Australian Government
Department of the Environment and Energy

COVER SHEET FOR SUBMISSIONS

Independent Review into the Future Security of the National Electricity Market

Overview

Please include this cover sheet with your submission on the Preliminary Report of the Independent Review into the Future Security of the National Electricity Market.

Background

The Preliminary Report outlines the Panel's observations about the current state of the NEM and offers questions on the major issues the Panel has identified. The questions are designed to elicit suggestions or answers that may help form the Panel's final recommendations.

The Preliminary Report serves as an issues paper for broad public consultation. As such, the questions and views will be subject to further consideration and discussion, in anticipation of the final blueprint being produced in 2017.

Stakeholders are encouraged to keep their submissions as succinct as possible, and include a one-page executive summary.

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Submission Instructions

The submission period will be open until close of business on Tuesday **21 February 2017**.

All submissions should be emailed to the NEM Security Review at the mailbox: NEMSecurityReview@environment.gov.au

The author

Dr Mark Diesendorf has a BSc with first class honours in physics from the University of Sydney and a PhD in applied mathematics from UNSW. Recently 'retired', he is currently Honorary Associate Professor in Interdisciplinary Environmental Studies, School of Humanities & Languages, UNSW Sydney. Previously, at various times, he was a Principal Research Scientist in CSIRO, Professor of Environmental Science and Founding Director of the Institute for Sustainable Futures at University of Technology Sydney, Director of Sustainability Centre Pty Ltd, and Associate Professor and Deputy Director of the former Institute of Environmental Studies at UNSW. His principal research is on rapid mitigation of global climate change. In particular, he is a member of an interdisciplinary UNSW research group of electrical engineers and scientists who are researching the integration of renewable energy on a large scale into electricity supply-demand systems. He has researched this particular topic in various organisations by means of simulation modelling and other approaches for nearly 40 years. His most recent book is *Sustainable Energy Solutions for Climate Change* (UNSW Press and Routledge-Earthscan, 2014).

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Summary

This submission focuses on Theme 4 of the Review's Issues Paper: *Variable renewable electricity generators, such as wind and solar PV, can be effectively integrated into the system*. It is based on hourly computer simulations of the operation of the National Electricity Market with 100% renewable electricity, conducted since 2010 by a research group to which the author belongs at UNSW Sydney.

This submission proposes a strategy for the transition of the National Electricity Market system to 100% renewable electricity over a period of a few decades. With appropriate design, the transformed system would meet standard reliability criteria, would be affordable and would be able to maintain the grid frequency. Using South Australia (SA) as a case study, the submission outlines how SA could transition to a 100% renewable electricity system, one that can handle future occasional disconnections from neighbouring states. It explicitly addresses the challenge of meeting peak demand at times when wind and solar generation are low. The submission considers only commercially available technologies and the policies needed to implement them rapidly. New technologies under development offer even more options.

The key requirements for reliability and stability are a diverse set of renewable energy sources, especially a balanced mix between variable and flexible-dispatchable renewable energy technologies; some storage of various types; geographic dispersion of wind and solar farms where possible; energy efficiency and smart demand management; and, as an optional extra, a new high-voltage, high-power, transmission spine joining SA and NSW. Policies for growing these technologies are outlined in the submission.

Contents

1. Introduction

The electricity industry is undergoing major changes in Australia and many other countries. Climate change and, in some countries, air pollution are motivating a transition to much cleaner energy sources. The transition is speeding up as wind and solar power are rapidly becoming economically competitive with fossil fuels, even where the external costs of the latter are not included in their prices, e.g. via a carbon price.

At present electricity is responsible for about 35% of Australia's greenhouse gas (GHG) emissions. However, as the transition to an ecologically sustainable energy system based on renewable energy and energy efficiency continues, most of heating and transportation are likely to become electrical as well. Hence transforming electricity is the key to cutting substantially Australia's GHG emissions.

In the electricity industry old business models are collapsing under pressure from the Merit Order Effect in the wholesale market and the threat of the 'death spiral' in the distribution/retail market (Diesendorf 2014, chapter 9). Vested interests are attempting to delay the inevitable changes to an ecologically sustainable electricity system by spreading incorrect or exaggerated myths about renewable energy and energy efficiency. These include the myths that:

- base-load power stations are essential in a grid and renewable energy cannot provide them (refuted by Diesendorf 2016);
- variable renewable energy can provide reliably at most *x*% of annual generation in a grid, where *x* was originally set at 5% by renewable energy sceptics and deniers, then 20% and now about 50%, but *x* keeps on increasing as practical experience and simulation modelling (e.g. Elliston et al. 2016) refute old dogma;
- the South Australian blackout of 28 September 2016 was caused by wind farms.

These and other misconceptions and over-simplifications are being disseminated in the media by politicians, GHG emitting industries, sections of the electricity industry and others, fostering public fears about energy insecurity. However, while the myths need correction, there is also an urgent need for all spheres of government to develop strategies for the ongoing transition, rather than leave it to the invisible hand and the unseeing eyes of the market. It is hoped that the *Independent Review into the Future Security of the National Electricity Market* will sort out the misconceptions and 10% truths from reality and identify pathways to a sustainable electricity future.

In response to the Preliminary Report (i.e. the issues paper) of the Review (Finkel et al. 2017), this submission focuses on Theme 4: *Variable renewable electricity generators, such as wind and solar PV, can be effectively integrated into the system*. The submission first outlines how the whole National Electricity Market (NEM) can transition to 100% renewable electricity and then focuses on the special case of South Australia (SA).

2. 100% renewable electricity for the National Electricity Market

Several research groups in Australia have conducted hourly simulation models, spanning 1-6 years, of the operation of the NEM with 100% renewable energy. The UNSW group uses only commercially available renewable technologies in its energy mixes – wind, solar PV, concentrated solar thermal (CST) with thermal storage, biofuelled open-cycle gas turbines (OCGTs) and existing hydro – with all except the latter technology scaled up to meet the NEM's reliability criterion. The most recent simulations cover six years of real hourly data on demand, wind and sunshine across the NEM region. (Elliston et al. 2012, 2013, 2014, 2016).

Simulations by the Australian Energy Market Operator include, in addition to the above technologies, small contributions by wave power and hot rock geothermal power, which are not yet commercially available. (AEMO 2013)

A recent set of simulations by Lenzen et al. (2016) optimised wind and solar farm locations over the entire Australian continent. However, it over-estimated the cost of the transition, because inter alia it assumed incorrectly that the average capacity factor of Australian wind farms is 20% when it is actually 33-35%.

Many thousands of simulations were conducted by the above groups, so that economic optimisations of the mix of renewable energy technologies, the use of storage, power station locations, etc. could be performed. The principal results found in the three separate projects are:

- The NEM can be operated reliably on 100% renewable electricity.
- The studies by Elliston et al. (2012. 2013, 2014, 2016) and Lenzen et al. (2016) show that base-load power stations (e.g. coal or nuclear) are unnecessary for achieving a reliable system.
- The key to achieving reliability, in an electricity supply system whose annual energy generation is predominantly variable renewable energies, is to balance the variations in wind and solar PV with dispatchable, flexible renewable energy sources such as CST with thermal storage, biofuelled OCGTs and hydro with dams, including pumped hydro.
- Reliability can be achieved with surprisingly little storage in the system. In modelling conducted so far, storage comes from existing hydro, thermal storage with CST and the fuel for OCGTs.
- Geographic dispersion of wind farms and solar generators further assists reliability.
- Elliston et al. (2012) found that quite small reductions in peak demand (e.g. as could be implemented in a smart grid) could further increase the reliability of the generating system substantially, given biofuelled OCGTs with a fixed capacity and annual generation. Alternatively, for a fixed reliability, quite small reductions in peak demand reduced the operation in OCGTs to very low levels (e.g. to 2% of total annual electricity generation in the NEM) and hence their fuel use can be very low..

- Using conservative cost projections, 100% renewable electricity is affordable, although is likely to be more expensive than a new fossil fueled system in which external costs are ignored.

  Note: However, the costs of solar PV, wind and CST have all declined substantially since the estimates used in the above studies were made, so that now some energy investment experts, such as Bloomberg New Energy Finance, consider that new wind and solar electricity technologies are already competitive with new fossil fueled technologies in several regions (Bloomberg website A) and will continue to dominate annual additions to global generating capacity (Bloomberg website B).

- New and enhanced interstate transmission lines have several benefits (see below), but are not essential.

  Note: However, strengthening of some regional transmission lines within states, e.g. in western Victoria, may be necessary. This aspect was not investigated in the above simulation studies.

Similar results have been obtained by dozens of hourly simulations from around the world, e.g. including the USA (Jacobson et al. 2016). Additional references are given in Elliston et al. (2016).

3. 100% renewable electricity for South Australia

How does SA compare with the NEM as a whole? SA has the advantage of even greater wind and solar potential per square kilometre or per head of population. Thus, given strengthened transmission links and one or two new interstate links, it could export large amounts of renewable electricity to the eastern states where demand is much higher.

SA has the disadvantages, compared with the whole NEM, of having no hydro-electric potential on rivers and less geographic diversity for wind and solar farms. However, it appears to have potential for seawater pumped hydro (see below). Furthermore, the reduced geographic diversity of RE resource can be offset by increased diversity of the RE mix of technologies and storage (see below).

As variable renewable electricity, e.g. wind and solar PV, continues to grow in SA, the principal future challenge will be meeting the peak demand during periods of typically 2-3 hours on summer (and possibly winter) evenings when wind generation happens to be low, as in the heatwave on 8 February 2017. Although sufficient gas-fired generated capacity existed to meet peak demand on that occasion, not all of it was available at the time and therefore brief, localised, rolling blackouts were implemented. (AEMO 2017a)

Without strategic preparation over the short- and medium-term, these events would be more difficult to handle if the principal transmission interconnector between SA and Victoria failed at those critical times.

On the scenario that SA could transition to 100% renewable electricity (Diesendorf 2015) over a period of (say) 15-20 years, this submission proposes transition strategies, for short-term (2-3 years) and medium-term (up to 10 years) timescales, that maintain reliability of the generating system.

3.1 Short term technologies and policies

The key point is that the challenging periods will be infrequent and only last for a few hours (AEMO 2017a). A base-load (e.g. coal or nuclear) power station, that operates best when running continuously at full power, would be too inflexible in operation to do the job. It would also be too expensive, too hazardous and too slow to construct.

In the short-term (2-3 years), the feasible, flexible solutions are open-cycle gas turbines (OCGTs), preferably each with dedicated gas storage, concentrated solar thermal (CST) power with thermal storage, batteries and an enhanced energy efficiency program. Given appropriate SA government policies commencing in 2017, these technologies could make significant contributions to peak supply within a short timescale.

Currently 320 MW of OCGTs have been proposed for SA (AEMO 2016a). OCGTs have low capital cost and, since they would be operated infrequently, low annual operating cost. Some types can be started from cold in 10 minutes, compared with 1-2 days for coal or nuclear power. OCGT owners would have to be recompensed for keeping their units on standby for providing reliability insurance and frequency control. In return, the SA government as well as AEMO should be granted the power to direct the OCGTs to operate when needed. OCGTs have the sustainability feature that they can operate on renewable fuels such as biofuels, hydrogen and ammonia produced using renewable energy.

Another feasible short-term solution option is CST with thermal storage. Currently there are several proposals for CST power stations near Port Augusta (e.g. Repower Port Augusta website). Since CST is still expensive, it would be wise to start by installing a single module of about 100 MW. Subsequently, as the global CST market expands and the cost declines further, additional modules could be installed. So that it can be dispatched reliably at peak periods when required, CST would not be operated as base-load (i.e. continuously at rated power). A necessary support policy is to pay higher feed-in tariffs or contract price for supply during evening peaks.

Battery prices are declining rapidly as mass production takes off, so these technologies could also make a significant short-term contribution to cutting evening peaks. Rooftop solar PV on both residential and commercial rooftops, together with batteries, can reduce the demand on the grid. Residential and commercial solar owners should be incentivised to install batteries and use them during peak demand periods by requiring retail electricity prices to vary with time, peaking during peaks in demand. This would encourage prospective owners of solar + battery systems by increasing the economic savings from self-consumption and feed-in of any excess solar generation.

While additional solar PV farms and wind farms should be constructed, they should also be balanced by the above dispatchable, synchronous energy generators. To drive the implementation of CST and large batteries in the absence of federal government support, SA could hold reverse auctions, as in the Australian Capital Territory (ACT Government website).

To offset, at least partially, increased peak electricity prices and to assist electricity users to reduce unnecessary demand, state and federal government energy use efficiency programs should be expanded. There is huge potential for the short-term implementation of energy efficiency for all electricity users in all sectors in Australia. Since demand-side measures can greatly reduce the supply-side requirements, their potential should not be overlooked by the Review report. Energy efficiency should be incorporated into the core structure of the NEM. In particular:

- AEMO or a new organisation should be required to publish an *Energy Efficiency Statement of Opportunities*.
- Electricity suppliers should be given incentives to become Energy Service Companies aka Energy Performance Contractors.
- Electricity pricing policies that undermine energy efficiency – such as high fixed ‘supply’ or ‘service’ charges and declining block tariffs – should be made illegal.

3.2 Medium-term technologies and policies

Globally we are at the beginning of a transition to ‘smart’ grids, in which demand for electricity can be modified almost instantaneously by both the customer and the utility (Klimstra & Hotakainen n.d.; Saddler 2017). For the utility to do this, a contract is needed to reward the customer for being occasionally off-loaded partially (e.g. air conditioning, refrigerator, hot water) for short periods of time, e.g. 30 minutes. Off-loading for up to an hour already occurs occasionally with some aluminium smelters, which are huge electricity consumers and can handle such interruptions to power supply. For residential and commercial customers of grid electricity, the only technology needed is a ‘smart’ switch that can be operated remotely on the power cords supplying electricity-intensive appliances. While the technologies already exist for smart demand reduction, it could take 5-10 years to mass-produce and roll them out on a large scale.

The cheapest form of electricity storage for the grid is pumped hydro, where excess electricity generated during off-peak periods, e.g. by wind and solar, can be used to pump water from a low to a high reservoir. During peak periods the water is released from the upper reservoir, generating electricity. Pumped storage is well-established around the world and exists on the Tumut River as part of the Snowy Mountains Hydro-Electric Scheme. Although SA has negligible potential for hydro-electricity based on rivers, it appears to have potential for pumping sea-water up into many small reservoirs in coastal hills (Lu et al. 2015; Dargaville 2016). A research group, led by Prof. Andrew Blakers at ANU and funded by ARENA, is investigating this.

Another medium-term option is to build a major new transmission line to join SA directly to eastern NSW (AEMO 2016b; Parkinson 2016) via Broken Hill. To reduce energy losses and increase stability, a major section could be ultra-high-voltage DC. Although such a line could take a decade to plan and build and would be expensive, it would have multiple benefits:

- Increasing the operational resilience and controllability of the whole transmission grid of the NEM, which currently has the disadvantage of being very long (about 5000 km) and skinny.

- Enabling SA to send more wind power to load centres in NSW.
- Enabling future solar power stations in western NSW to be connected to load centres in the east.
- Helping to feed any future hot rock geothermal power from central Australia to the east via Broken Hill.

Since it would be valuable national infrastructure, the cost could be shared between the federal and state governments.

It must be emphasised that SA has so much RE potential that, given appropriate technology dissemination policies by the SA and federal governments, it could in future operate continuously on 100% RE while separated from its neighbours. However, I do not recommend deliberate separation, since, with one or two new transmission spines, SA could export sufficient RE to assist its neighbours on their future pathways to 100% RE.

4. Federal government policies to assist the transition

The following federal government policies would assist the transition of SA and indeed the whole NEM to 100% renewable energy.

- As a driver of long-term investment, a national carbon price that steadily increases to a high level would compensate for the external costs of burning fossil fuels.

  Note: A carbon tax is the simplest and most difficult-to-avoid form of carbon price, although it is politically unpopular. The oft-claimed disadvantage that it doesn't explicitly cap emissions can be overcome by gradually increasing the price over time. In my view (Diesendorf 2014, pp.216-219), a cap-and-trade emissions trading scheme (ETS) is the second best option. Although it specifies an explicit cap on emissions, it is so complicated that it can be easily designed to fail. Even with the best of intentions, it can fail, as witness the recent very low prices of permits in the European ETS. Both carbon tax and cap-and-trade ETS have the advantage that the carbon price flows through the whole economy. The carbon price can raise revenue to compensate individuals who are disadvantaged by the carbon price and assist in funding the transition to renewable energy.

- The weakest form of carbon price (although possibly the most palatable to politicians) is a baseline and credit scheme such as the Emissions Intensity Scheme proposed by the federal Labor Opposition. It has neither carbon price nor cap in emissions and can readily be designed to delay the dissemination of renewable energy unnecessarily by increasing the use of natural gas. Therefore, if it is ever introduced, it should be designed to penalise all fossil fuels.
- Retirement of base-load and intermediate-load gas should be encouraged by means of a carbon price.

Note: On the basis of climate science, base-load gas (e.g. Torrens Island in SA) and intermediate-load gas (e.g. Pelican Point in SA) should be retired as soon as possible along with coal-fired power stations in the eastern states. In SA this can be done as soon as it has sufficient dispatchable solar and/or pumped hydro and sufficient available capacity of OCGT with dedicated gas storage. Thus, even though peak-load gas must remain for a transitional period, there can be a net reduction in total gas use in SA.

- The Renewable Energy Target (RET) should be extended from 2020 to 2030 and increased in magnitude. Separate targets for CST with thermal storage and large-scale storage (e.g. off-river pumped hydro; large batteries) are recommended.
- Finally, the NEM Objective and several of its rules will have to be changed to include the environmental goal of reducing greenhouse emissions and boosting renewable energy and energy efficiency.

However, even without national drivers, SA could transform its grid to one that's predominantly renewable, reliable and affordable. Furthermore, CST with thermal storage, OCGTs, rooftop solar and batteries with appropriate inverters, and synchronous condensers (Depoian n.d.) can all contribute to frequency stability of a 100% renewable SA.

5. Conclusion

Over a period of 15- 20 years, it is entirely feasible for SA and, in the longer term, the NEM as a whole, to aim for 100% annual renewable electricity. The important requirements for reliability and stability are a diverse set of renewable energy sources, especially a balanced mix between variable and flexible-dispatchable technologies; storage; geographic dispersion of wind and solar farms; energy efficiency and smart demand management; and possibly a new transmission spine joining SA and NSW.

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