ISSN 1835-9728

Environmental Economics Research Hub Research Reports

The economics of transmission constraints on wind farms: some evidence from South Australia

Nicholas Boerema and Ian MacGill

Research Report No. 89

September 2010

About the authors

Nicholas Boerema is from the School of Photovoltaics and Renewable Energy Engineering at UNSW

E: nicholas.boerema@student.unsw.edu.au

Iain MacGill is from School of Electrical Engineering and Telecommunications and Centre for Energy and Environmental Markets University of NSW

i.macgill@unsw.edu.au

Environmental Economics Research Hub Research Reports are published by The Crawford School of Economics and Government, Australian National University, Canberra 0200 Australia.

These Reports present work in progress being undertaken by project teams within the Environmental Economics Research Hub (EERH). The EERH is funded by the Department of Environment and Water Heritage and the Arts under the Commonwealth Environment Research Facility.

Crawford School of Economics and Government

THE AUSTRALIAN NATIONAL UNIVERSITY

http://www.crawford.anu.edu.au

TABLE OF CONTENTS

ABSTRACT

The impacts of transmission congestion and network investment on the development of the Australian wind energy industry have received growing attention from wind farm developers as well as relevant policy stakeholders such as the Australian Energy Market Commission (AEMC).

There are many potential wind farm sites across the country with excellent wind regimes yet only limited transmission capacity. At least one wind farm in South Australia has spent a period following construction where its output was curtailed by transmission constraints (NEMMCO, 2009). Current market rules do not guarantee dispatch to an existing wind farm as more wind generation connects to the same transmission. Given the expense of transmission network extension and augmentation, there are interesting questions of what economic impacts such constraints might have for wind farm operators.

This paper examines this issue in the context of the South Australian region of the Australian National Electricity Market (NEM). The State currently hosts almost half of total Australian wind generation capacity and has significant transmission capacity limitations for further development. Half hour wholesale electricity spot prices were used along with generation data from nine South Australian wind farms over the 2008-9 and 2009-10 financial years to assess the potential impact that transmission constraints might have had on wind farm revenue.

Results showed that a number of the wind farms would have suffered only very limited revenue reductions from having significantly greater wind farm capacity than the rating of their transmission connection to the NEM. Importantly, some wind farms could be limited to a maximum power output of half their rated capacity and still achieve higher capacity factors then other already existing unconstrained wind farms.

The key reasons for this are that wind farms do not generate at rated capacity for a great deal of the time over the year, periods of high wind generation appear to be associated with lower wholesale prices and there is significant variance between the wind farms capacity factors. Our findings suggest that there may be circumstances where wind farm developers might benefit from installing more wind turbines than the capacity of their transmission connection.

Keywords: Integration, market price, NEM, South Australia, Wind

1.0 INTRODUCTION

As the level of wind generation capacity within Australia increases network access for new sites with adequate wind resources is expected to require significant transmission additions and augmentation. The design, approval and installation of additional network assets is a lengthy and expensive process. The AEMC (2009) has stated that network development is unlikely to keep pace with the speed of new wind generation investment. Of significant importance to any investment is the security of the rate of return. A significant drawback of renewable energy technologies is the large capital expenditure required and the long payback time. This increases the risk of the investment as the capital is committed at the beginning, and the project must maintain forecast returns year after year for the project’s financial success. Considerable advantages exist in developing strategies that delay expenditure and reduce the risk involved with investment into renewable energy project implementation. Thus to assist in wind achieving high levels of deployment whilst still being economically competitive, an idea has been looked at that increases the number of accessible wind sites with good wind resources, whilst avoiding immediate expensive transmission development.

The idea to be investigated is that it may be a more attractive investment option to construct or expand a wind farm whilst not upgrading the available transmission, even if the result is that a maximum power output constraint is enacted on the wind farm. For example a wind farm achieving a high capacity factor could be expanded, or a site exposed to a significant wind resource could be developed, but with the output of the farm limited to that permitted by the existing transmission. Thus at times power will have to be curtailed. This deliberate design of a wind farm of capacity greater than that permitted for transmission has been given the term “over-sizing”. The aim of over-sizing is to allow wind farms to be built at high wind sites, and thus achieve greater capture of energy from a renewable resource, whilst providing time for a more systemic transmission system to be developed, to reduce the capital expenditure required per MW of installed capacity, and to reduce the cost per MWh of electricity produced.

Network Service Providers (NSPs) have already previously enforced a maximum power limit on particular wind farms as part of their connection agreement (NEMMCO, 2009). This demonstrates the benefit that wind curtailment could create for wind farms trying to secure connection agreements with NSPs in locations where a significant wind resource exists that is only accessible with limited transmission. Alternative curtailment strategies other than enforcing a maximum power limit could also help to ensure connection agreements. For example wind power curtailment could be used when storm fronts are approaching that could present wind speeds greater than the cut-out speed of the turbines, or during wind conditions that present high fluctuations in power output. These curtailment options would reduce occurrences of wind farm power outputs suddenly decreasing. Wind power curtailment could also be used to limit wind farm ramp rates when other generators using the same transmission lines cannot ramp down their generation fast enough such that the transmission line limit may be exceeded. This is another form of constraint that would only be required in certain situations but would help in maintaining security. For semi-scheduled wind farms more dynamic constraints are possible as the wind farm is incorporated into security calculations and can be dispatched accordingly.

A wind farm for which adequate transmission exists may face the possibility of power constraint in the future if generation development in the region (for example a new wind farm) means that transmission constraints may at times be exceeded. This is a result of the fact that according to existing market rules it is not the generator that was first constructed that is given preference for dispatch but the generator with the highest market benefit. This highlights the importance of understanding the effects that a constraint may have on a wind farm, even if at present there is adequate transmission available (AEMC, 2010).

The aim of the modelling performed was to provide information to allow an analysis on the energy and income gains and losses associated with over-sizing the wind farms of South Australia. The State, which lies within the Australian National Electricity Market (NEM), currently hosts almost half of total Australian wind generation capacity and has significant transmission capacity limitations for further development (ABARE, 2010). The intention was to develop conclusions on the suitability of over-sizing that could be more broadly applied to wind farms in general. Construction of wind farms that are over-sized allows for higher levels of energy to be captured compared with building wind farms to capacities for which the power output will not at times need curtailment. The occasions of power curtailment will however reduce the revenue per megawatt of capacity installed, compared to the uncurtailed case. The aim is to assess the increases in energy and revenue produced and the amount of curtailment required to determine whether it is better to oversize and attain access to sites with high levels of wind or to place the wind farm where there is excess transmission capability but with the compromise of a lower value wind resource.

2.0 DATA AND METHODOLOGY

Modelling of the effects of over-sizing has been undertaken on nine South Australian wind farms, using half hourly output data obtained from the Australian Energy Market Operator (AEMO) website[1] for the period 1st July 2008 to 1st July 2010.

The common data time resolution used is 30-minutes and the total rating of these farms is 742.75 MW. Two of the wind farms modelled had constraints placed upon them for the first 4 months of the period studied. Thus over this period the total rating of the wind farms increases from approximately 627 MW to 727 MW, with Mt. Millar still appearing to be operating at a maximum of around 54 MW instead of its installed capacity of 70 MW.

Table 1 shows the variations in capacity factors occurring year to year, where the capacity factor of a wind farm is defined as:

$$\text{Capacity Factor} = (\text{Actual amount of power produced over time}) / (\text{Power that would have been produced if the wind farm operated at maximum output})$$

Note that the 2009 capacity factors are created from data for only the first part of the year and that Snowtown S1 and Mt. Millar were constrained for much of this time. Starfish Hill is connected to ETSA's 66 kV distribution network while the other eight existing wind farms connect directly to the transmission system (ElectraNet, 2009).

Table 1: Available capacity factors for the nine existing wind farms of South Australia (ESIPC, 2009).

[1] AEMO website: www.aemo.com.au

Year	Canunda	Starfish Hill	Lake Bonney	Cathedral Rocks	Wattle Point	Mt Millar	Hallett S1	Lake Bonney S2	Snowtown S1
2006	34%	31%	23%	19%	30%	70%			
2007	38%	20%	28%	33%	35%	15%		9%	
2008	34%	29%	28%	35%	35%	19%	32%	25%	27%
2009	26%	26%	21%	26%	32%	24%	35%	21%	39%
Network connection	132 kV	66 kV	132 kV	132 kV	132 kV	132 kV	275 kV	132 kV	132 kV

Spot prices were also obtained from the AEMO website for the same time period. Prices ranged from -1000 $/MWh to 10000 $/MWh. For the majority of the time the price was 20 to 40 $/MWh with an average price of 53 $/MWh. Figure 1 shows the importance of high price events as contribution to spot market revenue. It can be seen that approximately 50% of the revenue is generated within about 2% of the time.

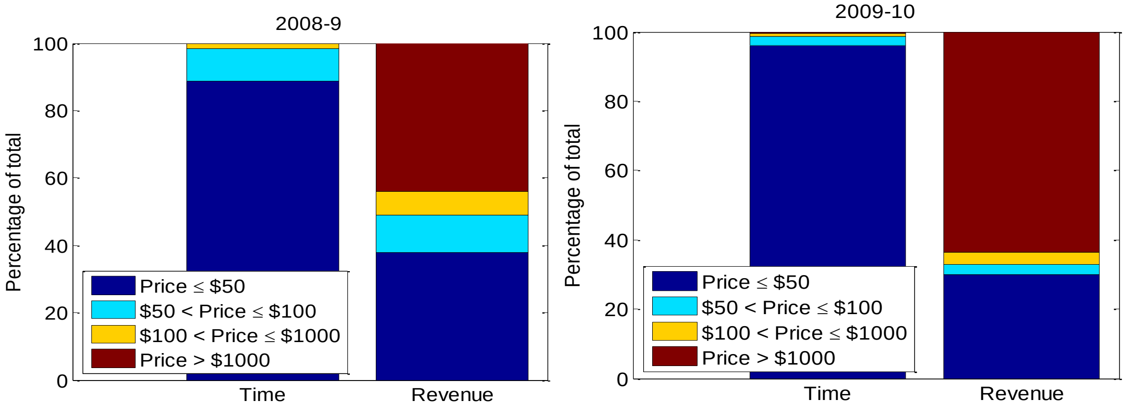

Figure 1 Time/Revenue stack for 2008/09

Whilst constraints placed on wind farms can be complex and are likely to depend on local network flows, generation and demand, a maximum power output constraint has been used for the modelling so as the results are less site specific and can be applied to wind farms in general.

For each wind farm a hypothetical maximum allowable power for transmission was used such that the amount of energy and revenue lost due to wind power curtailment could be calculated. The installed capacity of the wind farms was used for this value. Increasing the wind farm capacity (represented by a scaling of the data for the wind farm output) results in power having to be curtailed. The wind farms have been resized by factors ranging between 1 and 2. With 1 indicating a wind farm that is subjected to no power curtailment, and is thus not over-sized and 2 meaning a wind farm that has twice the installed capacity as that available for transmission. This is equivalent to a wind farm that is over-sized by 100%, or to a wind farm whose power output is constrained to 50% of its installed capacity. Programming was used for the manipulation of the aforementioned data to produce outputs for this range of resize coefficients. The output for the resized wind farm is the original wind farms average output observed for the half hour multiplied by the resize coefficient and then limited to the maximum power output. An analysis has been performed to determine the significant factors for maximizing the profit when over-sizing. Where necessary various set prices for Renewable Energy Certificates (RECs) have been incorporated into the modelling.

3.0 RESULTS AND ANALYSIS

First the capacity factors, average price per MWh and the product of these two (average income per hour per MW of installed capacity) were calculated for each wind farm for the data range.

The average price is given by:

$$\text{Average Price} = \frac{\sum Output_i Price_i}{\sum Output_i}$$

The half hour capacity factor (f_i) is given by:

$$f_i = \frac{Output_i}{OriginalCapacity}$$

The Yearly average capacity factor (F) is given by:

$$F = \frac{\sum Output_i}{n.OriginalCapacity} = \frac{\sum f_i}{n}$$

The average income per hour per MW of installed capacity is given by:

$$Ave.\ Income\ per\ hr\ per\ MW\ installed = Average\ Price.F$$

Where:

$Output_i$=The power that is approximately being produced for the period t_i, where t_i is half an hour for the data.
$Price_i$=Price at time t_i. Includes a set Renewable Energy Certificate price.
n=number of time divisions.
OriginalCapacity= the installed capacity of each wind farm.

The results of these calculations are listed in Table 2. It is interesting to note that although Hallet S1 has the highest capacity it does not have the highest income (per MW of installed capacity) due to it also having the lowest average price for the energy produced. This highlights the importance of siting wind farms not only for a high wind resource but also for locations where the wind resource is better correlated to higher prices. Snowtown S1 and Hallet S1 are located relatively close to each other yet the calculated average price received by Snowtown S1 is much higher. This is due to the fact that the power output of Snowtown S1 was being limited during late winter and early spring when prices are lower, meaning that the weighted average price was calculated with a higher percentage of the energy produced in summer when prices are higher. Actually the output of Snowtown S1 is quite correlated with Hallet S1 and thus the average price for Snowtown is likely to be closer to $40 per MWh. The weighted price of Mt Millar would likely also be affected from having been under constraint.

Table 2: Wind farms sorted from highest to lowest value according to Average income per hour per installed MW of capacity.

Wind Farm	AEMO Name	Original Capacity (MW)	Maximum Output (MW)	Original Capacity Factors	Original Ave Price per MWh	Ave Income (Ave$/hr/MW installed capacity)
Snowtown S1	SNOWTWN1	99[2]	98.11	39.3%	$ 48.97	$ 19.22
Wattle Point	WPWF	90.75	92.03	32.9%	$ 51.82	$ 17.04
Hallet S1	HALLWF1	94.5	94.37	40.3%	$ 40.54	$ 16.33
Cathedral Rocks	CATHROCK	66	60.24	32.6%	$ 47.34	$ 15.42
Mt Millar	MTMILLAR	70[3]	71.24	27.2%	$ 54.09	$ 14.73
Cununda	CNUNDAWF	46	43.48	29.5%	$ 44.01	$ 12.99
Starfish Hill	STARHLWF	160	34.34	28.7%	$ 44.46	$ 12.77
Lake Bonney S1	LKBONNY1	80.5	79.07	25.9%	$ 44.80	$ 11.59
Lake Bonney S2	LKBONNY2	35	154.68	21.9%	$ 46.89	$ 10.28

Table 2 shows that locations across a region can experience significantly different average prices, with differences of over 20% observed between locations. Year to year changes in average prices are also significant, with changes of near to 20% experienced between the two financial years. The large variation shows the importance of siting wind farms to obtain higher average prices. As shown in Figure 1, a large level of revenue is generated from infrequent high price events, meaning that the average price achieved by a wind farm will however be quite sensitive to the exact timing of these events.

The effects of over-sizing were then calculated and plotted. The fraction of energy that must be curtailed (W1) due to over-sizing is given by:

$$\text{W1=1-}\frac{\sum Output_j}{\sum Output_i} \text{ where Output}_j = \begin{Bmatrix} Ouptut_i \text{ if R.Output}_i < MaximumCapacity \\ MaximumCapacity / R \text{ if R.Output}_i > MaximumCapacity \end{Bmatrix}$$

The amount of energy curtailed increases roughly linearly with resize coefficient for over-sizing above about 25%, and remains relatively low comparative to the level that the farm is oversized by (Figure 2). For example the farm with the greatest losses was Hallet S1 for which it can be seen that if its output was limited to 50% (oversized by 100%) of its installed capacity during the same period, the amount of annual energy lost from the constraint would have been 25% (2008-9) and 28% (2009-10). The losses are particularly low for over-sizing values up to about 25% (equivalent to having the output limited to 80% of installed capacity) and are all less than 10% for over-sizing values up to 40% (approximately equivalent to limiting to 71%) which is perhaps thus a more realistic range for the use of over-sizing.

[2] Ramps from 38 to 99 over Jul-Nov 2008
[3] Mostly curtailed at 16 MW for Jul-Nov 2008, then ~54 MW for most of the time

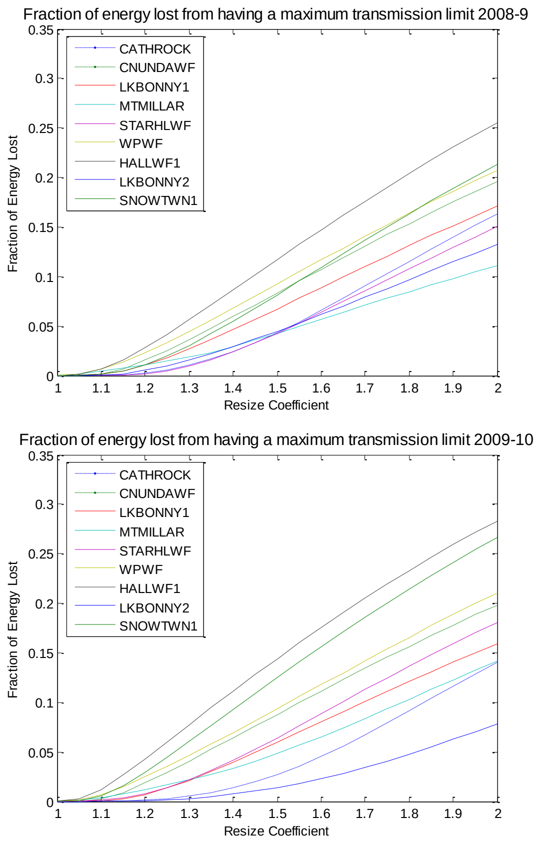

Figure 2: Fraction of energy lost from having a maximum transmission limit.

The normalised increase in energy produced from over-sizing (W2) (rather than having a smaller wind farm size to avoid facing constraints) can be calculated by:

$$\text{W2}=\frac{R\sum Output_j-\sum Output_i}{\sum Output_i}\quad \text{where Output}_j=\begin{Bmatrix} Ouptut_i \text{ if R.Output}_i < MaximumCapacity \\ MaximumCapacity/R \text{ if R.Output}_i > MaximumCapacity \end{Bmatrix}$$

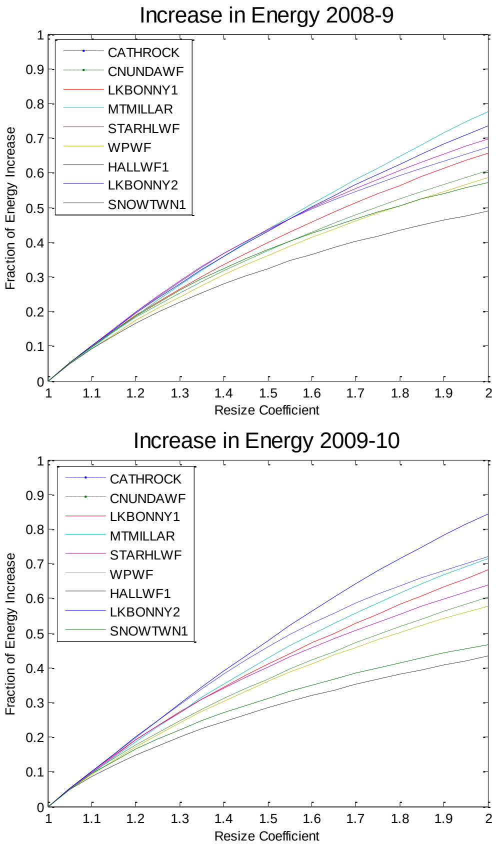

Figure 3: Increase in Energy with the use of over-sizing.

Figure 3 shows the fractional increase in energy with the use of over-sizing. For resize coefficients less than about 1.45 the percentage of increased energy is quite close to the percent of over-sizing, showing the low frequency of being subject to the constraint for lower resize values.

The average price with over-sizing is given by:

$$\text{Average Price}=\frac{\sum Output_j.Price_j}{\sum Output_j} \quad \text{where Output}_j=\begin{Bmatrix} Ouptut_i \text{ if R.Output}_i < MaximumCapacity \\ MaximumCapacity/R \text{ if R.Output}_i > MaximumCapacity \end{Bmatrix}$$

The Capacity Factors for the wind farms are now given by:

$$F=\frac{\sum Output_j}{n.OriginalCapacity} \quad \text{where Output}_j=\begin{Bmatrix} Ouptut_i \text{ if R.Output}_i < MaximumCapacity \\ MaximumCapacity/R \text{ if R.Output}_i > MaximumCapacity \end{Bmatrix}$$

Where:
The MaximumCapacity has been selected as the installed capacity of each wind farm (as detailed previously)
R is the resize coefficient

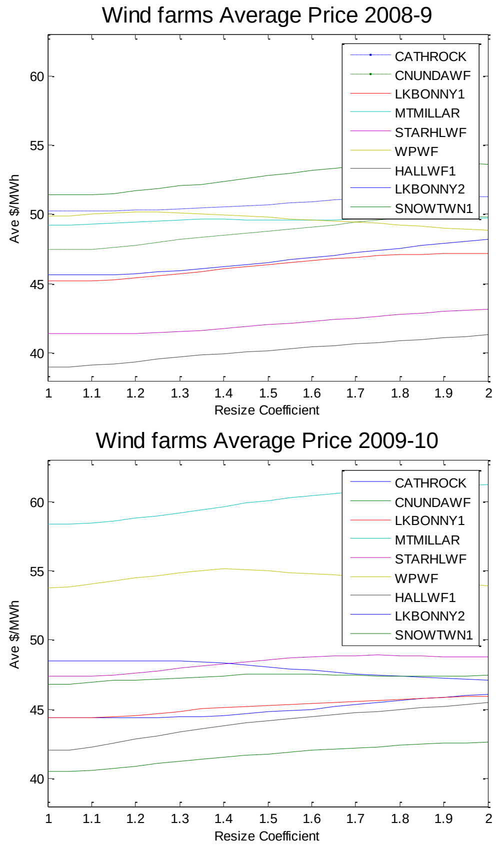

Figure 4: The average price for the wind farms at different resize coefficients. Note that it increases for most farms. The Resize coefficient is the ratio of the installed capacity to the maximum power allowed to be transmitted. For example a 100MW wind farm limited to 75MW would have a resize coefficient of 1.33. This is over-sizing the wind farm by 33%.

It was found that often the times when the wind power must be curtailed due to insufficient transmission and excessive amounts of wind is when the spot prices are low. Thus for most sites the average price that the wind farm receives is actually increased by over-sizing (Figure 4). Cutler (2009) has shown that the power production from the combined output of all wind farms in South Australia has a slightly negative correlation with demand and prices. This means that when power must be curtailed the price is generally lower than average. Thus any locations that also have a negative correlation between wind farm power output and demand are likely to produce wind farms that have an average price that increases with over-sizing.

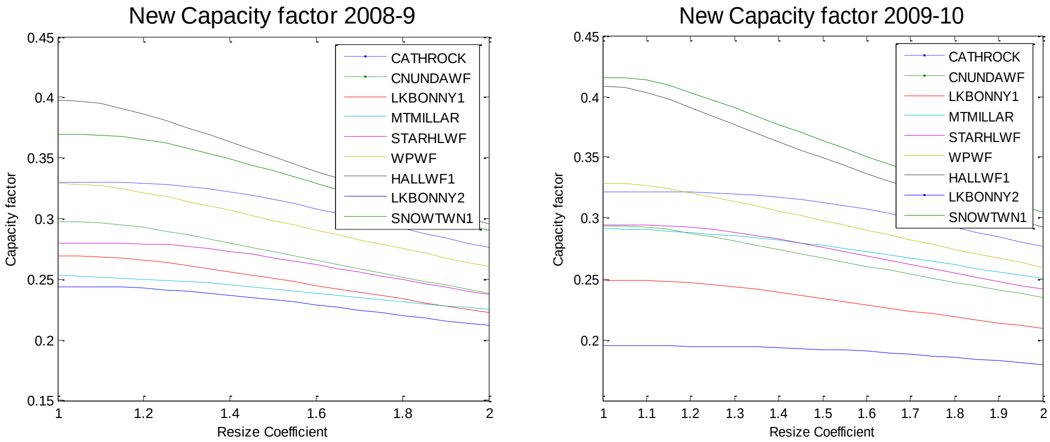

Figure 5: Capacity factor vs. Resize coefficient. Note that the capacity factor for some farms oversized by a factor of 2 is still higher than other farms without over-sizing.

Figure 5 shows the large differences in wind farm capacity factors and the dependence of over-sizing on the wind farms original capacity factor. The analysis revealed that some wind farms could be oversized to a capacity that is twice that of the maximum output and still receive a higher capacity factor and a higher average hourly income per MW of capacity installed than some non over-sized wind farms. This can be seen in the following graphs (Figure 6, Figure 7 and Figure 8). Note that the only difference between the three graphs is that the set value of the RECs has been changed.

Figure 8 is strong evidence to suggest that even with a high RECs value, accepting at times to curtail wind farm output can provide substantial economic benefits over investing in a wind farm with a less desirable wind resource in an effort to avoid transmission upgrade expenditure or wind power curtailment.

Put simply a higher income per MW of capacity installed would have been attained by building a wind farm that had to be constrained by up to 50% in a location with a wind resource equivalent to one of the high income sites compared to building one of the lower income wind farms. Precaution should be noted as the data range only extends for a single year, however as the capacity factors are annually quite stable (once the wind farms are fully commissioned and exempt from constraints, see

Table 1) this conclusion would likely hold for a larger data range.

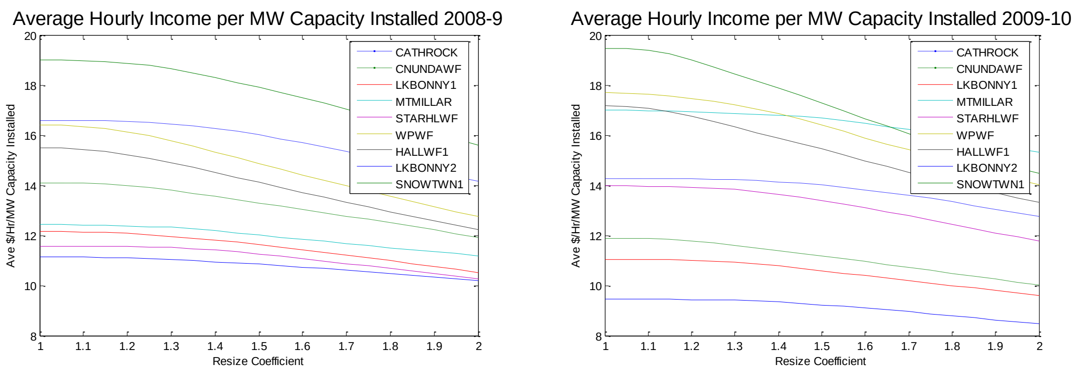

Figure 6: Average hourly income per MW of installed capacity vs. Resize coefficient (RECs=$0). Note that the Average hourly income per installed MW of capacity for some farms oversized by a factor of 2 is still higher than other farms without over-sizing.

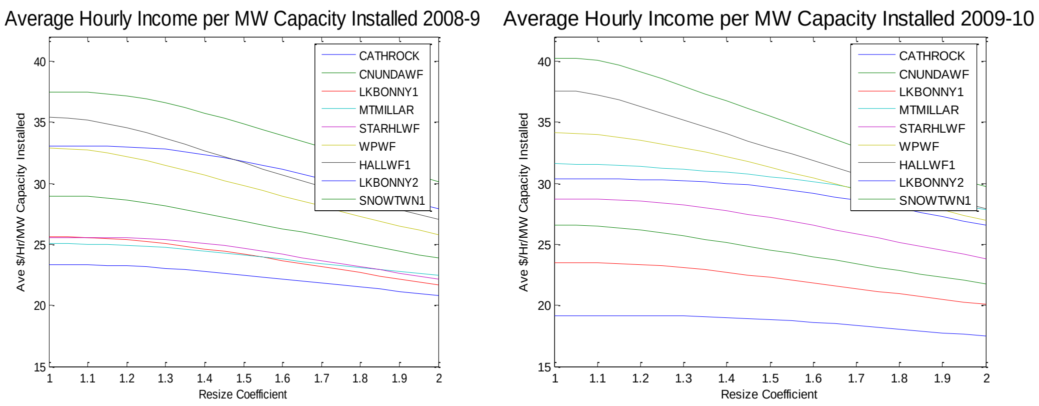

Figure 7: : Average hourly income per MW of installed capacity vs. Resize coefficient with RECs=$50 included.

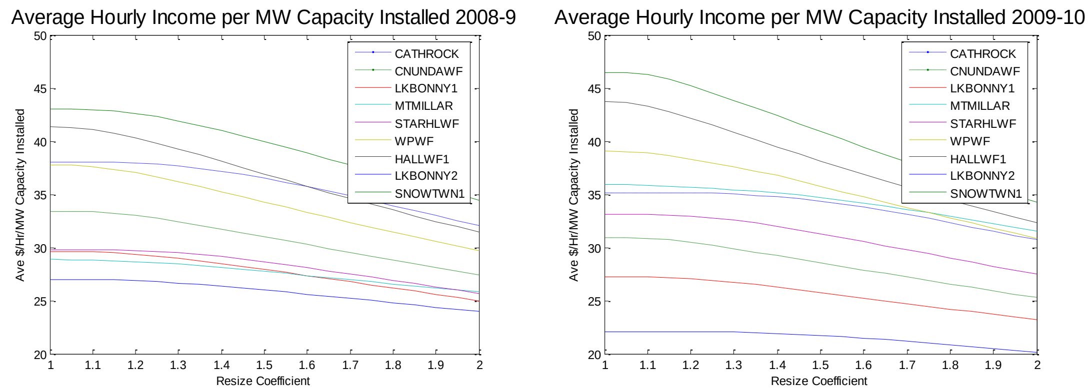

Figure 8: Average hourly income per MW of installed capacity vs. Resize coefficient with RECs=$65 included.

Boerema (2010) has shown that Australia's vast nature and the expense of transmission upgrades results in situations where over-sizing will be a cost effective method compared to upgrading transmission lines. This is particularly the case for current wind farm sizes, which are too small to capture economies of scale. The economics, however, are very dependent on the situation. Existing infrastructure, power quality and security issues, distances to higher capacity transmission, wind farm capacity, the wind resource, wind/load correlation, RECs prices, discount rates, project capital intensity, security of return, construction and planning timeframes, project lifetimes and the potential for further wind farm development near to the site, all need considering.

Assessments into the economics of over-sizing must also include the time value of money, where future costs or losses are discounted. This benefits over-sizing, which introduces continued losses as a compromise for minimising capital expenditure. The risk of an investment must also be considered. All investments have an associated risk, for which the greater the risk, the greater that the return must be. Over-sizing has the benefit of reducing the investment risk. Firstly, if the expected capacity factors fail to be achieved (due to a lower than expected wind resource) then the losses from having a constraint will be reduced, along with the economics of upgrading transmission. Conversely, if the expected capacity factors are exceeded transmission upgrades can be constructed if economical, with greater security that they are required.

A simple example of the economics of over-sizing versus transmission upgrades is given below, using wind farms to be built at 50km and 250km from substantial transmission. Transmission has been assumed available to the sites for 100 MW, but a site exists for a 140MW wind farm to be constructed (Thus R=1.4 also equivalent to being constrained down by 28.6% of the installed capacity).

Table 3: MVA-km capacities and costs for different voltage levels and configurations used in South Australia (Meritec, 2002; PAGE, 2010)

Voltage Level (kV)	**Conductor Size and Configureation**	**Summer Day Rating (MVA) (75 DegC Design)**	**MVA-km Capacity**	**First Approximate Cost ($M/km)**
275	2 x 373 mm2 Al Eq ACSR	630	48,250	1
	2 x 508 mm2 Al Eq ACSR	740	51,250	1
	1 x 508 mm2 Al Eq ACSR	370	47,250	1
132	1 x 282 mm2 Al Eq ACSR	130	7,400	0.5
	2 x 373 mm2 Al Eq ACSR	302	11,100	0.5
	2 x 508 mm2 Al Eq ACSR	355	11,800	0.5

Using the values from Table 3 the MVA ratings and cost of the transmission lines can be calculated for the six configurations.

Table 4: Ratings and costs of the six transmission lines for 50km and 250km.

MVA rating over 50km	MVA rating over 250km	Cost ($M)	Cost ($M)
965	193	35	250
1025	205	35	250
945	189	35	250
148	29.6	25	125
222	44.4	25	125
236	47.2	25	125

As only 40MVA of capacity is required a 132kV transmission line will be sufficient, resulting in a cost of 25 million dollars for the 50km line and 125 million dollars for the 250km line.

Continuing with the calculations assuming the use of 132kV transmission gives:

Table 5: Final costs of transmission for 50km and 250km

	Cost ($M/yr)		**Cost ($/MW/yr)**	
	50 km project	250 km project	50 km project	250 km project

20 year project life	1.25	6.25	31250	156250
45 year project life	0.56	2.78	13889	69444

During 2008-9 and 2009-10 the equivalent losses for the wind farms of South Australia that would have been experienced if constrained by 28.6% of their rated capacity ranged between about 1400-27000 dollars per MW installed per year. This shows that for an expected project lifetime of 20 years over-sizing is the economical option whilst for a project lifetime of 45 years it may be more economical in some cases to upgrade the transmission lines, however note again that discounting has not been considered, which would further improve the economics of over-sizing. The cost of transmission per MVA-km capacity is greatly reduced for higher MVA-km requirements. This allows for large reductions in transmission upgrade costs per MW of wind farm capacity installed if multiple wind farms of a region can coordinate a combined investment in the transmission upgrade to that region.

4.0 CONCLUSION

The use of constraints on wind farms power output was presented as a technique for increasing the immediate deployment of wind farms in Australia, where limited transmission exists. An analysis of the effects of submitting wind farms to a maximum power limit that necessitates times of power curtailment has been undertaken. Quantitative results have been presented detailing the reductions in capacity factors, the increase in total energy gained and the losses from the enforced curtailment. Power curtailment has been suggested as a possibility for securing connection agreements with network service providers, in particular for wind farms trying to access wind resources situated where limited transmission opportunities exist, and as a means to allow immediate access to wind farm sites whilst providing the opportunity for a coordinated approach to transmission upgrades between multiple wind farms and network service providers. An understanding of the effects of constraints on a wind farm was also highlighted as being necessary due to current market rules which do not guarantee a wind farm dispatch simply because it was connected first.

Results showed that some of the wind farms of South Australia could be limited to a maximum power output of half their rated capacity and still achieve higher capacity factors then other already existing unconstrained wind farms, demonstrating the economic advantage of accessing a superior wind resource even if it at times requires the wind farm to curtail power. This is an unintuitive result and is important as it makes more potential wind farm sites immediately available. The large variation in average prices achieved by the wind farms was also detailed, however the sensitivity of these prices to the exact timing of high price events means that siting a wind farm to achieve high prices could be difficult.

APPENDIX

Table 6: National Electricity Market data information.

Data name	Description and comments	Location
SA Demand	From "Aggregated Price and Demand data in the Operational Market Data". Native demand for SA to be met by scheduled and non-scheduled generation is calculated by adding this demand figure to non-scheduled wind power generation.	http://www.aemo.com.au/data/aggPD_2006to2010.html (and requires 'non-scheduled wind power generation' – see below)
SA Price	NEM spot prices in South Australia from same data set as above.	Same as above
Non-scheduled wind power generation	The measured (metered) generation output from the 6 currently non-scheduled wind farms in SA. These are obtained with 5-min resolution but averaged in 30-min intervals. Total rating: 388.25 MW	http://www.aemo.com.au/data/csv.htm. See archived non-scheduled generation data.
Scheduled wind power generation	The dispatched scheduled generation from the 3 currently scheduled wind farms in SA. Total rating: 353.5 MW	http://www.aemo.com.au/data/csv.htm. See archived daily aggregated dispatch data.

REFERENCES

ABARE (2010). Energy in australia. Australian Government Department of Resources Energy and Tourism.

AEMC (2009). Review of energy market frameworks in light of climate change policies-final report. Australian Energy Market Commission.

AEMC (2010). National electricity rules. Chapter 3: Market Rules. Australian Electricity Market Commision. **Version 37**, from http://www.aemc.gov.au/Electricity/National-Electricity-Rules/Current-Rules.html.

Boerema, N (2010). Renewable energy integration into the national electricity market: Characterising the energy value of wind and solar generation.

Cutler, N (2009). Visual forecasting tool for large, rapid changes in wind power generation, CEEM.

ElectraNet (2009). Annual planning report 2009-2029. South Australia.

ESIPC (2009). Electricity supply industry planning council: Annual planning report.

Meritec (2002). Eyre peninsula infrastructure investigation. Prepared for the Electricity Supply Industry Planning Council.

NEMMCO (2009). Incident report violation of the secure operating state for the network in the cultana system. System Operations Planning and Performance. **V2**, from http://www.aemo.com.au/reports/232-0132.pdf.

PAGE (2010). Assessment of alternatives: Woolooga-eerwah vale transmission & substation project. Powerlines Action Group Eumundi Inc.