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Can the NEM Survive More Renewables?

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Introduction

In October of 2018 I attended, with many others, an Australian Institute of Energy (AIE) event where Robert Barr presented the results of a NEM model he has developed, along with a group of associates.

I was impressed by the presentation and the ensuing debate. So I thought it useful to lead out in this Insider with a discussion of it, as it got me thinking also. I ask (along with many of our dear readers); how can the NEM deliver reliable, reasonable cost power while lowering emissions using intermittent renewable energy?

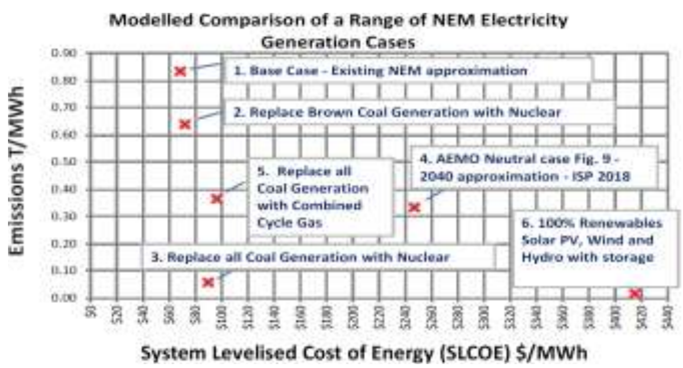
The Robert Barr Model

What the model does

Robert Barr's NEM model is outlined on his company website[1]. Its operation is straightforward:

- Load and renewable data are taken as half hourly values from a single calendar year – 2017 was chosen in the example. The NEM is assumed to operate unconstrained.
- Generation and storage cost data are assembled from published sources. Costs are either fixed or variable and each technology is also assigned an emissions footprint.
- To run a case, a plant mix is chosen, essentially arbitrarily, from the available plant options so that the mix meets the appropriate reliability standard.
- Renewables and fossil fuel plant are then loaded in merit order to meet the demand in each half hour. Storages are run to maximise reliability (at the expense of cost saving, as will be argued later).
- The resulting fixed and variable costs are calculated in this way, and summarised as a System Levelised Cost of Energy (SLCOE). Emissions for each case can also be calculated once plant has been scheduled.
- The results are then plotted in a chart reproduced as Figure 1 below. While such a chart is not novel, it remains an effective way to illustrate the relative merits of different plant mix strategies in terms of emissions and cost.

Figure 1: Plot of SLCOE v. Emissions for 6 Cases



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Good points about the model and presentation

The best thing about Robert's model and presentation is its transparency. One can see what is going on and debate

[1] See https://epc.com.au/index.php/nem-model/ A booklet containing the examples referenced in this article can also be downloaded from that page.

elements of it, as happened at the AIE event and which I intend to do in this Insider.

The other good thing emphasised in Robert's AIE presentation was the unreliability of the wind resource at the national level. It is not widely recognised in some quarters that the wind can stop blowing everywhere in the NEM area for days on end. Given that peak load can occur when there is little or no sun shining, until significant new cost effective storage options arrive, it is best to assume that wind and solar together contribute NOTHING to reliability.

This fact does NOT imply that coal or nuclear base load plant is required for reliability and that systems without such plant are necessarily unreliable and costlier; gas plant with some load management can also do the job.

Not so good points about the model

The model ignores network constraints, ancillary services load growth, dynamic pant schedules and other details. These are not criticisms, but features!

There is a major problem with the logic of storage operation. To maximise reliability:

- Storages are used after all other options to maintain reliability
- Storages are replenished as soon as spare energy is available (regardless of cost)

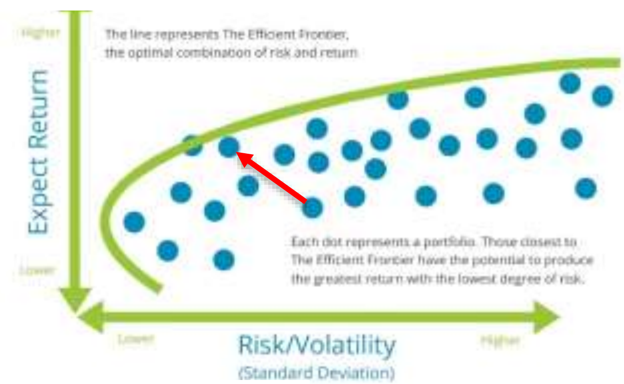
While this strategy does appear to maximise reliability, it does so at a very high energy cost. Further the regular on-peak-off off-peak operation of storages to capture value is not implemented. This weakness means that plant mixes with lots of storage are likely to overestimate SLCOE. This is likely one reason why the SLCOEs of Cases 4 and 6 in Figure 1 are so high. For this reason, I choose to ignore these points.

In the model results presented, the cases selected are not all of equal merit as some are clearly inferior to others by any measure. If Case 4 were valid, for example it would clearly be inferior to, say, nuclear (Case 3) in terms of both cost and emissions. But the plant mixes selected for analysis by no means represent all of the good options available, so it would be quite premature to conclude from the analysis that, for example, "nuclear is the answer".

To formalise this critique, we draw an analogy with the widely used concept of portfolio optimisation in finance. Under this model, different mixes of assets are shown as the blue dots in Figure 3. We seek a portfolio that is in some sense "the best", considering both expected return and risk, as measured by standard statistical measures.

It is easy to see that the portfolio we seek must lie on or near the green line, or "efficient frontier". For example, if on began with an interior portfolio, one could improve in terms of return and risk by moving to the frontier, as shown by the red arrow in Figure 2 below.

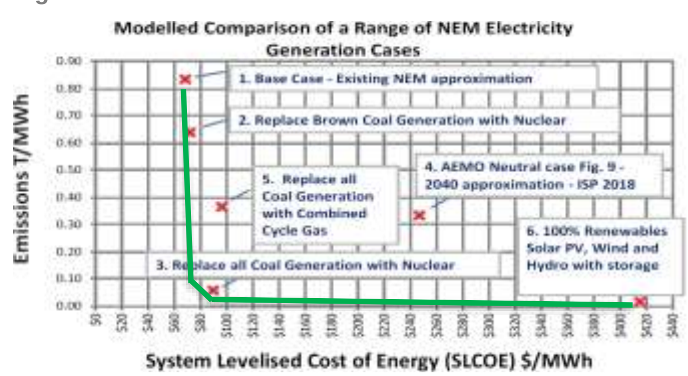
Figure 2: Financial Portfolio's Efficient Frontier



Source: Wikipedia

By analogy, we can postulate an efficient frontier for our plant portfolios which expresses the best set of trade-offs for any combination of SLCOE and emissions. I have sketched in a notional efficient frontier onto Figure 1 to give Figure 3 below.

Figure 3: Notional Plant Mix Efficient Frontier



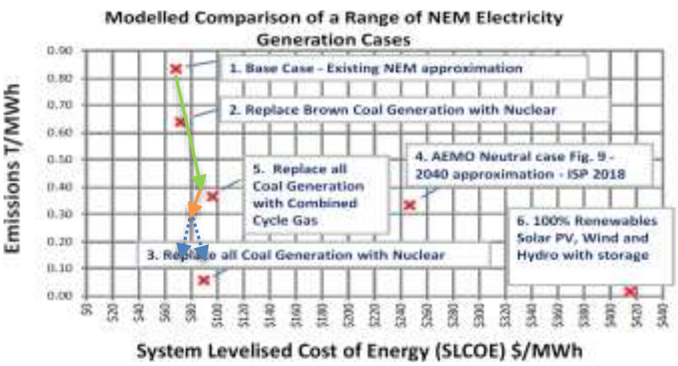
Derived from © Electric Power Consulting Pty Ltd 2018

We can now ask the question; can we find a plant mix that is near to the frontier and reasonably close to Case 3, which appears to have a relatively attractive cost emissions tradeoff? The short answer is yes, and we can illustrate the evolution of that plant mix over time on this figure. This is done in following sections.

Building a Plant Mix Strategy

The chart of Figure 1 provides a graphic way to illustrate how we can build up a credible plant mix development strategy for the NEM. We emulate a process of optimisation; identify an initial feasible solution and then seek ways in which that solution might be improved. We argue for our assumptions as we go. The Cases referenced relate to Figure 4, which is a marked up version of Figure 1.

Figure 4: A Credible Plant Mix Development Strategy



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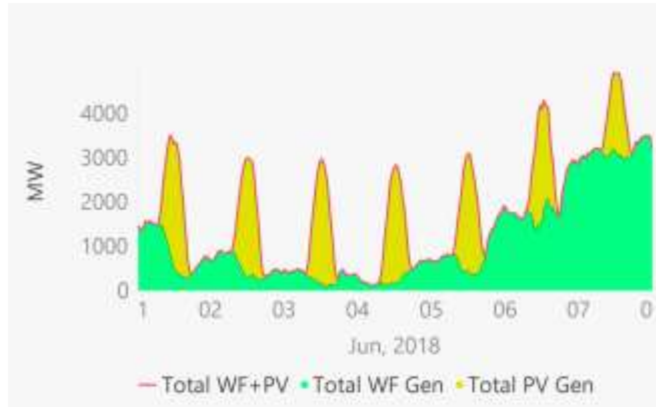
Initial feasible solution

Case 1 is the current situation which we assume to be feasible; that is, there is currently sufficient capacity available to meet the reliability standard. Because wind availability nationally can fall to near zero over extended periods (multiple days), the required capacity for reliability is made up of entirely of thermal plant, long storage hydro (mainly Snowy) and contracted load management.

Wind, solar and daily cycle pumped storage cannot provide the capacity required for reliability. To see this, take a good look at the wind and rooftop PV profiles in Figure 5 In the 3 days in the middle of the week, wind output nationally is just a few hundred MW on average, compared with over 5,000 MW of installed capacity. This is by no means a worst case scenario. Clearly, wind alone cannot be counted on to support reliability.

Figure 5: Wind and solar traces over a Week in 2018



I will not demonstrate it here, but solar appears to be much more reliable system-wide, as hinted at with the yellow peaks in Figure 5. Further, rooftop PV does have the effect of shaving daytime peaks, but those (lower) peaks now occur in the evening and early morning. Even with battery support, an extended period with low wind is likely to run batteries down, so PV and batteries may not help much with system reliability.

The above analysis is not fully robust but, to be conservative, we assume that gas turbines and the existing Snowy scheme must, for the time being, provide the peaking capability required to maintain reliability.

Moving along, then, we assume first that coal capacity is replaced by gas combined cycle plant as it is retired, ultimately leading us to Case 5. In practice, we would include some open cycle plant in the mix, so we would end up with slightly higher emissions but lower costs. We illustrate these developments (over, say, 30 years) by the by the solid green trajectory.

Renewables as energy cost savers

The initial feasible solution described above is viable[2], but can it be improved upon, and how must it be adjusted to reflect current policy settings?

Renewable sources provide low cost energy at the margin. Without some sort of additional incentive, they must justify themselves as energy cost savers, which are mainly fuel costs of either gas or coal, as expressed in the market. They earn no credits for reliability as the need for reliability plant will remain when renewable generation is absent.

[2] Subject to adequate gas supply, discussed later in this article.

An intermittent renewable plant installed today will save a mixture of coal and gas fuel. Going forward, there will likely be less coal plant and more gas plant in the mix but also, most likely, more renewable plant as well. At the time of writing the RET is still active and various State-based schemes have ambitions for renewables uptake. At the same time, renewable costs have dropped and look likely to continue their decline.

With this background, the installed level of renewables is likely to increase for some time. More renewables may increase costs or, at some time in the not too distant future, more renewables may reduce costs. Certainly, the case for behind-the-meter solar seems compelling under current tariffs, even without subsidy[3].

In the absence of cost effective storage (other than Snowy and some other pumped storage), how far can renewables penetrate the system? The limit is NOT driven by reliability concerns, as we ensure reliability by having sufficient gas plant available[4]. Bear in mind that gas turbines have relatively low capital cost.

To answer this question, consider a system where the nominal capacity of installed renewables is equal to the maximum demand in the system. The renewable energy generated in this system must be spilled quite a lot. Why? Not infrequently, renewable plants could be generating simultaneously at or near their nominal ratings. However, thermal plant in the system cannot be entirely backed off or shut down, so some fraction of the renewable output must be spilled. Network constraints would add to this spillage.

It follows that, in the absence of storage, it would be very difficult for renewables to penetrate to the point where the nominal rating matches the system load, as their cost effectiveness would decline rapidly as more energy is spilled.

Now the capacity factor[5] of wind without spillage is typically around 30%; solar is typically somewhat less and focussed in daytime hours. It follows that, in the absence of storage or an ongoing and significant subsidy, it would be very difficult for renewables to penetrate to save thermal energy beyond the levels of their capacity factors.

In the absence of storage or significant subsidy, this puts a pretty firm practical upper limit on the level renewable penetration at around 30% of energy generated, a fair way short of the 50% stated ambition of some parties, and even further from the 100% target of others.

We show this move to renewables as the orange line in Figure 4 . The emission reduction is at most around 25-30% from the mostly gas Case 5, and the costs slightly lower or higher, depending on what we assume about the cost of renewables relative to the cost of gas over time. The chart shows a slight increase as an example. In practice, we could get to this end point in many ways.

Roll in the storage!

For the cases so far we will have coal and gas marginal at various times, with lesser periods of tight supply and zero or negative prices when renewables must be spilled. Despite renewed interest in pumped storage, it seems unlikely that a large number of economic new or expanded sites will suddenly be found after so many years[6]. Further, battery costs remain too high for batteries to be justified on the basis of spot market energy cost savings alone[7].

Domestic and other embedded options, however, are different, because retail tariffs are much higher than wholesale prices. Currently, a solar/battery package can almost make sense to those with a suitable load and who are also inclined to be early adopters. If they also had access to ancillary service income and income from removal of network constraints, (deliverable with software and rule changes), the case would be that much better[8]. As battery costs decline, the justification would improve again. Early

[3] Some may argue that this is due to pricing distortions at the retail level which cannot be sustained. There are ways to deal with this which would take another Insider article to explore!

[4] Whether the market can and will deliver this outcome is another matter, discussed later in this article.

[5] Capacity factor is defined as the actual energy output as a fraction of the nominal energy output if all generation is at the rated capacity. For renewables, the capacity factor is limited by the pattern of availability of the resource.

[6] This remark includes Snowy II, the business case for which remains unscrutinised

[7] Existing large scale batteries have generally been government supported and justified on the basis of fast construction and for their value in providing ancillary services. These are valid reasons but not currently available to all.

[8] In this section we assume that storages/batteries would operate essentially on a daily cycle. Storage costs to operate for longer than a day would in most cases be prohibitive.

growth of the electric vehicle fleet may also accelerate the use of batteries at the distribution level.

At the time of writing, high battery penetration without assistance seems to be some way off. However, offering some assistance when combined with improved market arrangements could see significant early take-up of batteries.

We illustrate the scope for further cost and/or emission reduction using batteries (with renewables) by the dotted blue arrows in Figure 4. Note that the direction and extent of change is uncertain. However, emissions cannot reach zero because there will be times when gas must be used to carry the system through extended periods of low renewable production.

Is there scope for coal and nuclear?

The market price outcome under the cases discussed so far depend largely on the interplay between gas costs and renewable costs as well as the uptake of storage. We can consider the various possibilities in turn.

If gas costs (short and long term) and renewable costs are both low, coal and nuclear will have no practical opportunity, as cost and long lead times will likely count against them. This is so regardless of whatever policy is applied to renewables and storage.

If gas costs are high (short and long term, as seems likely) and renewable costs are sufficiently low for them to act as fuel savers, there could be extended periods where prices are near zero as well as other periods where gas is marginal and supply occasionally constrained. Coal and nuclear may have a market opportunity here but, again, long lead times and clashes with emissions policy could be telling factors.

If gas costs are high and renewable and battery costs also remain high, then coal and nuclear have a chance. Coal will have a chance if emissions are judged to be unworthy of policy consideration (i.e. current policy extended long term). However, the long lead time would be inhibiting; the market for base load power at a good price would likely need to be established before an investor would commit. Nuclear could be favoured if emissions are judged to be important while renewable and gas costs are high, and if other objections to nuclear can be set aside. Again, the long lead time of this Case does not address the short to medium term needs of the system.

There is no reason to arbitrarily exclude these options from consideration, but scenarios with new coal and nuclear appear to be less likely than gas-based scenarios, with or without aggressive renewables and/or emissions targets.

Things to Ponder

Will the market deliver?

Over the last few years, supply problems in South Australia and elsewhere as well as the cumulative effect of years of policy neglect and folly have strained the public's faith that the NEM as currently constituted can deliver affordable and reliable power.

The NEM should be able to deliver the Case described in this paper, unless derailed by clumsy government intervention and a failure to address outstanding NEM issues. Reasonable gas availability and cost is an example. Over a 30-year timescale the NEM must evolve to accommodate small scale and autonomous generation and to deal with associated security and market operations issues. These and other issues are discussed in following sub-sections.

Gas supply

With the rapid development of Queensland's LNG export industry and constraints on gas exploration in place in some states, the cost and availability of gas is a key issue for the plant development plan outlined in this paper.

We must assume that gas will cost at least the export netback price which, looking forward, is typically considered to be in the range of $8/GJ. The challenge is delivering the required volumes to NEM generators, as and when needed.

If an aggressive renewables policy continues, the pattern of gas usage is likely to be intermittent and, to a substantial degree, unpredictable.

One possible way to quickly deliver such gas is through one or more LNG receiving terminals on the east coast, an apparently strange idea[9]. Gas turbine and combined cycle

[9] Apparently strange but not original. See https://www.smh.com.au/business/the-economy/forrest-to-build-nsw-s-first-lng-import-terminal-at-port-kembla-20180604-p4zja7.html

plant can be located nearby, perhaps owned by competing entities. The advantage of LNG import is that LNG can be stored locally, removing the requirement to build and pay for high capacity infrastructure for only occasional use. The cost would be closely aligned to world LNG prices.

Declining Inertia

As coal plant retired and is replaced by gas plant, the inertia in the system will decline. If some gas plant is shut down, when renewable output is high, the decline would be even more, and renewables offer limited or no inertia to the system. How can this be made to work?

- FCAS can be improved by supporting fast acting responses and generally improving FCAS arrangements to bring in non-scheduled participants.
- Through the above improvements or by other means, keep gas plant on line and spinning as a synchronous generator, even if not generating. Suitably designed plant would help.
- Dedicated synchronous condensers could be used to provide inertia.
- Ultimately, there may be some power electronic mechanism to maintain synchronisation of the grid. However, such a system has yet to be demonstrated.

If the necessary R&D is done, this issue should not inhibit the plant development program.

Large scale v. small scale renewables and batteries

Large scale renewable and storage such as Snowy II under the current NEM rules only need to pay their connection costs to the network, regardless of any further grid strengthening that may be required. Planning can concentrate this additional expenditure into areas rich in quality renewable resource so such costs can be reduced and shared, but they remain.

In contrast, batteries embedded in commercial and domestic environments will almost always be operated to flatten load and reduce the pressure on local networks. They can also be used to relieve local network constraints and provide FCAS, given suitable incentives. There will be local safety and voltage issues to deal with, but the commercial case for behind the meter PV and batteries appear more compelling than for large scale transmission-connected systems, provided the market mechanisms are in place.

The AEMC has examined how small scale facilities might operate in the distribution network, without making much progress. It has identified a requirement for an “optimising function” to allow all the various value streams to be managed efficiently. It seemed to suggest that it would be the job of a retailer or perhaps some entity such as a Virtual Power Plant (VPP) to manage customer systems.

However, needed most are appropriate pricing policies at the distribution level; to encourage responses to wholesale price volatility, to meet FCAS requirements and for local network relief. Very little practical progress is evident in this area. With these pricing arrangements in place, middle men would then need to add real value to customers, rather than being a necessary party to deal with to get access to value streams beyond retail tariffs.

Market arrangements to support distributed options, especially batteries, should be given priority with a crash R&D program.

Conclusions

There remains a popular perception the high levels of renewables necessarily imply unreliability. This is false. This article has developed a specific scenario with moderately high renewable penetration which, in principle, should be reliable and affordable. The notion of affordable must account for the choice we have made to expose local industry to export gas prices.

Assuming adequate supply arrangements, gas plant can *always* provide cost-effective backup for system reliability.

However, there is a threshold of around 30% where the economic case for renewable energy declines rapidly due to increasing spillage. Penetration of renewables beyond this threshold will require the development of large volumes of cost effective storage, wherever that may be. Right now, embedded options look the most attractive to this writer.

However, AEMO must also learn to operate the system more securely as these newer technologies begin to dominate. The Final Report of the Incident of 25 August 2018 is a reminder that all is not well with system security right now.

AEMO’s work program on system security (endorsed by AEMC) is focussed on trying to make existing systems work better when some of these systems are no longer fit for purpose. More robust, long term solutions appear to have receded from view. As Churchill once said of Americans; you can always count on AEMO to do the right thing after they have tried everything else.

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