARENA) and the Clean Energy Finance Corporation (CEFC).

The Australian Labor Party (ALP) Federal Opposition has an easily achievable renewable electricity[3] target for 2030 (50% of electricity), several worthwhile minor policies supporting renewable energy, but no support for its target from Renewable Energy Certificates between 2020 and 2030, and no other policy capable of driving its target or a stronger one. The main policies of the two major parties and the Australian Greens are summarized with comments in Table 1.

Since neither major party is implementing the will of the people, energy policy is one more failure of nominally democratic government. Vested interests appear to be determining policy, particularly in the federal sphere. To make matters worse, the Federal Government – backed up by vested interests, a large fraction of the mainstream media and a few proponents of nuclear energy – is disseminating false and misleading statements about the reliability needs of a large-scale electricity system and the alleged technical limitations and costs of renewable electricity. The

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[1] Ebony Bennett 2018. *Climate of the Nation 2018. Tracking Australia's attitudes towards climate change and energy*. Canberra: The Australia Institute. http://www.tai.org.au/sites/default/files/180911%20-%20Climate%20of%20the%20Nation%202018%20%5BPRINT%5D.pdf

[2] 2018 Lowy Institute Poll, https://www.lowyinstitute.org/publications/2018-lowy-institute-poll/.

[3] 'Renewable electricity' is electricity generated from renewable sources.

most common myths are listed in Table 2. They have been refuted in detail elsewhere.[4,5,6]

This Discussion Paper proposes simple, affordable, federal and state government policies to drive the transformation of the large-scale electricity supply system from one that's dominated by fossil fuels to one based on, and dominated by, clean, safe, everlasting, renewable energy.

Electricity is the focus of this paper, because it's the easiest form of energy supply to transition and so almost all energy in a future ecological sustainable energy system will be used directly as renewable electricity. The main exceptions are air and sea transport, and long-distance rural road transport in remote areas. These will require renewable liquid and/or gaseous fuels, such as hydrogen and ammonia, which could be produced in future by using renewable electricity, and biofuels. Policies for energy efficiency, which is equally important to renewable energy, deserve a separate article.

This paper argues that, given the political will, Australia could and should transition quite rapidly to a reliable 100% renewable electricity system and hence a predominantly renewable energy future. Indeed, climate science demands a rapid transition (Section 2). Although barriers exist, they are not primarily technological or economic, but rather are political and institutional. To overcome these barriers, we need a portfolio of policies in the federal and state spheres of government. We could make the transition without a carbon price, although its presence would assist greatly (see Section 4). Furthermore, we don't need the lapsed National Energy Guarantee (NEG), which would likely be counter-productive if designed by fossil fuel proponents.[7]

The suggested policies fall into two sets. The first set, discussed in Section 5, is simple and affordable. It could and should be implemented immediately. The second set, discussed in Section 6, is inexpensive but complex, because it requires major institutional changes, and so may need several years to be implemented. Given the policies proposed in this article, the modified market will do the rest. But without

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[4] Giles Parkinson 2018. The fake arguments against 100% renewable energy. *RenewEconomy* 19 June. https://reneweconomy.com.au/the-fake-arguments-against-100-renewable-energy-65406/.

[5] Mark Diesendorf & Ben Elliston 2018. The feasibility of 100% renewable electricity systems: a response to critics. *Renewable & Sustainable Energy Reviews* 93:318-330. https://www.sciencedirect.com/science/article/pii/S1364032118303897/.

[6] Simon Holmes à Court 2018. NEG promises death of wind and solar, and even battery storage. RenewEconomy, 6 August, https://reneweconomy.com.au/neg-promises-death-of-wind-and-solar-and-even-battery-storage-83047/.

[7] Simon Holmes à Court 2018, *ibid*.

these policies, renewable electricity growth will slow and could stall far short of 100%, despite its increasingly favourable economics.

Before discussing the proposed policies, this article draws upon recent climate science to justify the need for a *rapid* transition to 100% renewable electricity (Section 2) and then argues (Section 3) that there are no longer any major technical or economic barriers.

Table 1: Principal climate & renewable electricity policies of Federal LNC, ALP and Australian Greens

Policy	Comment
Liberal–National Coalition	
Emissions reduction target of 26 to 28% below 2005 levels by 2030	This weak target could possibly be reached without any new specific policies
Former renewable electricity target 26% of electricity by 2030, discarded in 2018	Target appears to have lapsed with cancellation of NEG in 2018. Target will probably be reached without federal policies, based on current trend.
Snowy 2.0	A big pumped hydro project. If commissioned around 2024-2025, will initially increase the use of coal power (for pumping); in the longer term could help smooth the variability of wind and solar PV in NSW and Vic.
Former National Energy Guarantee (NEG)	Its cancellation removed a potential barrier to renewable electricity.
Emissions Reduction Fund (ERF)	A 'pay-the-polluter' scheme with very limited funding and limited scope -- excludes renewable electricity apart from landfill gas.
Legislation to close ARENA and CEFC	Still before the Senate
Australian Labor Party	
Target: zero net greenhouse gas emissions by 2050	Aspirational target with no policies to achieve it
Renewable electricity target: 50% of electricity by 2030	No certificates or other specific policies to achieve it. Nevertheless, it may be achieved by State policies and household solar purchases
'Greater certainty & flexibility for CEFC': i.e. making it 'technology neutral'	'Technology neutral' would be a backward step, if it doesn't exclude coal with carbon capture & storage and fossil fuels generally. A specific tranche for dispatchable renewables & storage is needed.
More funding for ARENA grants: specific additional $207M over 4 years for CST	Increasing ARENA's budget is a positive step, but the additional specific funding is required for dispatchable renewables & storage, not limited to CST.
Community Power Network: $99M over 4 years	Good
Review NEM and amend National Electricity Objective to include reducing carbon pollution	Good, but substantial changes to NEM rules are also needed.
Implement a baseline-and-credit emissions trading scheme	It's unclear if this policy is still current. Anyway, it should be discarded as ineffective window-dressing.
Greens	
Net zero or net negative Australian greenhouse gas emissions by no later than 2040	A challenging target that's achievable, given the political will, and may be consistent with Australia's share of the global carbon budget for 2°C.
Binding national emission limits for each year to 2050	Implies a regulatory approach, which could be difficult to implement.
Renewable energy target 100% of electricity ASAP, by increasing RET and other policies	Excellent aspiration, but needs a target year. It's unclear whether RET will still have certificates.
A ban on new coal-fired power stations, gas mines or oil wells, and no expansions thereof	Good, but it's unclear whether a federal government has power to make such bans.
Pricing electricity and fossil fuels to reflect their true cost, including externalities	Excellent policy which includes a carbon price. Needs more detail. Should be linked explicitly to social equity measures.
Many other policies or aspirations	These are very general, which may be unavoidable for a party that is unlikely to win government in its own right

Note: A 'dispatchable' power station is one that can generate power upon demand at short notice (see Footnote 11.)

Table 2: The principal false myths about renewable electricity

Myth	Refutation based on science & engineering
Base-load power stations are necessary for large-scale electricity supply systems	Refuted by (i) computer simulation modelling; (ii) practical experience when 100% renewable electricity is already being reached for short periods of time in Denmark, Germany & South Australia; (iii) the inflexibility in operation of base-load power stations, which makes them poor partners for large amounts of variable renewables.
Base-load power stations must run continuously to back-up variable renewables	Refuted by practical experience (e.g. in South Australia) and computer simulation modelling. Base-load power stations are unnecessary in a system where variable renewables are supplemented with dispatchable renewables, other storage and strengthened grid interconnections.
All power stations in a large-scale electricity supply system must be dispatchable	Refuted by computer simulation modelling and extensive practical experience. Only a modest amount of dispatchable power is required and this can be renewable – e.g. hydro, OCGTs with renewable fuels, CST with thermal storage.
A 100% renewable electricity system based on predominantly variable renewables needs vast amounts of storage	Computer simulation modelling for Australia shows that the vast majority of generation can be provided by variable renewables with a relatively small amount of dispatchable renewables and/or other forms of storage.
The subsidy to variable renewables increases the price of electricity substantially	The subsidy is the cost of Renewable Energy Certificates (RECs) which adds about 7% to the retail price of electricity. This will shrink from 2020, when the Renewable Energy Target is reached. However, the cost of RECs is partially offset by the reduction in wholesale price of electricity due to increasing generation by large-scale renewables. This reduction will increase over time (see Section 6.1).

Sources: Refutations are based on the Australian peer-reviewed studies by Elliston et al. (2016), Blakers et al. (2017) *ibid*. and Diesendorf & Elliston (2018), as well other Australian and overseas studies cited in the latter paper.

Notes: OCGT is open cycle gas turbine; CST is concentrated solar thermal; 'renewable electricity' is electricity from renewable sources; 'renewable fuel' is fuel produced by using renewable energy; 'variable renewables' include wind and solar PV.

2. Australia's carbon budget

The Paris Agreement, reached at the 2015 meeting of the United Nations Framework Convention on Climate Change, represents a concerted global effort to keep global temperature increase to less than 2°C above pre-industrial levels and to strongly pursue efforts to limit the temperature increase even further to a maximum of 1.5°C. To achieve these limits, most fossil fuels will have to be left in the ground, as there is only a limited remaining global carbon emissions budget.

A recent study by a UNSW Sydney[8] research group assumed generously that Australia's 'fair share' of the global climate budget is 1% and then noted that electricity generates one-third of Australia's emissions. Then Australian electricity industry's share of the global carbon budget post-2011 becomes 1.3 gigatonnes (Gt) for the 1.5°C budget, 3.3 Gt for the 2°C budget and 7.9 Gt for a 3°C budget. For comparison, Australia's total annual emissions in 2017 were 0.556 Gt or 556 megatonnes (Mt) of CO_2 equivalent, of which about 185 Mt were produced by electricity generation. Then the group calculated the cumulative carbon emissions of 22 scenarios for transitioning electricity to predominantly renewable energy. Thus, assuming annual emissions are constant, we have only about seven years left to reach our share of the global electricity target for the 1.5°C limit and 19 years for the 2°C limit.[7]

The calculations took account of the life-cycle emissions (including mining the raw materials and constructing the renewable energy technologies) and the reduction in these life-cycle emissions by renewable energy 'breeding', that is, as time evolves, renewable electricity technologies will be made increasingly by using renewable electricity. Even the scenario with the most rapid transition – to 98% renewable electricity together with a 35% reduction in electricity demand compared with business-as-usual by 2030 – just failed to achieve the 1.5°C carbon budget. However, 13 out of the 22 scenarios achieved the 2°C budget, but only by with substantial contributions from renewable electricity by 2030.[9]

Therefore, policies to achieve a *rapid* transition to 100% renewable electricity are essential if Australia is to play its role in the global challenge. Leaving it to the imperfect unguided market is not an option. In a rapid transition, stranded fossil fuel assets are inevitable. However, in the view of the present author, these are the

[8] Formerly called 'the University of New South Wales'.

[9] Bahareh Howard, Nicholas Hamilton, Mark Diesendorf & Thomas Wiedmann 2018. Modeling the carbon budget of the Australian electricity industry's transition to renewable energy. *Renewable Energy* 125:712-728.

responsibility of the owners of, and shareholders in, these assets, not taxpayers. They have had many years to allow for the financial risks of climate change.

3. Vanishing technical and economic barriers

There are no major technical barriers to the next stage of the transition towards 100% renewable electricity that cannot be overcome by good physical design of the system and tweaks to some of the NEM rules. Variable renewables, especially wind and solar PV, can provide the bulk electricity, replacing base-load[10] power stations. The key to maintaining reliability in a 100% renewable electricity system is to supplement the variable renewables with flexible, dispatchable[11] renewable generators, batteries and other forms of storage. Dispatchable renewables include pumped hydro (discussed below), batteries charged with excess renewable electricity, concentrated solar thermal (CST) with thermal storage, and open-cycle gas turbines (OCGTs) that burn renewable fuels. Hourly computer simulation models spanning one or more years show that reliability can be maintained with a relatively small amount of dispatchable renewables. Reliability can be further increased by utilising a diversity of renewable energy sources, geographic dispersion of wind and solar farms, a few new (or upgraded) high-voltage interstate transmission links, and demand response.[12]

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[10] A base-load power station is one that generates 24/7 at close to its maximum or rated power, except when it breaks down or undergoes planned maintenance. They are mostly coal-fired in mainland Australia, nuclear in France.

[11] A dispatchable power station is one that can generate power upon demand at short notice. Dispatchable power stations have storage, whether it be electrical, thermal, mechanical or chemical (i.e. a fuel). Not all dispatchable power stations are base-load and not all base-load power stations are dispatchable, see Mark Diesendorf 2018. Is coal power 'dispatchable'? *RenewEconomy*, 22 August, https://reneweconomy.com.au/is-coal-power-dispatchable-71095/?utm_source=RE+Daily+Newsletter&utm_campaign=c1c15f122d-EMAIL_CAMPAIGN_2018_08_22_03_03&utm_medium=email&utm_term=0_46a1943223-c1c15f122d-24195345/.

[12] Mark Diesendorf 2017. Why 100% renewable energy is feasible. *InsurgeIntelligence*, https://medium.com/insurge-intelligence/the-feasibility-of-100-renewable-energy-f624d93e1424/. Andrew Blakers & Matthew Stocks 2018. Solar PV and wind are on track to replace all coal, oil and gas within two decades. *The Conversation*, 6 April, https://theconversation.com/solar-pv-and-wind-are-on-track-to-replace-all-coal-oil-and-gas-within-two-decades-94033. Peer-reviewed papers, upon which these popular articles are based, include Ben Elliston, Jenny Riesz & Iain MacGill 2016. What cost for more renewables? The incremental cost of renewable generation - an Australian National Electricity Market case study. *Renewable Energy* 95:127–39; Andrew Blakers, Bin Lu & Matthew Stocks 2017. 100% renewable electricity in Australia. *Energy* 133:471-482. See also Diesendorf & Elliston (2018), *ibid*.

Previous economic barriers are vanishing too. Electricity from wind and solar PV farms is now much cheaper than from new fossil-fuelled power stations, as reported by Australia's Chief Scientist.[13] Economics is the reason why investors are so reluctant to commit to a new coal-fired power station in Australia without government subsidies. This is confirmed by studies in the USA[14] and an international study drawing upon recent auction prices[15]. Furthermore, very recently, energy industry insiders have been saying that new renewables are competitive with the *existing* fleet of old coal fired power stations in Australia.[16] Although batteries are still expensive, they too are becoming cheaper as mass-production grows.

At present, pumped hydro storage is the cheapest form of storage for large-scale electricity supply systems. During off-peak periods, excess renewable electricity pumps water from a lower to a higher reservoir. During peak demand periods, or when electricity supply is low, water is released to flow back downhill, generating power just before it reaches the lower reservoir. Although conventional on-river pumped hydro is very limited geographically in dry countries such as Australia, there is very large potential for off-river pumped hydro.[17] In this case the lower reservoir can be the ocean or a disused mineshaft or a small dam in a valley. To balance the fluctuations in variable renewables, energy storage is only required for a few hours during peaks in demand and periods of 5-7 days for typical weather patterns. Seasonal storage is unnecessary in Australia. Furthermore, where pumped storage is located within a Renewable Energy Zone (REZ, see Section 5.6), it can greatly improve the utilisation of a heavily loaded grid, reducing the extent of grid augmentations required to connect the new renewable generation.

Before discussing the principal non-technical, non-economic barriers to a rapid transition and some simple, politically feasible solutions, a brief comment is made on a carbon price, which the two major political parties reject at present.

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[13] Alan Finkel et al. 2017. Independent Review into the Future Security of the National Electricity Market: Blueprint for the future. https://www.energy.gov.au/sites/g/files/net3411/f/independent-review-future-nem-blueprint-for-the-future-2017.pdf/.

[14] e.g. Lazard 2017. Levelized Cost of Energy 2017. Version 11.0. https://www.lazard.com/media/450337/lazard-levelized-cost-of-energy-version-110.pdf

[15] IRENA 2018. *Renewable Power Generation Costs in 2017*. International Renewable Energy Agency, https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2018/Jan/IRENA_2017_Power_Costs_2018.pdf/.

[16] https://reneweconomy.com.au/origin-says-solar-cheaper-than-coal-moving-on-from-base-load-70999/?utm_source=RE+Daily+Newsletter&utm_campaign=5f19dd45cb-EMAIL_CAMPAIGN_2018_10_01_10_20&utm_medium=email&utm_term=0_46a1943223-5f19dd45cb-24195345/.

[17] Blakers & Stocks 2018, *ibid.*; Blakers et al. 2017, *ibid*.

4. Carbon pricing

A carbon price has strong justification from elementary economics, because it can be seen as incorporating the external (environmental, health and social) costs of burning fossil fuels in their prices. If applied upstream (e.g. at the coal mine, gas field or oil well), the carbon price flows down through the whole economy, sending a market message to every economic transaction. It would be a valuable part of a policy portfolio for assisting the retirement of existing fossil fuelled power stations, however, in the imperfect energy market, it would not be sufficient for driving the transition to a renewable energy system. In the face of the non-technical barriers discussed below, positive policies are also needed to grow rapidly the new technologies, even those that are already economically more competitive than new fossil-fuelled electricity.[18]

In recent years a carbon price, in the form of a carbon tax or cap-and-trade emissions trading scheme[19], has become political anathema to both major political parties in Australia, despite its success in cutting electricity emissions during the short period of its existence from mid-2012 to mid-2014.[20] Therefore, this paper puts a carbon price temporarily on the back-burner and focuses on policies that may be more feasible politically in the short-term.

The paper next discusses the main barriers and policy proposals for overcoming them. Barriers with simple affordable solutions, that could be implemented immediately or within a few years, are addressed first (Section 5). These can drive the transition until renewable energy dominates electricity supply. At that stage, more challenging barriers, that require substantial institutional change, will be reached (Section 6).

[18] Mark Diesendorf 2014. *Sustainable Energy Solutions for Climate Change*. London: Routledge and Sydney: UNSW Press, Chapter 8.

[19] Baseline-and-credit schemes are more acceptable politically, perhaps because they are ineffective in cutting emissions significantly; see http://www.climateinstitute.org.au/verve/_resources/cap_and_trade_vs_baseline_briefing_paper_june_25_2009.pdf/.

[20] Hugh Saddler 2018. National Energy Emissions Audit: Electricity Update. Canberra: The Australia Institute, August, Figure 2, http://www.tai.org.au/sites/default/files/NEEA%20Electricity%20Update%20Aug%20%5BWEB%5D.pdf/.

5. Overcoming low barriers: simple solutions

Overcoming some of these barriers requires political action, while overcoming others involves guiding the physical design of the electricity system so that the market can work better while fostering renewable energy.

5.1 STANCES OF FEDERAL AND STATE GOVERNMENTS

To overcome this barrier, strong efforts are needed by community groups, renewable energy organisations, media, the Australian Greens and the ALP to make renewable energy an important election issue and to correct public misconceptions about energy policy and renewable energy.

While the ALP in a future Federal Government appears unlikely to actively undermine renewable energy, it is under pressure from some powerful trade unions (AWU and CFMMEU) with a foundation pillar in coal mining. The ALP's target of 50% renewable electricity by 2030 is easily achievable, but falls far short of the requirements of climate science (see Section 2), although it may help encourage investor confidence up to the early 2020s. Furthermore, the federal ALP has announced no policies for a future Federal Government strong enough to *ensure* that even this modest target will be reached (see Table 1). Nevertheless, existing state government policies (see Table 3 and Section 5.4), new policies proposed for the States of New South Wales (NSW) and Western Australia (WA) which currently have no adequate policies (see Section 5.4), and continuing investment in renewable electricity by households, commercial organisations, local governments and several industries may be sufficient to achieve this target, provided these policies and actions are continued.

5.2 INCENTIVES FOR DISPATCHABLE RENEWABLES AND STORAGE

Because electricity from new variable renewable sources, notably wind and solar PV farms, is now much cheaper than from new fossil fuelled power stations, the unguided market will implement these technologies preferably above all others. The problem is that an electricity supply system cannot be composed of only variable renewables. To maintain reliability and security of supply, it needs a contribution from supply that's dispatchable, i.e. can supply power on demand at short notice. The last thing it needs is inflexible, slow-response, coal-fired power stations; instead it needs (together with demand response) flexible, dispatchable renewables and/or other forms of storage. When the annual average contribution from variable renewables exceeds about 40%, some storage is generally required. The previous and present South Australian governments have recognised this and are supporting the Hornsdale Power Reserve 100MW/129MWh battery[21], Solar Reserve's proposed Aurora 150MW/1100MWh CST power station with eight hours of thermal storage to be built at Port Augusta[22], and a proposed 250 MW virtual power plant comprising 50,000 home solar PVs and batteries[23]. In addition, there are four proposals for off-river pumped hydro plants – merchant projects that may not all come to fruition without grants from ARENA and loans from the CEFC.

At present dispatchable renewables and other forms of storage are in the early growth stage and so have high capital costs. In operation they will generally have low capacity factors[24], i.e. they will only be operated typically for a few hours per day. For these reasons their costs per unit of electrical energy will be higher than those of the variable renewables. Until the market for these dispatchable technologies expands and their capital costs decline, they will need some assistance.

Therefore, this paper proposes that a future Federal Government provide an additional tranche of funding of $4 billion over four years for ARENA grants specifically for dispatchable renewable electricity, other forms of storage and demand response. This tranche should be additional to any ARENA funding allocated to Snowy 2.0. Current ALP policy commits to a specific additional $207M over four years for CST. Although this is a positive gesture, it is not sufficient to obtain a reliable mix of variable and dispatchable renewable energy sources.

A future Federal Government should also provide an additional tranche of funding of $2 billion over four years for CEFC loans specifically to dispatchable renewable electricity and other forms of storage. Provided the recommended tranche of ARENA grants is allocated, the CEFC loans would be very likely to be repaid, as most previous loans have been. As experience is gained with dispatchable renewables and other forms of storage, their costs will fall and the need for ARENA grants will fade away.

[21] https://hornsdalepowerreserve.com.au

[22] https://www.solarreserve.com/en/global-projects/csp/aurora/.

[23] https://virtualpowerplant.sa.gov.au/virtual-power-plant/.

[24] Capacity factor is defined to be average power output divided by rated power.

Subsequently, as financial institutions gain more confidence in these technologies, the need for CEFC loans will also decline.

5.3 SIMPLE RULE CHANGES

One of the shortcomings in NEM rules, which enables generators to push up wholesale electricity prices while disadvantaging dispatchable renewables and other forms of storage, is the situation that settlement period of the wholesale spot price of electricity is 30 minutes while the dispatch period of power stations is 5-minute intervals. The Australian Energy Market Commission (AEMC) has agreed to change the settlement period to 5 minutes, but this will not be implemented until 2021.[25] Since this rule change will provide a better price signal for investment in fast response technologies (batteries, demand response, dispatchable renewables, and OCGTs generally), as well as reducing spot prices, implementation should be brought forward to 1 July 2019. In addition, a new FCAS (frequency control and ancillary services) rule is needed to reward batteries for their very rapid response times (tens of milliseconds). The Hornsdale Power Reserve has already demonstrated its value in this regard.[26]

5.4 ADDRESSING INACTION BY TWO STATES

Following the lead of the Australian Capital Territory (ACT), which is on track to achieving 100% renewable electricity by 2020,[27] Victoria (Vic), Queensland (Qld) and South Australia (SA) are implementing policies to drive large-scale renewable electricity. The key policies of Vic and Qld are reverse auctions with contracts-for-difference (Table 3). This means that the winning (lowest) bids in dollars per megawatt-hour ($/MWh) of electricity for renewable electricity generators are guaranteed by the government. If the wholesale price of electricity received by the winning owners is less than the guaranteed contract price, the government pays the difference to the owners; but if the converse is true, the owners pay the difference to

[25] Giles Parkinson 2017, https://reneweconomy.com.au/garnaut-slams-aemc-move-to-delay-5-minute-settlement-switch-89819/. See also Box 1.

[26] Giles Parkinson 2018, https://reneweconomy.com.au/tesla-big-battery-defies-skeptics-sends-industry-bananas-over-performance-38273/.

[27] This is an annual average. The ACT's renewable electricity includes wind and solar farms located in states outside the ACT that were developed under ACT's reverse auction scheme.

the government, which benefits consumers.[28] At the time of writing, the latter situation exists in the ACT.

Two States, NSW and WA, have few policies. At present, the high wholesale electricity price is encouraging the growth of solar and wind farms in NSW despite the absence of government policies, but this price is falling as renewable electricity capacity grows across the NEM, so positive policies similar to those of Vic and Qld are required. The WA Government appears to be inhibited from supporting large-scale renewable electricity by its take-or-pay contract for natural gas from the North-West Shelf. Increased public pressure is needed to push the NSW and WA governments to take effective action to facilitate the energy transition. Credible targets and reverse auctions to achieve them are recommended.

Tasmania (Tas) is already close to 100% renewable electricity, mostly hydro. To reduce the impact of droughts, this state should tap more of its substantial wind resource. To justify this and hydro upgrades, it is investigating a proposal for a second transmission link to the mainland (see Section 5.6).

5.5 INCENTIVES TO RETIRE THE MOST POLLUTING COAL POWER STATIONS

The rapid growth of renewable electricity must be matched with the retirement of coal-fired power stations. To assist this transition, the policy suggested by the ANU Centre for Climate Economics & Policy to phase out the most polluting coal stations could be adopted. Plants bid the payment they require for closure and the regulator chooses the most cost-effective bid. The plants remaining in operation then make financial transfers to the plant that exits, in line with their emissions, under government regulation. This policy would cost the government nothing.[29]

5.6 BUILDING KEY TRANSMISSION LINKS

> The transmission network will play a critical role in the transformation of the power system, providing an interconnected energy highway that allows diverse resources to be shared across the NEM more efficiently…Increased investment

[28] E.g. for the ACT, see https://www.environment.act.gov.au/energy/cleaner-energy/how-do-the-acts-renewable-energy-reverse-auctions-work/.

[29] Frank Jotzo & Salim Mazouz 2015. https://theconversation.com/farewell-to-brown-coal-without-tears-how-to-shut-high-emitting-power-stations-50904/. This article is based on a peer-reviewed paper published in *Economic Analysis and Policy* 48:71-81 (2015); corrigendum pp.131-132.

> in an interconnected grid provides the flexibility, security, and economic efficiency associated with a power system designed to take maximum advantage of existing resources, integrate variable renewable energy, and support efficient competitive alternatives for consumers.[30]

In particular, clustering new renewable generators (e.g. wind, solar, pumped hydro, batteries) in Renewable Energy Zones can reduce the costs of new transmission infrastructure needed to connect these generators to the grid.[31] The identification of these potential REZs should take account of the locations of renewable energy resources and existing and probable future transmission lines. Conversely, planning the routes of future transmission lines should take account of the likely locations of REZs.

The construction of key transmission lines must be commenced as soon as possible, because they take longer to plan and build than the rapidly growing wind and solar farms. In the Integrated System Plan (ISP) of the Australian Energy Market Operator (AEMO)[32], AEMO's four principal 'Neutral' scenarios have an emissions reduction from electricity of only 28% from 2005 to 2030, while the remaining 'Fast Change' scenario has 52%. To help speed up the emissions reduction to 100% by 2030 would entail bringing forward some of the ISP's recommended transmission augmentations from its Group 2 (medium-term action) to Group 1 (immediate action).

[30] AEMO 2018. *Integrated System Plan.* Australian Energy Market Operator, p.76, https://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Planning-and-forecasting/Integrated-System-Plan/.

[31] Finkel 2017, *ibid*.; AEMO 2018, ibid.

[32] AEMO 2018, *ibid*.

Table 3: Principal renewable electricity policies of Australian States & Territories

State	Policy	Comment
SA	LNC government has no RE target	Even without target, SA's huge RE resource attracts projects. Likely to exceed 75% RE by 2025.
	Committed $4M p.a. for Hornsdale Power Reserve (big battery)	√√. Its performance is already giving big financial savings
	Proposed new transmission line SA-NSW	√. May require shared funding with NSW & federal governments
	Subsidising 40,000 households $100M for installing home batteries	√√
	Planning Virtual Power Plant for 50,000 home solar & battery systems	√√
Vic.	RE targets: 25% by 2020; 40% by 2025,	√√
	Reverse auctions for up to 650MW of large-scale RE	√√
	Purchasing RE certificates from wind (100MW) & solar (75MW) farms	√
	Issuing Green Bonds ($300M) to finance RE and other environmental projects	√
	Established the Victorian Renewable Energy Advocate	√
	Established minimum feed-in tariff, 11.3 c/kWh from 01-07-2017	√
	Establishing 3 pilot Community Power Hubs	√
	Committed to at least two 40MW/100MWh big batteries	√
Qld	RE target: 50% by 2030	√√
	Reverse auction for up to 400MW of RE, incl. 100MW of storage, before 2020	√√. Rapid growth in solar farms occurring
WA		No RE target or substantial incentive for RE
NSW	No RE target	No target or substantial incentive for RE
	Support for community RE projects via seeding grants & information	√
	Established NSW RE Advocate to work with communities & industry	√
	$55M to support the commercialisation of new large-scale projects that use emerging, dispatchable technology.	√ A token amount sending a positive message shortly before the State election
Tas.	LNC RE target: 100% by 2022;	Already close to 100% net based on large hydro resource; needs more wind, but no substantial policy to achieve it.
	Business case study for 2nd Bass Strait interconnector	√. Interconnector would enable increase in RE exports to mainland
ACT	Target: 100% RE by 2020	√√. On track to achieve target
	Reverse auctions for large-scale solar (40 MW completed) and wind (400MW)	√√. The first reverse auctions for RE in Australia
	Household battery grants	√
NT	Target 50% by 2030	Roadmap under development; meanwhile economics is driving growth from a tiny base
	Signed PPA for 25MW solar farm	√
	Solar for remote indigenous communities	√

Sources: https://www.energy.vic.gov.au/renewable-energy/victorias-renewable-energy-action-plan; https://www.dnrme.qld.gov.au/energy/initiatives/powering-queensland/; http://www.renewablessa.sa.gov.au/; https://www.environment.act.gov.au/__data/assets/pdf_file/0003/581664/EDS_ACT_Sustainable_Energy_Policy_FA_web_A.PDF/.

Note: RE = 'renewable electricity'; √ = good; √√ = excellent

With the growth of solar farms supplemented by wind in Qld, the state is becoming a net exporter of renewable electricity to NSW. According to Qld's Transmission Network Service Provider (TNSP), Powerlink, "A total of more than $4.2 billion worth of projects are currently either under construction or financially committed, offering a combined employment injection of more than 3500 construction jobs across regional Queensland and more than 2000 MW of power."[33] This is more additional power than Qld could use and so upgrading the NSW-Qld transmission links and associated transmission lines in northern NSW is urgently needed. Combining ISP's Group 1 and 2 recommendations for this link would entail an immediate start to an upgrade of 568 MW of transmission capacity. Uprating the existing lines between Armidale and the Hunter Valley is an essential first step, but a commitment to a New England Renewable Energy Hub, as proposed by the NSW Government in its submission to the ISP, and a new double circuit connection to the Hunter Valley must also be expedited to take advantage of the synergy of both wind and solar energy resources in the one locality that also has excellent pumped storage potential.

SA is a net exporter of electricity and still has enormous untapped wind and solar resources. At present it is only connected to one neighbouring state, Vic. A new high-voltage transmission line to join NSW and SA directly is included in the ISP. This line is needed to make the South Australian power supply more resilient and to enable increased export of renewable electricity from SA. It will overcome current grid limitations in south-western NSW, affecting the connections of solar farms already under construction in the REZ, and will provide a means of connecting many more wind and solar farms in western and south-western NSW to the main load centres in eastern NSW and to Victoria. Because of its multiple benefits to the two states and the operation of the NEM as a whole, it should be funded jointly by both states and the Federal Government. Combining ISP's immediate and medium-term recommendations would entail an immediate start to a new transmission line of capacity 750MW. This is currently under investigation by SA's TNSP, ElectraNet. For added security and capability, a double circuit line with higher capacity would be required.

It could be mentioned that, in the absence of this proposed link, SA has more than sufficient diverse renewable energy resources to operate in isolation in the medium-term if necessary, provided existing policies to encourage dispatchable renewables and other forms of storage in SA are expanded and synchronous condensers[34] are installed.

[33] https://www.powerlink.com.au/news-media/renewables-flow-queensland/.

[34] Commercially available technologies for stabilizing the voltage and frequency of alternating current in an electricity grid and hence maintaining system stability. They can burn both fossil and renewable fuels.

With the growth in wind and solar farms in western and north-western Victoria, transmission upgrades in this region are urgently needed, as recommended by ISP.

There is no need to connect the South-West Integrated System (SWIS) of WA to SA, as some commentators have suggested. Connection over such a long-distance would be very expensive and unnecessary. SWIS, like the NEM, has sufficient renewable energy resources to operate entirely on renewable energy as an isolated grid, as demonstrated by computer simulation modelling.[35]

If Snowy 2.0 goes ahead, then upgrades to transmission links to its north in NSW and to the south into Victoria will be needed.

A proposal for a second Basslink joining Tas. to Vic. is under investigation to make Tas. a 'Battery of the Nation'[36]. The proposed link could justify additional wind, pumped hydro and an upgrade of existing hydro in Tas. However, if numerous off-river pumped hydro plants are built around mainland Australia, it's possible that both Snowy 2.0 and a second Basslink will unnecessary.

[35] http://www.sen.asn.au/modelling_overview

[36] https://www.hydro.com.au/clean-energy/battery-of-the-nation

6. Addressing more complex barriers

Policies to overcome the barriers discussed in the previous section are straightforward and affordable. However, the following barriers are more complex, although inexpensive, and may take longer to overcome.

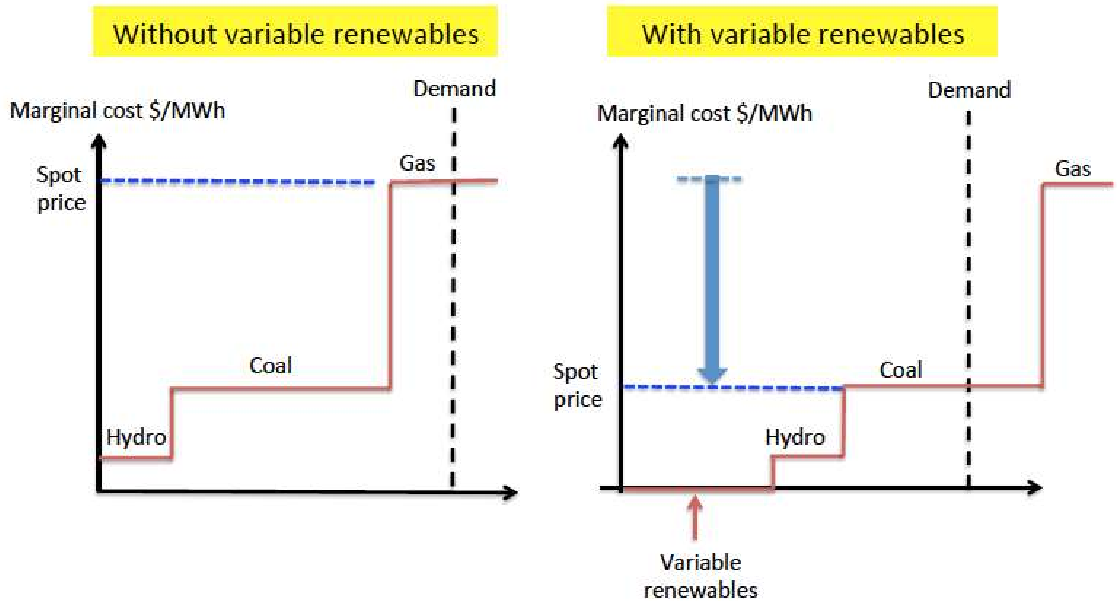
6.1 THE MERIT ORDER EFFECT

This is a subtle barrier, because at present it is actually assisting the growth of renewable electricity and applying economic pressure on fossil fuelled generators to retire (Box 1). However, in the longer term as renewable electricity continues to grow and wholesale prices decline, the Merit Order Effect will stop the growth in renewable electricity too, unless institutional changes are made. To resolve the problem requires rule changes and restructuring of the NEM and the business models of the generators.

As explained in Box 1, the NEM is an energy market, i.e. it pays generators only for the electrical energy they generate.[37] The growth in renewable electricity reduces the operating time of fossil fuelled generators and hence the revenue they earn. Simultaneously it reduces the wholesale price of electricity by means of the Merit Order Effect, further reducing the earnings of all generators, both fossil and renewable. Initially this is very helpful to the renewable electricity transition, providing space in the generation mix for the further growth of renewable electricity. However, continued renewable electricity growth pushes down the wholesale price even further, until it becomes too low to provide sufficient revenue to pay off the capital cost of any new and existing generating capacity, including renewable electricity capacity. Under the current market structure, growth in large-scale renewable electricity, and indeed in all generating capacity, would cease.

[37] An exception is the separate market for frequency control and ancillary services (FCAS) in the NEM: Jenny Riesz, Joel Gilmore & Iain MacGill 2015. *The Electricity Journal* 28(3):86-99.

Figure 1: The reduction in wholesale spot price in the Merit Order Effect



Box 1: The Merit Order Effect

In the wholesale spot electricity market of the NEM, every 5 minutes each generator unit bids a price to supply electricity. Wind and solar farms have low operating costs, so they can bid zero prices. Coal has a higher operating cost, mostly fuel costs, and gas even higher, and so these fossil fuelled generators must bid higher prices to avoid operating at a loss. The Australian Energy Market Operator (AEMO) ranks the bids from the lowest to the highest that are needed to meet the demand for that 5-minute period and dispatches them. Thus the expected demand for electricity is supplied by the least cost mix of generators.[38]

The ranked order is known as the 'merit order' and wind and solar are 'top of the merit order' – i.e. they are chosen first in the mix of power stations to be dispatched in that period. This is not a special privilege for renewable energy, as some opponents of renewable energy claim, but simply the least cost way of operating the market.

At present AEMO averages the *top* six 5-minute prices in a 30-minute interval to obtain a settlement spot price that's is paid to *all* the generators in the chosen mix for the electrical energy they supply in the settlement period. This enables generators to pay off their capital costs, which would be impossible if they were simply paid for their bids that only cover their operating costs.[39]

As the wind and solar capacities grow, they displace the most expensive-to-operate generators entirely and reduce the operating times and hence the capacity factors of some of the remaining fossil fuelled generator units. In particular, the latter generate less during peak periods, when all operating power stations receive the highest prices for electricity. Thus fossil fuelled generators receive less revenue and so find it harder to pay off their capital costs. Also, the wholesale price of electricity is reduced, as illustrated in Figure 1, and this is known as the Merit Order Effect.[40]

To conclude, the growth of large-scale renewable electricity simultaneously reduces wholesale electricity prices while reducing emissions.

[38] https://www.aemc.gov.au/energy-system/electricity/electricity-market/spot-market

[39] Having a 30-minute settlement price and a 5-minute dispatch price creates problems discussed in Section 5.2 – both prices should be 5 minutes and this anomaly will eventually be rectified.

[40] Dylan McConnell et al. 2013. *Energy Policy* 58:17-27.

Four possible solutions have been suggested:

i. To provide an additional payment, known as a ‘capacity payment’ to dispatchable generators, even when they are not generating. Strong objections to this option are that polluting fossil fuelled generators, including inflexible base-load power stations, will demand this payment, and variable renewables will not receive a capacity payment.
ii. The force of the objection to Option (i) can be reduced by limiting capacity payments to flexible, fast-response generators. Fossil-fuelled OCGTs would still be included until they could no longer compete with dispatchable renewables, but base-load coal-fired and gas-fired stations would be excluded. Small capacity payments should be made to variable renewables, as justified below.
iii. To increase the Market Price Cap (the cap on the wholesale spot price of electricity) from $13,500/MWh to over $60,000/MWh.[41] The high market cap would provide occasional bursts of high revenue to generators (including variable renewables) during periods of scarcity of supply, helping them to repay their investments, but these bursts would impose high costs on customers and hence a high political barrier.
iv. By means of comprehensive demand side participation, to allow each customer to select their preferred level of reliability and associated cost, removing the need for an administratively determined Market Price Cap.[42] Generators would receive revenue during many periods of moderately high prices, when some customers decline to purchase electricity.

My personal view is that Option (i) should be rejected on environmental grounds, Option (iii) would receive strong public and political opposition, and neither of the remaining options may deliver sufficient revenue to investors in new supply.

However, Option (ii), with capacity payments limited to flexible, fast-response generators and demand response, could be designed to give limited assistance to investment in variable renewables. To balance supply and demand continuously and hence maintain reliability, we need capacity that can be increased and decreased rapidly. Because variable renewables are ‘dispatchable downwards’, i.e. can rapidly reduce their power output[43], they could receive capacity payments for that limited

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[41] Jenny Riesz, Joel Gilmore & Iain MacGill 2016. Assessing the viability of energy-only markets with 100% renewables: an Australian National Electricity Market case study. *Economics of Energy & Environmental Policy* 5:105-130.

[42] Riesz et al. 2016, *ibid*.

[43] Actually, wind turbines can be operated in a way that allows them to be dispatchable upwards for brief periods. This may not be sufficient to justify an equivalent capacity payment to (say) pumped hydro or a battery.

capacity role, but such payments would have to be smaller than those to generators that are dispatchable both upwards and downwards. However, even with this payment, it seems unlikely that Option (ii) would deliver sufficient revenue to investors. Therefore, additional payments, in the form of reverse auctions or tenders, may be needed to reach 100% renewable electricity. What is clear is that the current market structure may not be appropriate for electricity systems in which variable renewables dominate.

6.2 SHORTAGE OF ELECTRICAL ENGINEERS AND TRADESPEOPLE

Rapid growth in renewable electricity generation capacity and associated transmission lines requires experienced electrical engineers, particularly electric power engineers, for power system planning, grid connection of wind and solar farms, planning new transmission lines and augmentation of existing transmission lines and substations, and use of software for both steady state analysis and dynamic response analysis of the power system. In addition, for long-term planning, contracts and project management, state and federal government departments will need electrical engineers, as members of staff instead of external consultants; they must understand the grid and AEMO's Integrated System Plan(s).

These engineers cannot be trained overnight. They will have to be trained in several successive cohorts and will need time to gain experience in the field. University academic staff numbers in engineering will have to be increased too. According to Engineers Australia, "The engineering labour market fell rapidly from December 2012 when engineering vacancies began a thirty-month slide. This deterioration continued right through to 2015, and has now stabilised at low levels."[44]

In addition, suitably qualified electricians will be needed with experience in rooftop solar, batteries and inverters. Hence, specialised TAFE teachers will also be needed.

Under circumstances where renewable energy is growing rapidly overseas, importing overseas experts may not be an option.

[44] Mark Stewart 2017. *The State of the Engineering Profession*. Canberra: Engineers Australia, https://www.engineersaustralia.org.au/sites/default/files/resources/Public%20Affairs/State%20of%20the%20Engineering%20Profession%20Report%202017%20-%201-page%20view.pdf/.

6.3 REVIVING LOCAL MANUFACTURING

Under the present circumstances where renewable energy is growing rapidly overseas, importing large quantities of hardware in competition with overseas demands may push up prices. A better, job-creating alternative may be local manufacture, especially of large components (e.g. wind turbine blades; big mirrors) that are expensive to ship to Australia. In 2006, when an increase in the Mandatory Renewable Energy Target was expected (incorrectly, as it turned out), large blades and other wind turbine components were being manufactured in Portland Vic. and Wynyard Tas., respectively.

6.4 MODIFYING THE NATIONAL ELECTRICITY OBJECTIVE

The National Electricity Objective is:

> to promote efficient investment in, and efficient operation and use of, electricity services for the long term interests of consumers of electricity with respect to:
>
> - price, quality, safety and reliability and security of supply of electricity
> - the reliability, safety and security of the national electricity system.

Faced with the reality of global climate change and the absence of carbon pricing in Australia, some environmental organisations have called for the inclusion of a climate goal into this objective. While this would be a positive step, it would require the agreement of the Federal Government and all the States and Territories. Even if eventually achieved, it may not become effective without changing several market rules, which would also require the agreement of all the above parties. The Australian Greens have proposed to avoid this log-jam by introducing a bill into the House of Representatives to establish a statutory authority charged with drafting laws to rewrite the country’s energy system and to oversee the planned closure of coal-fired power stations.[45] With or without the passing of this legislation, it is time for a public enquiry to re-examine whether the design of the NEM is adequate in the context of climate change, the rapid growth of renewable electricity and the need to implement substantial energy efficiency.

[45] Sophie Vorrath 2016. Greens bill calls for new government authority to rewrite electricity market rules. https://reneweconomy.com.au/greens-bill-81477/.

7. Discussion and conclusion

In a future ecologically sustainable energy system, most energy users will either use renewable electricity directly, or use liquid and gaseous fuels that are produced by using renewable electricity. Hence the transition to 100% renewable electricity will take Australia a long way towards a carbon neutral economy. This Discussion Paper proposes key policies to be implemented by state governments and a future federal government in order to accelerate the electricity transition.

The growth of large-scale variable renewable electricity generation, driven mainly by its favourable economics, will continue to displace fossil fuelled generators. Reliability can be maintained by initially providing incentives for dispatchable renewable electricity generators and other forms of storage from ARENA and CEFC, together with oversight and monitoring by AEMO. Several new transmission links are needed. The spot price of electricity should be determined every five minutes (the dispatch period), instead of every 30 minutes. An industry-funded process could retire the most polluting coal-fired power stations. The community must pressure NSW and WA to introduce reverse auctions with contracts-for-difference. These are all relatively easy policies to implement technically and economically, and may be politically feasible.

The growth in renewable electricity generation will also bring down the wholesale price of electricity.[46] As the wholesale price continues to decline, spot prices, and contract prices influenced by spot prices, will no longer be sufficient to fund the capital costs of new generation of any type. If capacity payments are introduced, they must be restricted to flexible, fast-response generators – including pumped hydro, batteries, CST and OCGTs – and demand response. Variable renewables should receive smaller capacity payments for being 'dispatchable downwards'. Additional funding, for example from reverse auctions and tenders, may be needed to provide sufficient revenue to investors in large-scale renewables.

To support rapid growth in renewable electricity, education, training and local manufacturing must be strengthened and resourced.

Many other worthwhile policies are needed but, because they are not potential principal drivers of the transition, they are not highlighted in this paper. These additional policies would, for example:

- encourage the growth in numbers of electric vehicles;

[46] Legislation or rule changes in the electricity market may be needed to ensure that these reductions are passed on to retail customers.

- boost R&D into the efficient production of renewable liquid & gaseous fuels;
- facilitate replacement of gas space heating with electric heat pumps, and gas hot water with solar or electric heat pump hot water;
- encourage the addition of batteries to rooftop solar PV systems;
- remove subsidies to the production and use of fossil fuels;
- remove the barriers to community renewable energy projects;
- make all government operations at all levels carbon neutral;
- allow virtual power plants to sell electricity into wholesale markets;
- allow local electricity trading;
- require more appropriate tariff structures for retailing grid electricity and for feed-in of rooftop solar into the grid; and
- foster contracted demand response.

Action on most of these items would be low in cost and some would reduce costs to consumers.

While the principal policy recommendations of this paper are being implemented, continuing community pressure on the federal government is needed for the return of a carbon price, preferably in the form of a carbon tax, which is simple to implement and more difficult to undermine than a cap-and-trade emissions trading scheme.[47] In the absence of a carbon price reflecting the external (environmental, health and social) costs of electricity generation, the notion of 'technology neutral' policies has no support in economic theory.

Energy efficiency and renewable energy must be implemented together, because implementation of energy efficiency makes implementation of renewable energy easier. Furthermore, many energy efficiency technologies and measures are low-cost, highly effective and pay back the initial investment rapidly. Australia still has huge potential for cost-effective energy efficiency in buildings and appliances, and for efficient urban restructuring, but that potential is not being realised because of market failure, such as split incentives between landlord and tenant.

Although the transition to a renewable electricity future, and hence a renewable energy future, is inevitable, given the declining prices of wind, solar PV and batteries, intervention is needed by federal and state governments to ensure a *rapid* transition in line with the requirements of climate science and to reduce the probability of sudden shocks.

[47] Diesendorf (2014) *ibid*.

This paper has shown that several simple, affordable policies could take us rapidly most of the way. Thereafter we will need to consider complex changes to the electricity market, as well as implement strategies for education, training and industry.

Abbreviations

ACT	Australian Capital Territory
AEMC	Australian Energy Market Commission
AEMO	Australian Energy Market Operator
ALP	Australian Labor Party
ARENA	Australian Renewable Energy Agency
CEFC	Clean Energy Finance Corporation
CST	Concentrated solar thermal
FCAS	Frequency control & ancillary services
GWh	Gigawatt-hour
Gt	Gigatonne
ISP	Integrated System Plan
LNC	Liberal National Coalition
M	Million
Mt	Megatonne
MW	Megawatt
MWh	Megawatt-hour
NEG	National Energy Guarantee
NEM	National Electricity Market
NT	Northern Territory
NSW	New South Wales
OCGT	Open-cycle gas turbine
PV	Photovoltaic
Qld	Queensland
RE	Renewable electricity
RET	Renewable Energy Target
REZ	Renewable Energy Zone
SA	South Australia
SWIS	South West Integrated System
WA	Western Australia
Tas	Tasmania
Vic	Victoria

Glossary

Base-load power station	One that generates 24/7 at close to its maximum or rated power, except when it breaks down or undergoes planned maintenance
Capacity	Nameplate or maximum power output of a power station; aka 'rated power'
Capacity factor	Annual average power output divided by rated power, usually expressed as a percentage
Carbon budget	The remaining quantity of greenhouse gas emissions that humans can make and still keep global temperature increase within a specified limit with a specified probability. Can be apportioned to individual countries
Contract-for-difference	A contract price for electricity received e.g. by the winners of a reverse auction for wholesale electricity generation. If the wholesale price in the market is less than the contract price, the government pays the difference to the developer; if the wholesale price is greater than the contract price, the developer pays the difference to the government.
Dispatchable power station	One that can generate power upon demand at short notice
Energy	Note that the concept 'energy' is not restricted to electricity; it also includes heat and transport energy
Local electricity trading	Small- and medium-scale generators assign their exported generation to specific local electricity customers; includes microgrids that are connected to the distribution network and direct transfer of electricity between neighbours
Merit order	Ranking order for dispatch of wholesale electricity into the grid. The lowest bid in $/MWh is 'top of the Merit Order', i.e. top ranking
Power (electrical)	Rate of energy generation or use
Pumped hydro	When demand is low and electricity cheap, water is pumped from a lower to a higher reservoir. When demand is high and electricity expensive, water flow back down, generating electricity en route
Rated power	Nameplate or maximum power output of a power station; aka 'capacity'
Renewable Energy Certificate	Tradable certificate issued to generators of renewable electricity (solar, wind and hydro) and solar or heat pump hot water as part of Australia's Renewable Energy Target (RET); one certificate = 1 MWh. The RET requires energy retailers to purchase a set amount of certificates each year, so there is a constant demand for these certificates. From 2011 there are separate certificates for large-scale and small-scale renewable energy systems
Renewable Energy Target	Current target is 33,000 GWh of renewable electricity per year by 2020. Nowadays it's divided into the Large-scale Renewable Energy Target (LRET) and Small-scale Renewable Energy Scheme (which doesn't have a target).
Renewable fuel	A liquid or gaseous fuel produced by using renewable energy
Renewable electricity	Electricity from renewable sources
Reverse auction	An auction in which the lowest bids are the winners; e.g. bidding in $/MWh for electricity supply
Virtual power network and virtual power plant	Network of dispersed small- and medium-scale renewable electricity generators, storage and demand management that can be centrally controlled to create a single 'virtual' power plant that can feed into the grid