100% Renewable Electricity for Australia: Response to Lang

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This is a personal response to Lang's (2012) article critiquing the peer-reviewed paper Elliston, Diesendorf and MacGill (2011) 'Simulations of scenarios with 100% renewable electricity in the Australian National Electricity Market', referred to hereinafter as EDM (2011).

I appreciate the large amount of work that Lang has done in attempting to assess our work. However, I think his critique is premature, because he has misunderstood the intent of our work, which was clearly identified as exploratory. It is the first of a series of planned papers that will pick up on some of the issues that he has raised (and others) and step by step prepare the ground for an economic analysis. Several other questions that he raises are simply repetitions of questions that we have already raised and in some cases answered in EDM (2011).

Lang appears to be confused and mistaken in some key issues, such as the reliability of generation, where his conclusions are incorrect and potentially misleading.

Reliability of generation

Lang misunderstands and hence misrepresents our result that, in its baseline scenario, supply does not meet demand on six hours per year. He draws an incorrect conclusion from this result to claim that 'renewable energy cannot realistically provide 100% of Australia's electricity generation'. However, he overlooks the fact, clearly stated in the abstract, the main body and the conclusion of EDM (2011), that all our scenarios meet the same reliability criterion as the existing polluting energy system supplying the National Electricity Market (NEM), namely a maximum energy generation shortfall of 0.002%. This criterion inevitably means that any energy supply system, including the existing fossil-based system, is likely to fail to meet demand on at least several hours per year.

This is simply realistic, because no electricity supply system has 100% reliability. To achieve this ideal would require an infinite amount of back-up and hence an infinite cost. For this reason, electricity supply systems have reliability criteria such as Loss-of-Load-Probability (LOLP, the average number of hours per year that supply fails to meet demand) or energy shortfall. The NEM uses the latter. Since Lang refers to LOLP later in his article, he presumably partly understands this fundamental principle of electricity supply, yet somehow forgets this when critiquing the principal conclusion of our paper.

His oversight invalidates his conclusion. Hence our conclusion stands: namely that, subject to the conditions of the model, a 100% renewable electricity system is technically feasible for the NEM based on commercially available technologies.

Lang's belief that we must add 20% reserve plant margin is also based on misunderstanding and confusion. The generating capacity of our baseline renewable energy system is 84.9 gigawatts (GW) and the maximum demand on the NEM in the year we simulated, 2010, was 33.65 GW at 3 pm on 11 January. Our baseline renewable energy mix met this demand with several GW of gas turbines in reserve. Applying the conventional definition would give us a reserve plant margin of 150%. Clearly the conventional concept of reserve plant margin needs rethinking when there is a very large percentage of renewable energy supply. However, Lang's notion that we would need 33 GW capacity of gas turbine capacity to become 'reliable' is inappropriate, because it would give our renewable energy supply system a greater reliability than the existing fossil fuelled system The key parameter is the reliability of the whole supply-demand system, whether measured by LOLP or energy shortfall, not the reliability of individual technologies or the amount of reserve plant.

Of course, a more detailed model would have to take account of network failures; regional variations in supply, demand and transmission capacity; and extreme weather events. These are expected to entail adjustments to the supply mix and a variety of demand-side measures.

EDM (2011 and 2012 submitted) show that we can reduce the baseline gas turbine capacity of 24 GW in the renewable energy mix, while maintaining the reliability of the generating systems, in several different ways. These include either increasing the CST generating capacity while keeping the solar multiple fixed (the approach of Wright & Hearps (2010)); or increasing the solar multiple while keeping the CST capacity fixed; or reducing the winter peak demand by various measures.

Biofuelled gas turbines

Lang claims incorrectly that "Gas turbines running on biofuels are not a proven, commercially viable electricity generation technology at the scale required (IEA, 2007)". Putting aside his phrase 'at the scale required', which I'll return to shortly, it should be noted that his IEA reference is five years old and does not support his assertion. It is a 4-page pamphlet, which does not discuss biofuelled open-cycle gas turbines, the technology used in our paper.

Open-cycle gas turbines are a commercial technology, proven for several decades. They are used both as peaking plants in electricity supply systems and as jet engines on aircraft. If you fly on some overseas airlines today, the jet engines of your aircraft may be fuelled partially or totally on biofuels. Gas turbines can be fuelled on oil, natural gas, bio-ethanol, biodiesel, etc., with little or no modification, although for some fuels a modified fuel preparation system may be required. However, it's actually easier to burn biofuels in gas turbines on the ground, because one doesn't have the problem of keeping the fuel temperature high. EDM's scenarios assume conventional aero-derivative gas turbines burning the above biofuels.

Small modifications to gas turbines are required to burn syngas (a mixture of hydrogen and carbon monoxide that can be produced from fossil fuels or biomass) and such flexible fuel turbines are commercially available from GE and other manufacturers. So, if syngas derived from biomass were to become one of the future biofuels, there seems to be no good reason why the turbines in mass production would be significantly more expensive than unmodified gas turbines.

An alternative option to gas turbines is conventional gas and diesel gen sets, which have increasingly impressive efficiency and low capital costs (eg. $800/kW for a 50MW plant in SA that can connect to grid and start in 2 minutes).

Lang's phrase 'at the scale required' could be applied unfairly to all the commercially available technologies in our 100% renewable electricity scenario. If we assume that the transition to 100% would occur over several decades, there would be no unsurmountable problem in scaling up the technologies, including gas turbines. Hence, the term 'at the scale required' is irrelevant. All the new renewable energy technologies used in our models can be scaled up very quickly, because they can be readily mass-manufactured and the installation on sites is straightforward. For instance, China doubled its wind capacity each year for five consecutive years commencing 2005. Global solar PV capacity has increased at about 40% per year over the past decade. For comparison, nuclear power stations are a much slower technology to scale up, because they are gigantic construction projects and much of the work is site dependent.

The biomass fuel would be derived mostly from the residues of existing crops and plantation forests. Hence the land required would not compete significantly with food production or native forests. During a non-drought year it is estimated that around 30% of Australia's electricity could be supplied from biomass residues (Diesendorf 2007, chapter 7). To allow for drought, our baseline scenario generates about 14% and other scenarios discussed in EDM (2011 and 2012 submitted) generate less than that.

Hydro, CST, PV and wind

Lang's comments on the constraints on water releases are pertinent and will be taken into account in our future work. However, hydro plays a minor role in EDM's current scenarios and his constraints are unlikely to change our principal results. More generally, there appears to be no good reason for assuming that the present operational strategy for hydro, or indeed for the whole electricity grid, would be optimal for a 100% renewable system. Hence some of the sensitivity analyses in our ongoing simulations are designed to explore different operational strategies.

Most of Lang's comments on CST and PV are actually questions and most of the answers are already given in the paper. For instance:

- Spilled energy is reported.
- The capacity factor for CST of 60% is not a direct assumption of the model, but instead is determined by the choice of solar multiple and locations.
- A check of the performance of Australia's existing wind farms shows that an average capacity factor of 30% is about right. Some have higher values and others lower.

Winter peak demand reductions

Although demand reductions play a minor role in the first EDM paper, the authors see no good reason for excluding them from the system. They are recognised as having huge potential by the IEA and in European Union energy policy. They play a more significant role in EDM's forthcoming second paper. Many energy researchers, including the present writer, consider demand reductions to be 'negawatts', a well-known term in sustainable energy. These reductions can be achieved from energy efficiency, solar air conditioning, solar hot water and by off-loading certain energy users for a few hours during periods of high demand and/or low supply. Indeed, occasionally off-loading aluminium smelters for periods up to two hours is current practice, helping to avoid blackouts in existing electricity supply systems when supply fails to meet demand.

Transmission and economics

EDM's first two papers have the 'copperplate' assumption and hence are not designed as a basis for doing the economics of 100% renewable electricity. If all goes to plan, our third simulation paper will begin the complex task of examining transmission requirements. After that a preliminary examination of the economics could be justified. Simulation modelling must first be done with the 'copperplate' assumption removed. Lang has not done this. His calculations are indeed 'crude', as he admits, and full of dubious assumptions, so there is no need to spend time and space commenting on them in detail here.

However, it must be mentioned that Lang's assumption, that the capital cost of open-cycle gas turbines is \$5,051/kW, is too high by a factor of over *six*. These are the same gas turbines as currently used with fossil fuels. EPRI (2010, Table 7.15), a study cited by Lang, gives a capital cost of \$801/kW sent out. Lang's huge error greatly inflates his cost estimates of the renewable energy scenarios.

Also, since the EDM model assumes a dramatic scale-up of the numbers of each of the renewable energy technologies, over a long time frame, it is inappropriate to use their current prices.

There is no doubt that all biofuels (except landfill gas) are more expensive than *current* world prices for fossil gas. However, with peak oil already reached (according to the IEA), and natural gas and coal seam methane being the principal potential substitutes for oil in transportation and petrochemicals, the long-term price trajectory for gas is likely to be up and up. Carbon prices may also become more widespread and much higher in the long-term. Meanwhile the prices of biofuels are likely to decline with scale of production. So it's unclear whether gas will still be cheaper than biofuels in (say) 2030.

Conclusion

'Simulations of scenarios with 100% renewable electricity in the Australian National Electricity Market' is the first in a series of planned papers that are step by step removing simplifying assumptions on the simulation modelling of 100% renewable electricity. The first paper removes several of the assumptions made in the ground-breaking work by Wright & Hearps (2010). The second paper, currently being peer-reviewed for an international scholarly journal, offers a much more detailed sensitivity analysis than the first. The third, for which research is in progress, will commence the examination the effects of transmission constraints. The fourth is planned to be a preliminary exploration of the economics. Meanwhile, other papers are being published on the analysis of Australia's solar and wind data. It is hoped that each paper will answer more of the questions that Lang and other readers may ask.

The conclusion of Lang's critique, that our first paper shows that "renewable energy cannot realistically provide 100% of Australia's electricity generation", is incorrect and potentially misleading. The error seems to be based on a misunderstanding of the fundamentals of the reliability of electricity supply. No electricity supply system can be 100% reliable. Our 100% renewable electricity systems have been designed to meet the same reliability criterion as the existing polluting system.

Our simulation modelling shows that a 100% renewable electricity system is technically feasible for the National Electricity Market based on commercially available technologies. It also shows that there is no need for base-load power stations. As acknowledged in our paper, the modelling needs further refinement, notably the removal of the 'copperplate' assumption and inclusion of a greater diversity of wind farm sites. However, these two particular refinements, taken together, will offset each other to some extent, and so they are unlikely to change our principal qualitative result. Other refinements, such as consideration of network failure and extreme weather events, must be considered in relation to the detailed geographic distribution of renewable energy supply and demand, and of demand management operations.

Lang's comments on hydro constraints are pertinent and will be addressed in future research. However, since existing hydro plays a minor role in our current scenarios, the hydro constraints are unlikely to affect the principal qualitative result, although they may have a small quantitative impact. Most of Lang's other objections and comments are minor.

At this stage it is premature to attempt an economic analysis. When this is eventually done, realistic assumptions must be made about future prices of renewable energy technologies in large-scale mass production, gas turbines and their fuels, and future carbon prices. Lang's economic estimates are tied to current prices, apart from an overestimate of the capital cost of gas turbines by a factor of over six. Hence his cost figures are gross over-estimates.

References

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