Peaking Capacity, CO2-e Emissions and Pricing in the South Australian Electricity Grid with High Wind Penetration 2005-2013

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Abstract

It is commonly claimed that intermittent renewable power sources are expensive, need to be matched by increased peaking capacity and that this additional reserve serves to negate emission reductions. This paper examines the South Australian experience to test these claims. South Australia has installed a number of wind farms over the last 8 years. Roughly one quarter of electricity consumed in the State is generated by wind. Publicly available data published by the Australian Energy Market Operator, AEMO is examined and trends in fuel mix and emissions are tracked. It is demonstrated that cost effective abatement can be achieved by integrating wind into a system such as South Australia's without a corresponding increase in peaking plant.

Introduction

South Australia now has high wind energy penetration by international standards. In the 2012/13 financial year wind produced 25% of its electricity. This makes South Australia a good test case for examining some of the common complaints made against this generation technology, namely; that it requires continual 'back-up', that its abatement is negligible, and that the costs are onerous. The paper relies heavily on data published by Australian Energy Market Operator, AEMO, and focuses on the eight year period from 2005/06, up to and including 2012/13.

Wind Generation in South Australia

In the eight years from 2005/06 to 2012/13, the amount of wind generation capacity in South Australia grew from 388 MW to 1203 MW[1,2]. At the end of that period, wind made up 24% of the state's installed capacity. Wind also makes up 28% of electricity produced within the State. This indicates that the capacity factor of wind exceeds that of the system, a point that critics often fail to note.

In 2005/06 wind turbines generated 765 GWh of energy, while in 2012/13, this has grown to 3487 GWh, an increase of over 350%; enough to power the average requirements of over 540,000 typical Australian homes[3]. For reference South Australia has 640,000 homes[4] and the wind generation is therefore approaching the point where it matches domestic electricity consumption. The 270MW Snowtown 2 wind farm was under construction at the end of the period examined. It is therefore likely that soon wind power will be producing the annual electricity requirements of every home in the State.

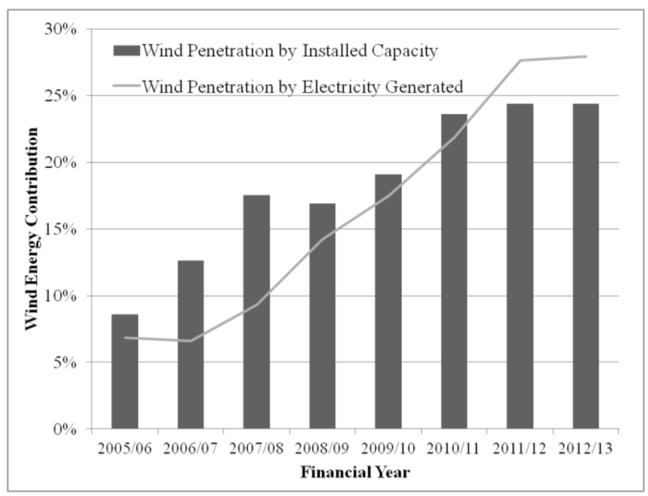

Figure 1 Wind energy penetration by installed capacity and generation.

[1] http://www.aemo.com.au/Electricity/Planning/South-Australian-Advisory-Functions/SA-Generation-Information (note that 270MW from Snowtown 2 was not commissioned at this time)
[2] http://www.aemo.com.au/Electricity/Planning/South-Australian-Advisory-Functions/South-Australian-Historical-Market-Information (AEMO Report)

[3] http://www.aer.gov.au/node/9751 (ACIL Tasman results for 3 person SA household, Table 17)
[4] http://profile.id.com.au/australia/households?WebID=130

Carbon Dioxide Emissions

In 2005/06 South Australia's generators were responsible for emitting 9.3 Million tonnes of carbon dioxide equivalent (Mt CO2-e). In 2012/13, this reduced to 6.2 Mt CO2-e. During this same period, electricity demand remained almost static at about 13,800 GWh[5]. Therefore, the emission intensity reduced from 0.68 to 0.45 tonnes of CO2-e per megawatt hour (t CO2-e/MWh). This is an emission intensity reduction of 34.5%.

In this study we are interested in what proportion of this reduction can be attributed to wind generation. During the period of 2005/06 to 2012/13, changes in the fuel mix have included reduced electricity imports from Victoria and changes in the relative proportions of fossil fuel generation. In addition, SA has built substantially more wind power. As a result of these changes, annual emissions have reduced by 3.1 Mt CO2-e.

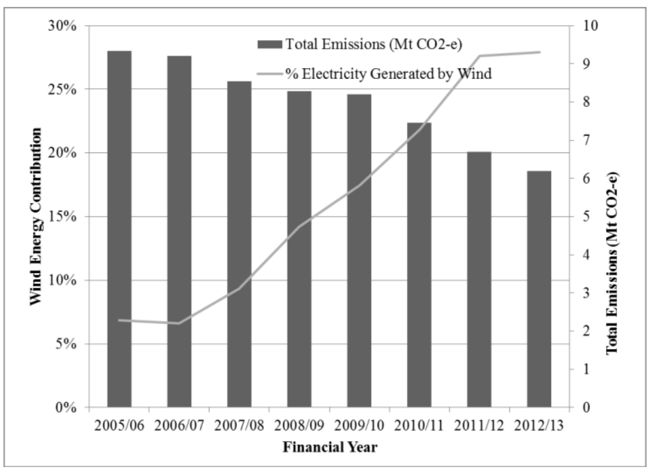

Figure 2 Emissions compared with wind energy contribution

Wind power has directly displaced both other generation (and imports). We can calculate that these direct displacements account for 57% of the emissions reduction.

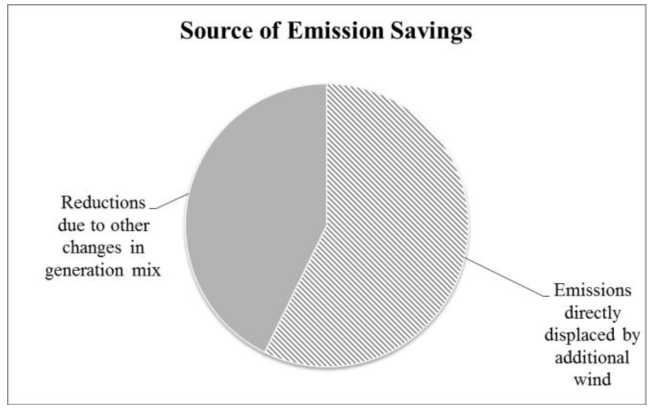

Figure 3 Source of emission savings 05/06 to 12/13

The remaining reductions come from changes in the remaining generation mix. The addition of wind has been accompanied by a move away from emissions-intensive coal and open-cycle gas toward cleaner fossil fuels.

The impetus for the changes in generation mix may in part be due to wind's impact on the spot market. The carbon price and changes in the availability of brown coal may also be factors for the move away from emissions-intensive sources.

Peaking Capacity

If critics of renewables are to be believed, we should have seen a substantial increase in peaking capacity as wind power has increased. Peaking plants respond rapidly to changing demand and supply. In South Australia this service is supplied by Open Cycle Gas Turbines (OCGT). Therefore, we examine how OCGT capacity and usage has changed over the last eight years.

[5] Usage figures obtained by adding generation figures from Table 5-1 (p84) to net interconnector power flow in Table 5-2 (p92) of AEMO report

The proportion of scheduled peaking generating capacity compared to peak demand stayed virtually unchanged at just over 25% which suggests wind has had little (if any) impact on OCGT installations.

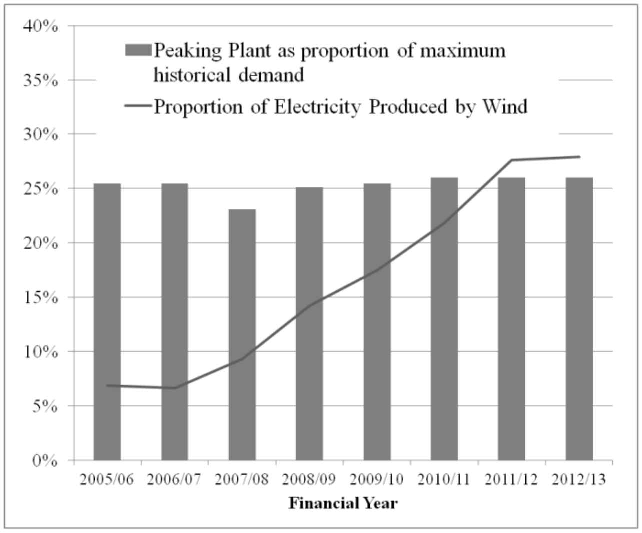

Figure 4 Peaking plant installations compared to wind generation.

The amount of power generated by the OCGTs fell from 501 GWh to 321 GWh in the eight year period. This is almost certainly due to wind power's 'free fuel'. When power is produced by a wind turbine and fed into the national grid, it displaces the highest cost energy that otherwise would have produced that power. In SA, that highest cost energy producer is frequently OCGTs. OCGTs are not only the highest cost, but also amongst the most polluting in terms of CO_2-e[6]. Their emission intensity is as poor as many coal power stations.

South Australia is connected to the Victorian network and it is possible that the peaking capacity is provided from Victoria. AEMO's data indicates that both total and net electricity imports from VIC have reduced in the last 8 years. This suggests the peaking capacity has not been imported from Victoria.

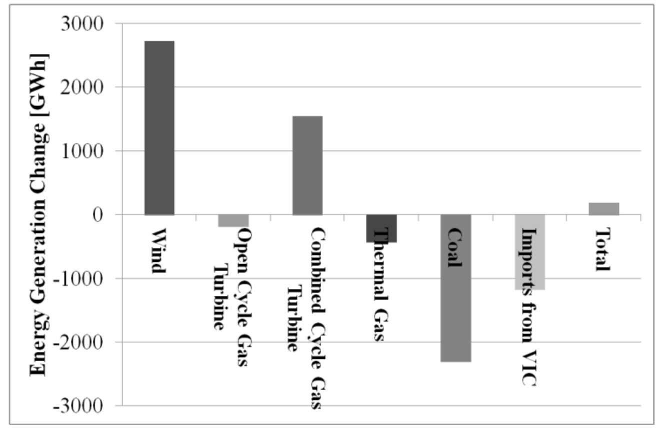

Figure 5 Changes in generation by generator type 05/06 to 12/13

Figure 5 shows a substantial change in South Australia's generation. A combination of policies has resulted in a move toward wind and baseload gas and move away from coal and imports. Peaking plants have generated less.

We can conclude that claims of wind causing the installation of 'back-up' generation are false. Furthermore South Australia has reduced utilisation of these emissions-intensive peaking plants.

Costs

South Australia gives us a good opportunity to examine the abatement cost of wind power. It is often claimed that the costs imposed on the system are large and disproportionate due to changes in the system. If this is the case we should see evidence in the wholesale price of electricity. Generators on the system receive payments linked to the 'pool' price. Wind power receives an additional revenue stream via large scale generation certificates (LGCs) which are typically sold at a price of around $40/MWh.

By examining historical trading data[7] we can compare the wholesale cost of generation in 2005/06 with the cost in 2012/13. To ensure we have the full wind costs we have added the LGC costs (note that most of these LGCs are actually funded from interstate). To remove any distortion we have removed the carbon price for 2012/13.

[6] http://www.nemweb.com.au/reports/current/cdeii/CO2EII_Available_Generators.csv

[7] http://www.aemo.com.au/data/price_demand.html

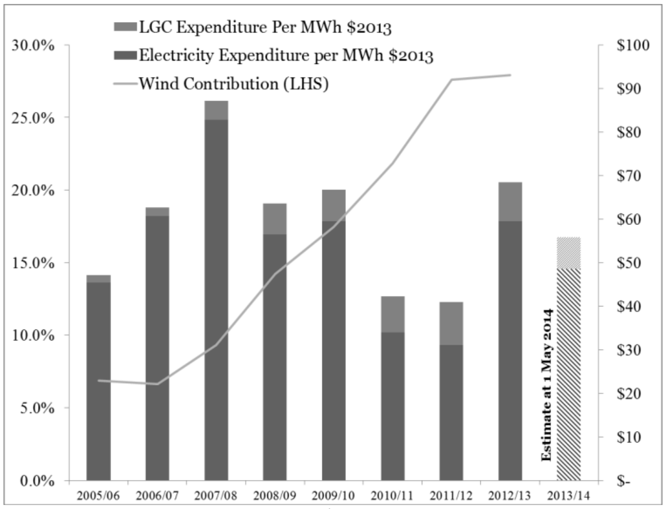

Figure 6 Wholesale prices in 2013$ inclusive of LGCs compared to the proportion of electricity from wind (ex carbon).

This analysis, completed in 2013$ (real terms) shows pricing volatility. Changes in unit price are due to a large range of factors including peak demand, gas prices, and shortages of cooling water in droughts. It is clear the prices do not correlate to the proportion of wind power. An examination of South Australia's pricing compared to other States shows its pricing has remained quite consistent with historical norms.

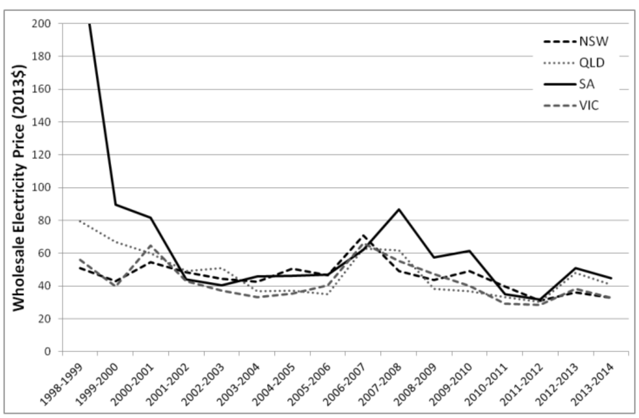

Figure 7 Historical wholesale prices in 2013$by State (ex-Carbon).

We conclude that emissions intensity has dramatically reduced whilst LGC-inclusive electricity pricing has remained substantially in line with historical norms and well below the peak in 2007/08. This suggests that abatement costs from wind power are low.

Summary

Wind power generation has increased substantially in South Australia in the last eight years, from supplying 6% of the state's needs in 2005/06 to 25% in 2012/13.

This increase in wind generation has been the primary reason for a 34% reduction in CO2-e emissions due to electricity generation. The electricity network has managed to accommodate this increase in wind power without increasing the amount of electricity required from peaking power plants.

Energy produced from these peaking plants has actually reduced during this same period, which has helped further reduce CO2-e emissions. Wholesale prices have not risen over the period (even with LGC costs included) and we conclude the cost of abatement using wind is low.