LARGE-SCALE WIND AND SOLAR DEPLOYMENT IN THE NEW ZEALAND HYDRO BASED ELECTRICITY MARKET -TOWARDS A ZERO CARBON SYSTEM.

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Overview

The New Zealand government has has recently announced an intention to have a net-zero emission economy by 2050. This means that electricity generation must have close to zero carbon emissions. In this paper, we discuss a potential framework for achieving this by significantly increasing solar PV and wind capacity. Building a low carbon electricity system is challenging, as renewable electricity supply is often volatile. A promising strategy is to diversify the types of renewable generation so that net demand is less intermittent. (Pritchard, Zakeri and Philpott, 2010; and Hirth, 2013), which is why we consider different combinations of solar and wind generation.

Recent years has seen a dramatic increase in solar PV capacity in New Zealand- albeit from a low base. Between 2014 and 2017, installed capacity increased 10 times to 50MW. Further cost decreases expected over the next decade are likely to increase the uptake of solar PV. Miller et al. (2016) estimate that eventually installed solar capacity in New Zealand could be as high as 5.5GW. To put this in context the current peak demand in New Zealand is about 6.5GW. Wind resources in New Zealand are good with capacity factor of up to 40% not uncommon. So it seems timely to examine the potential of both wind and solar to contribute to a 100% renewable electricity supply.

A potential obstacle to increasing the amount of renewable generation for the New Zealand market is the reduction in hydro generation (which produces 57% of total generation), and the need to increase other generation during dry years. During dry years, there are low inflows in the period leading up to winter when the need for generation is highest. From winter onwards, much of the precipitation falls as snow and inflows are small until the snow melts in spring. During dry years generation is reduced during the months leading up to winter to conserve hydro generation potential, which leads to water having a scarcity value and higher electricity prices. One of the aims of our investigation is to see how different combinations of solar and wind will affect the market during dry years, and to see to what extent are they complimentary sources of renewable energy.

The renewable electricity generation scenarios for New Zealand will likely include large amounts of electricity offered into the spot market at a price of zero, including the intermittent wind and solar generation, as well as geothermal (15% of total generation), and must-run hydro. The New Zealand Electricity Authority models generation expansion scenarios based on: expected demand; fuel and carbon prices; a merit order using long run marginal costs; combined with various constraints including security of supply constraints. Whilst the Generation Expansion Model (EA, 2010) calculates the equilibrium capacity mix it does not model actual price formation. The first aim of this work is to model price formation to understand the impact of large amounts of intermittent wind and solar on the electricity market. Prices are expected to become much more volatile as there will be large amounts of generation bid into the market at a prices of zero combined with price spikes when the intermittent supply is less available. We investigative how volatile prices change the risk profile and investment incentives for new generation especially for capital intensive generation such as wind. The computer agent based model we use to model prices and dispatch means that we can also investigate the impact of the new intermittent generation on market power. The final aim of the paper is to see to what extent the intermittent generation can combine with hydro acting as a "battery" to facilitate a zero carbon electricity network.

Method

To model electricity prices and dispatch realistically we use a computer agent based model developed by Young et. al. (2014) which uses a modified Roth and Erev algorithm and applies it to a 19-node simplification of the New Zealand electricity market. The computer agents have a portfolio of generator assets and bid into the market. Profits are computed, using a simplified dispatch model of the New Zealand market, which are fed into a learning algorithm. New bids are constructed and the process is repeated until prices converge. The NZ Electricity Authority's Generation Expansion Model (EA, 2010) is used to generate a number of different scenarios for 2025 with varying amounts of intermittent wind and solar generation imposed as a constraint. Apart from the baseline each of the scenarios is constructed so that potential intermittent generation is the same over the course of a year. The intermittent generation contributes up to 20% of the total yearly generation. The demand projections from the Statement of Opportunity (EA, 2010) are used as well as expected line upgrades. Simulated wind data as well as actual solar data is obtained from National Institute of Water and Atmosphere. We simulate wholesale electricity prices for two years with different wind, solar and hydro inflow profiles. The program keeps track of inflows and generation outflows and updates the hydro lake storage levels each simulated day and computes a water value. We then compare simulations for a “dry” year (2006 historic data) and a “wet” year (2004) to see which combinations of solar and wind works best in terms of limiting market power as well as achieving a near zero carbon system.

Results

Simulated prices and summary statistics are presented in table 1 below.

Table 1. National demand-weighted price and standard deviations and other descriptive statistics ($/Mwh).

	2004 (“wet” year)					2006 (“dry” year				
	Price	σ	Number of periods with price (%)			Price	σ	Number of periods with price (%)		
			<1	>500	>800			<1	>500	>800
Baseline	191	151	4	4	0	228	195	8	11	1
High wind	136	185	35	5	2	183	231	38	11	3
Solar/wind	130	154	35	4	1	186	237	38	12	3
High solar	219	242	30	12	3	278	296	28	24	9

The first point is that, unsurprsingly, simulated prices across the board are higher for the dry year with 2006 meterological conditions. This is due to low inflows and hence low hydro lake levels in winter and high water values. The second observation is that large-scale deployment of wind and the mixed solar/wind scenario perform considerably better than the baseline in terms of limiting market power. Large scale deployment of solar on its own performs condierably worse than all the other scenarios with very high prices and very high price volatility. Both the high wind and the mixed solar/wind scenarios have high levels of renewable generation - between 89% for the dry year and 93% for the wet year considerably higher than the baseline numbers of 73% during the dry year and 77% for the wet year. Large scale deployment of solar sees considerable spillage with lower renewable generation of 83% for the dry year and 87% for the wet year.

Conclusions

The simulations found that the scenario with large scale deployment of wind as well as the scenario with a mixture of solar and wind both achieve high levels of renewable generation but fall short of the 100% target. The problem being that higher levels of intermittent generation lead to spillage during the times when the intermittent resources are abundant. Whilst the hydro dams do have the capacity to act as a battery, helping to smooth the renewable output, this is not enough to achieve the target. It is likely that further storage capacity would be needed or bio-fuel plants would be needed to achieve a zero carbon electricity system. A positive result of the simulations is that the increasing amounts of solar PV can have a positive market impact if combined with a relatively modest increase in wind capacity (from 1500MW to 4000MW). Current policy settings do not include a feed-in tariff for roof top solar PV. The results presented here suggest that there may be a case for introducing one.

References

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