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

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Abstract

It is commonly believed 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 beliefs. South Australia has installed large numbers of wind farms over the last 5 years and now has roughly 21% of electricity generated in this manner. Publically 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 and in the 2010/11 financial year produced 21% of its electricity in this manner. This makes it 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 5 year period from 2005/6, up to and including 2010/11.

Wind Generation in South Australia

In the five years from 2005/06 to 2010/11, the amount of wind generation capacity in South Australia grew from 388 MW to 1150 MW[1]. Wind now makes up 23% of the state's installed capacity. Wind also makes up 21% of energy produced indicating that the capacity factor of wind roughly matches that of the system[2] and that criticisms about poor utilization are unfounded.

In 2005/06 wind turbines generated 765 GWh of energy, while in 2010/11, this has grown to 2994 GWh, an increase of almost 300%; enough to power the average requirements of almost half a million typical Australian homes[3].

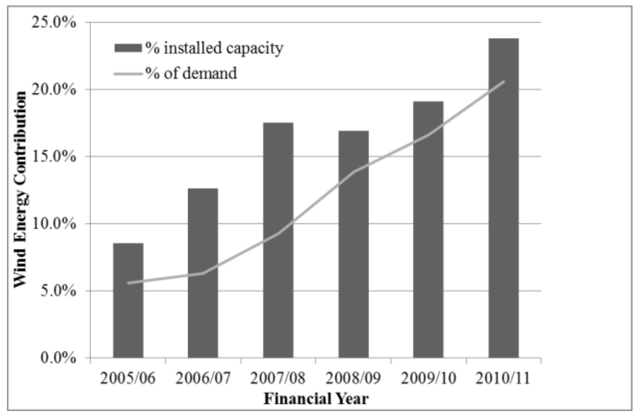

Figure 1 Wind energy penetration by installed capacity and generation.

Carbon Dioxide Emissions

In 2005/06 generators of South Australia's electricity were responsible for emitting 9.8 Million tonnes of carbon dioxide equivalent (Mt CO2-e). In 2010/11, this reduced to 8.0 Mt CO2-e[4]. During this same period, electricity demand increased from 13,718 GWh to 14,536 GWh[5]. Therefore, the emission intensity reduced from 0.72 to 0.55 tonnes of CO2-e per megawatt hour (t CO2-e/MWh). This is an emissions reduction of 18% whilst consumption rose by 6%, with intensity dropping 23%.

In this study we are interested in what proportion of this reduction can be attributed to wind generation. If South Australia's emission intensity had remained unchanged since 2005/06, then its emissions would have increased by 0.6 Mt CO2-e. During the period of

[1] http://www.aemo.com.au/planning/SASDO2011/sasdo.html (AEMO Report)
[2] http://ramblingsdc.net/Australia/WindSA.html#Installed_wind_power_in_SA
[3] See Fig 6 on page 14 of AEMO report.
[4] Data from Fig 6 AEMO report
[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

2005/06 to 2010/11, changes in the fuel mix have included reduced energy imports from Victoria and changes in the relative proportions of its own fossil fuel generation by adding more combined cycle gas turbines. In addition, it has built substantially more wind power. As a result of these changes, emissions have reduced by 1.8 Mt CO_2-e, giving a total reduction of 2.4 Mt CO_2-e compared to 'business as usual'.

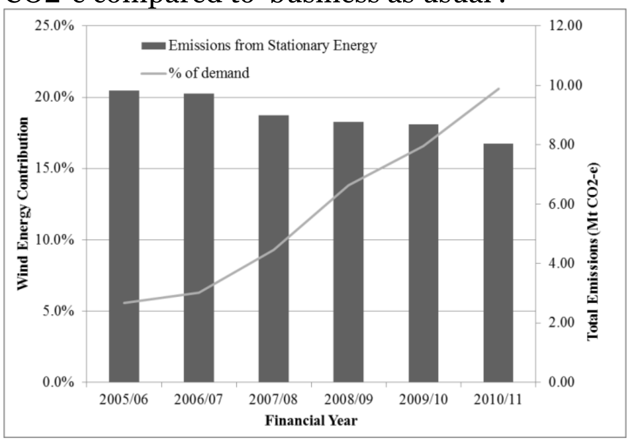

Figure 2 Emissions compared with wind energy contribution

By examining each change in turn we can identify the various sources of this reduction. Victoria produces most of its power from brown coal with very high emission intensity. South Australia substantially reduced its imports of Victorian electricity during these 5 years, by a total of 2,240 GWh. Replacing this high emission Victoria power and replacing it with non-wind South Australian power have saved 0.3 Mt CO_2-e. Improvements in the average emission intensity of its own non-wind generators have reduced the emissions by another 0.6Mt. Finally, producing an increasing proportion of its electricity from wind has improved emissions by another 1.6Mt of CO_2-e; by far the largest component of the improvement.

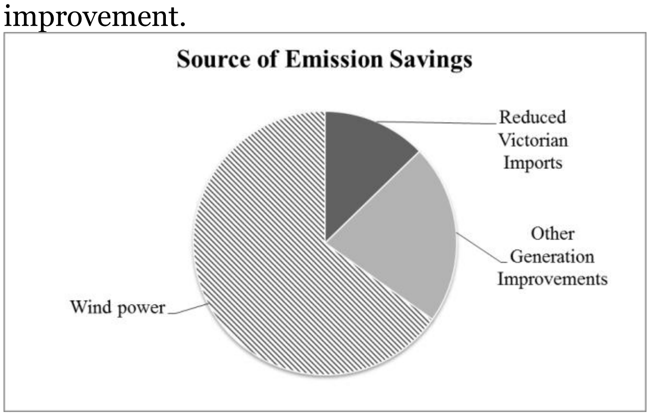

Figure 3 Source of emission savings 05/06 to 10/11

Peaking Capacity

If critics of renewables are to be believed, we should have seen an increase in peaking capacity as wind power has increased. Peaking plants need to respond rapidly to changing demand and supply. In South Australia this is supplied by Open Cycle Gas Turbines (OCGT). Therefore, we examine how OCGT capacity and usage has changed over the last 5 years.

We begin by examining the growth in peak electricity demand. Average usage in SA has increased by 93MW, or 6% in the last 5 years. By contrast peak demand has increased by approximately 370 MW, or 13%[6], much more rapid than average demand; indeed, the difference between average demand and peak demand has grown by 275MW[7], or 23%.

This naturally requires the installation of peaking capacity regardless of wind installations. This is confirmed by the AEMO data, as installed OCGT has increased by 200 MW, or 28%.

The proportion of peaking capacity compared total capacity remained virtually unchanged at about 18.5% which further suggests wind has had little (if any) impact on OCGT installations.

The amount of power generated by the OCGTs fell from 501 GWh to 325 GWh in the 5 year period, notwithstanding the 200MW of additional capacity. 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 typically OCGTs. OCGTs are not only the highest cost, but also amongst the most polluting in terms of CO_2-e[8]. Their emission intensity is almost as much as SA's coal power stations. This helps explain why SA's emissions of CO_2-e have gone down. Wind power has been displacing the high emitting OCGTs.

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[6] Based on Figure 2-11 of the AEMO report

[7] Quarantine Power Station increased its capacity by 129MW, Port Lincoln Power Station by 23.5MW and Hallet Power Station by 48MW.

[8] http://www.renewablessa.sa.gov.au/files/arp001sagovtemissionlimitspaperrev2-final.pdf

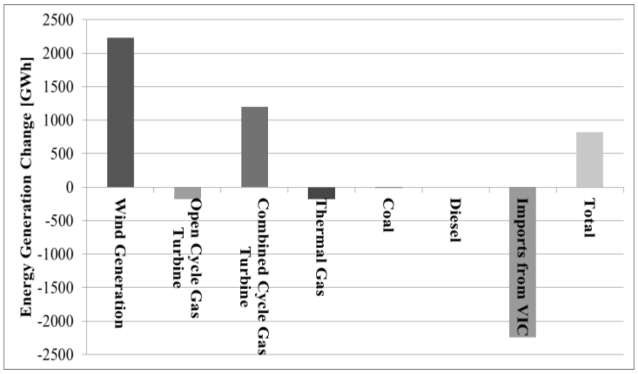

Figure 4 Changes in fuel mix and demand 05/06 to 10/11

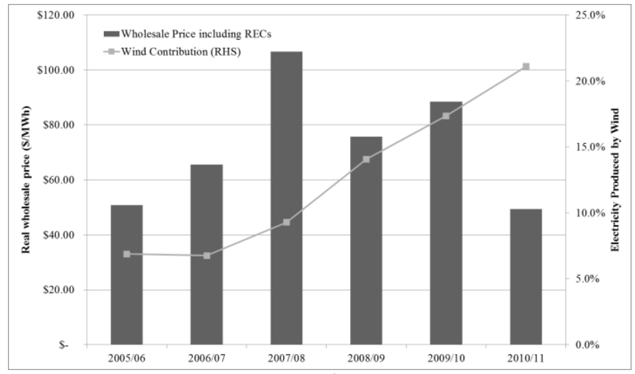

Figure 5 Wholesale prices in 2011$ inclusive of RECs compared to the proportion of electricity from wind

South Australia is connected to the Victorian network and it is necessary to verify that the peaking capacity required to balance the extra variability coming from the wind power is not provided from Victoria. AEMO's data indicates that net electricity flows between SA and VIC has reduced by 47% in the last 5 years. Thus the peaking capacity has not been imported from Victoria.

We can conclude that claims of wind causing installation of OCGT 'back-up' are false. Furthermore we can see that wind reduced the utilisation of these emissions intensive generation 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 renewable energy credits which are typically sold at a fixed price of around $50/MWh.

By examining historical trading data[9] we can compare the wholesale cost of generation in 2005/06 with the cost in 2010/11. To ensure we have the full wind costs we have added the REC costs.

This analysis, completed in 2011$ (real terms) shows that $700m was paid to all generators in 2005/06 or $50 per MWh. This rose to $717m in 2010/11 or $49 per MWh. Changes in unit price could be due to a large range of factors including trading strategies, the weather, system constraints as well as changes in the generation mix and we do not claim the fall in prices is completely due to wind. However we can see that South Australia has operated in 2010/11 with a large proportion of wind power, far reduced emissions, and with a wholesale price (including RECs) unchanged from 5 years earlier. This would suggest that abatement costs from wind power are low.

Summary

Wind power generation has increased substantially in South Australia in the last 5 years, from supplying 6% of the state's needs in 2005/06 to 21% in 2010/11. This increase in wind generation has been the primary reason for an 18% reduction in CO2-e emissions due to electricity generation, and a 23% improvement in emission intensity. The electricity network has managed to accommodate this increase in wind power without increasing the amount of electricity required from peaking power plants. The amount of peaking capacity has increased during this time due to a large increase in peak electricity demand, rather than from increased wind power. Energy produced from these peaking power plants has actually reduced during this same period, which has helped reduce CO2-e emissions. Wholesale prices have not risen over the period (with RECs included) and we conclude the cost of abatement using wind is low.

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