Wind Energy in Australia: Current Status and Projected Contribution to Future Electricity Supply

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Abstract

Over the last decade wind energy has seen exceptional growth around the world and is now a proven and established form of electricity generation. Wind energy provides substantial portions of the electricity demand across a diverse number of locations. States, Provinces and countries where wind generation exceeds 15% of total electrical requirements include: Iowa, Kansas, Oklahoma, North and South Dakota, Minnesota, Idaho, Denmark, Portugal, Ireland, Spain, Tamil Nadu (India) and Inner Mongolia (China); the State of South Australia generates approximately 30% of its electricity from wind.

The successful emergence of wind as a major energy source therefore raises the question of how much wind can contribute to future electricity supply.

In this paper the current status of wind energy in Australia is introduced together with an overview of the pipeline of projects under development across Australia. The technical and financial constraints of meeting Australia's Large-scale Renewable Energy Target (LRET) target with wind alone are explored together with a scenario analysis that assumes wind will grow to meet around 30% of Australia's electrical generation needs over the next decade.

1. Current Status

Australia's wind resource is well distributed and has a technical potential that significantly exceeds total generation requirements. This is reflected in Figure 3 and by the fact that wind has been installed in all corners of Australia, from Windy Hill in Far North Queensland to Woolnorth in north-western Tasmania and Collgar in the Western Australian wheatbelt.

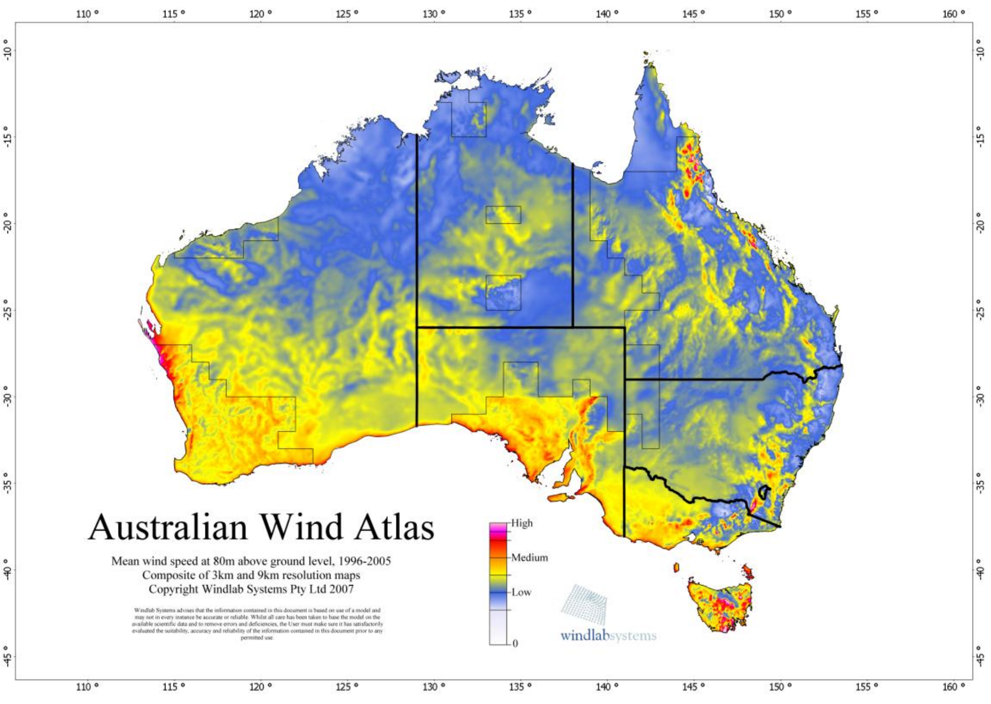

Figure 1 Australian Wind Atlas.

The historical growth of wind energy in Australia is captured in Figure 2. There are currently around 2,000 wind turbines with an installed capacity of around 4,000MW either operational or under construction. The majority of this growth has occurred over a short 10 year period since 2005.

Figure 3 plots the growth in generation (Gigawatt hours per annum) of wind. By the middle of 2015 it is calculated that wind energy from current operational or under construction projects will supply in excess of 12TWh per annum or around 6% of Australia's total electrical demand[1].

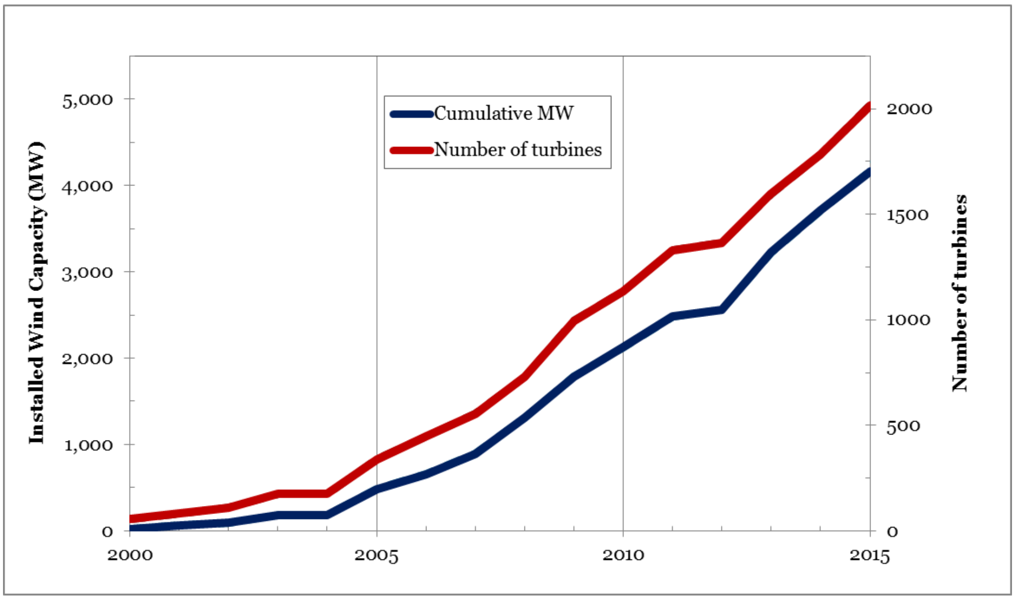

Figure 2 Cumulative installed capacity (MW) and number of wind turbines in Australia.

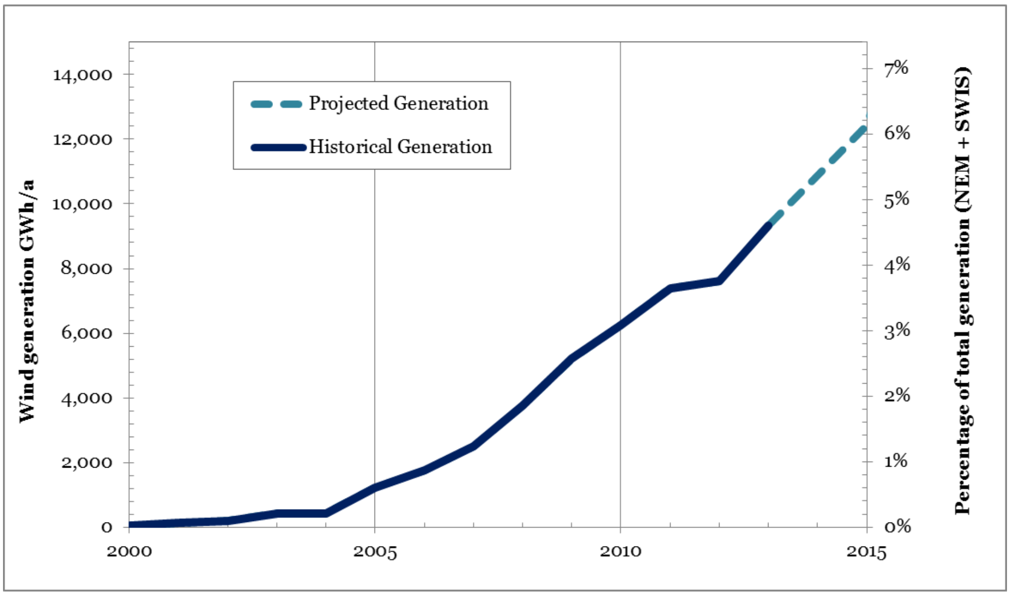

Figure 3 Historical growth of wind generation in Australia.

[1] Demand here refers to an estimated 200TWh per annum for the combined National Electricity Market (NEM) and South West Interconnected System (SWIS) for the year 2014.

2. WIND ENERGY PROJECT PIPELINE

Windlab maintains an internal database of all 'known' wind energy projects under development across Australia. This pipeline is tabulated below and for simplicity five distinct project stages are shown. The tables demonstrate that substantial wind resource is available across all States. In excess of 8,000MW is permitted and 'ready to construct'.

The numbers of projects in the 'permitting' and 'concept' phase are likely an underestimate as many projects do not become public knowledge until they are in the permitting phase. However, it is also likely that the number of Megawatts in the 'approved' stage is an overestimate. The main reason is that projects typically seek approval for more capacity than can be connected into local transmission networks and to ensure some flexibility in final construction design.

The table also shows mean project wind speeds[2] (at typical turbine positions) for projects in each stage. The LRET legislation is a market based mechanism that incentivises least cost renewable energy. Higher wind speed sites, predominantly in South Australia, have thus been built first. Lower wind speed sites across other parts of the NEM (Victoria, New South Wales and Queensland) will make up the bulk of projects constructed in the future. However, improvements to wind turbine technology (see section 3) mean that these sites will still produce power more efficiently and more cost effectively than most projects built to-date.

Project stage	**Number[3] of projects**	**MW**	**Mean wind speed**
Operational	61	3790	8.0 m/s
Under Construction	4	374	7.7 m/s
Financing /Approved	50	8133	7.5 m/s
Permitting	32	5881	7.2 m/s
Concept	30	5795	-
TOTAL	**177**	**23974**	

Table 1. Estimated Wind Project Pipeline in Australia.

Project Stage	**Number of Projects**	**MW**
New South Wales	42	6242
Queensland	16	2041
South Australia	35	5324
Victoria	42	5331
Western Australia	34	3486
TOTAL	**177**	**23974**

Table 2. Project Pipeline by State.

[2] These wind speeds are modelled estimates based on Windlab's detailed knowledge of the wind resource across Australia. Windlab and its staff have been measuring and modelling the wind extensively across Australia for the past 15-20 years.
[3] Where projects are split into project stages, each project stage is counted individually.

3. Scenario Analysis

The analysis in this section is based on the following set of simple assumptions:

- A (Near-term) Large-scale Renewable Energy Target of 41TWh/a is maintained;
- B (Medium term, post 2020) deeper cuts to Australia's emission intensity are legislated, resulting in 30% of Australia's electricity generated from wind by 2025 (and a greater proportion overall from renewables);
- C Moderate/slow wind turbine technology (conservative) development;
- D No significant technical barriers to supplying 30% of Australia's electrical needs with wind; and
- E No significant financial or economic barriers from supplying 30% of Australia's electrical needs with wind.
- F No significant changes in the overall electrical demand in Australia – assumed a constant 220TWh per annum

The projections of how much wind will be installed on Australia's electrical network, based on these assumptions, are provided in Figures 4 and 5. A doubling of the current number of turbines from 2,000 to 4,000 is expected to deliver an installed capacity of 12,000MW and around 41TWh of wind generated electricity by 2020. Deeper emissions cuts are delivered by 2025 at which point the modelling estimates 5,500 turbines can deliver 18,000MW of installed capacity and 64TWh of electricity each year.

The technical and financial limitations that underpin these assumptions together with the economic implications of the 30% wind by 2025 scenario are reviewed in the following sub-sections. Turbine technology improvements that have resulted in improved efficiency and cost of supplied energy are also introduced.

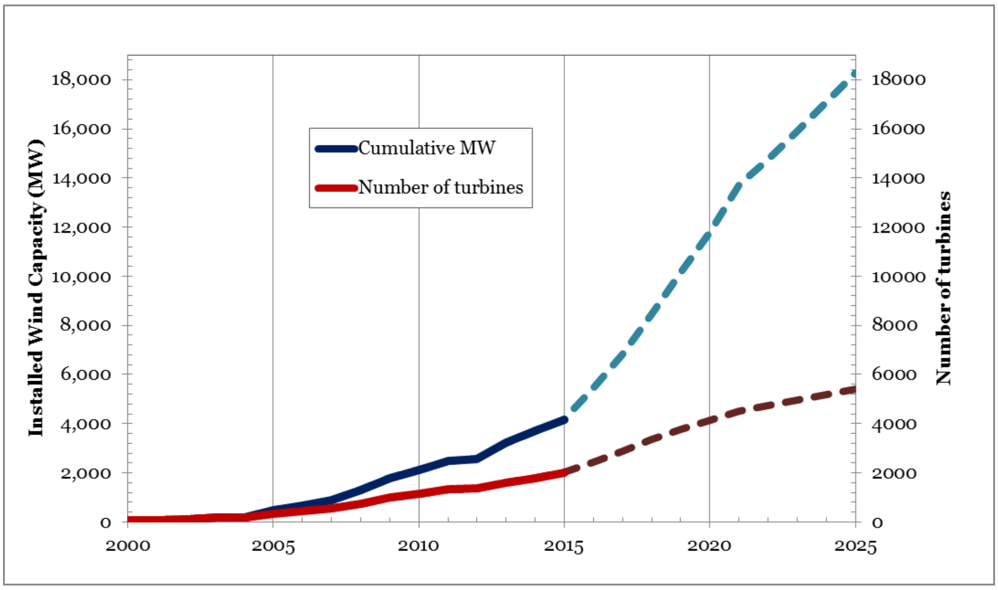

Figure 4 Projected growth of number of turbines and installed wind capacity in Australia.

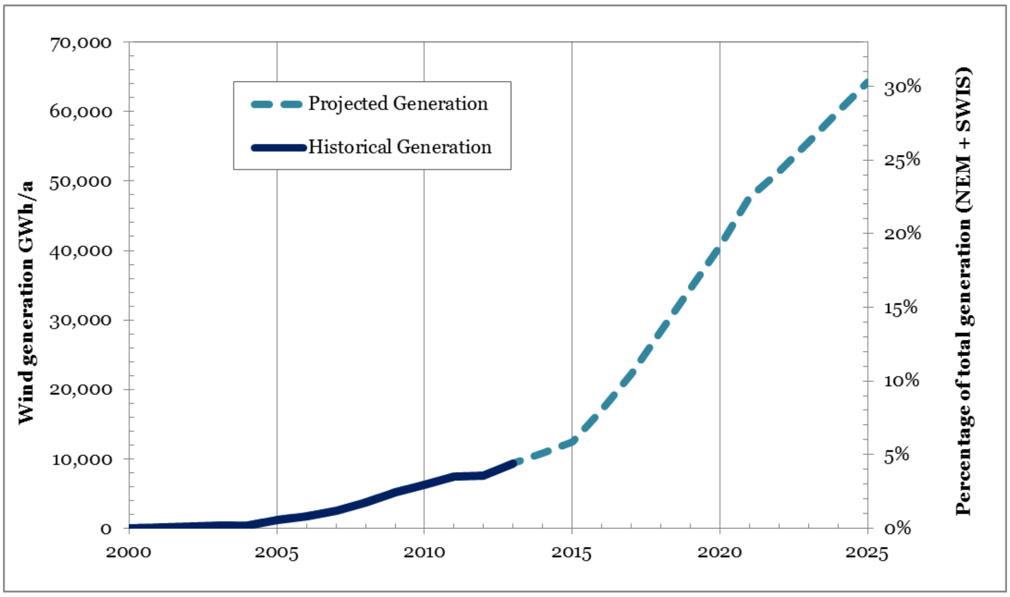

Figure 5 Projected growth of electricity generation from wind in Australia. NEM + SWIS demand is assumed to be 200TWh in 2014, growing to 217TWh in 2025.

a. TECHNICAL LIMITATIONS

Technical questions of renewables and wind integration are generally focused on the availability of sites and implications of low resource periods on steep ramps in power production.

The question of site availability was broadly answered in section 2. There are a considerable number of wind projects already approved across Australia with more than enough capacity available to meet the 2020 LRET target of 41TWh. Wind generation of 41TWh would represent approximately 20% of Australia's electricity demand. This is not unexpected as Australia is a large, windy country. China (see Appendix A) produced around 130TWh of wind electricity in 2013 and is on-track to produce the equivalent of Australia's entire electricity generation output (>200TWh/a) from wind energy by 2016.

The State of South Australia is relatively weakly interconnected with the rest of the National Electricity Market (NEM) but has already achieved a 30% level of wind integration. At present, there are no known significant implications of having this level of wind on the system. A study completed by Windlab[4] concluded that large proportions of wind have been integrated into South Australia's network without requiring a proportional increase of peaking plant installation or usage. Nor has there been any significant change in the level of interstate imports and exports of electricity.

A report[5] by Sinclair Knight Merz of market pricing during the January 2014 heatwave revealed that: *"In the seven days to January 19, wind farms contributed around 6 per cent of overall supply in SA and VIC, and as a consequence, wholesale prices were at least 40 per cent lower (on a consumption weighted average basis) than they would have been without the contribution of wind."*

There are many other markets around the world where wind now makes up a significant portion of local electricity supply and many studies[6] that indicate that wind can be integrated without major technical implications.

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[4] Osmond, D. and Osborne, L. (2014) Peaking Capacity, CO2-e Emissions ad Pricing in the South Australian Electricity Grid with High Wind Penetration 2005-2013, published by Windlab.
[5] Impact of Wind Generation on Spot Prices in Victoria and South Australia, Sinclair Knight Merz (February 2014).
[6] Cochran, J., Bird, L., Heeter, J. and Arent, D.J. (2012) Integrating Variable Renewable Energy in Electric Power Markets - Best Practices from International Experience, published by U.S. Department of Energy & U.S. Department of Commerce.

Another important factor in the technical analysis is the improvements to turbine and wind farm efficiencies that have benefitted the industry in recent years and which continue to improve wind economics. Figure 6 shows the increase in cumulative turbine size (line) and average turbine size (points) installed in each year and projected to 2025. The cumulative average size of all machines currently installed in Australia is just under 2MW – this is projected to increase to around 3MW by 2025.

A significant trend in recent years has been the growth of blade diameters to allow more wind to be captured by a given turbine. The combined side-effect of taller hub-heights and larger blade diameters is that machine efficiencies are continuing to increase even allowing for the fact that the windiest sites have typically already been developed. Based on a detailed knowledge of the wind resource across Australia, Windlab therefore expects the cumulative installed capacity factor to increase to at least 40% by 2025 from a current 35%. Beyond 2025 significant repowering of the oldest wind plant should be expected and this will further drive up the average capacity factor. The historical and projected growth in capacity factor is also shown in Figure 6.

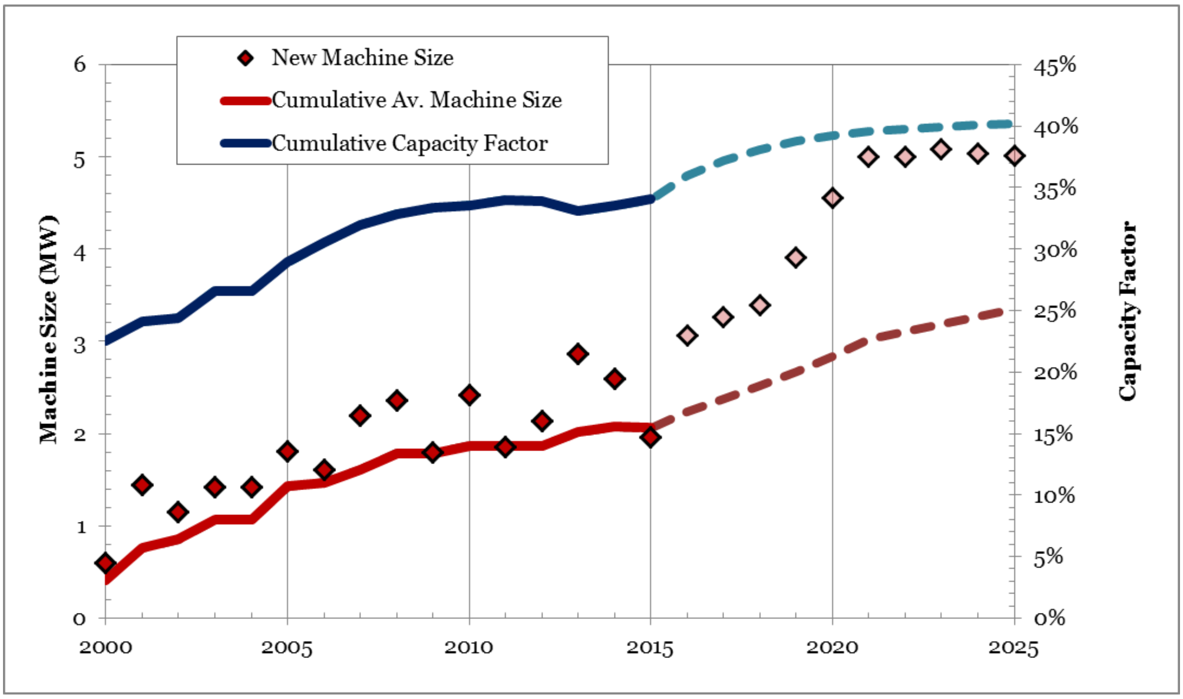

Figure 6 Historical and projected increase in turbine size and average wind farm capacity factor (post losses).

b. Financial Limitations

Approximately 10 billion dollars (AUD $10 billion) has been committed to construct the 4,000MW of wind capacity in Australia. The majority of this has been committed over the ten year period from 2005 to 2015, with an average investment of around one billion dollars per annum.

The projection is that this rate of investment will roughly double to two billion dollars per annum in order to achieve the RET target by 2020 and will increase further as wind achieves around 30% penetration level by 2025. A total additional investment of $25 billion over the ten year period to 2025 is required to deliver the 30% wind scenario.

The required investment is not considered an obstacle as other similar size markets are currently investing significantly greater dollars in renewables. In South Africa, for example, the first three rounds of the Renewable Energy Independent Power Producer Procurement (REIPPP) program have seen around $12 billion dollars committed over less than three years to construct around 4,000MW of mostly wind and solar PV projects. Round 4 is currently in progress and the rate of investment is expected to continue. South Africa's Integrated Resource Plan[7] recommends continuing to procure renewables at the rate of 1,000 to 2,000MW per annum.

The required investment is relatively small compared with other ongoing infrastructure investment around Australia. However, the investment over the period to 2020 is dependent on RET policy certainty.

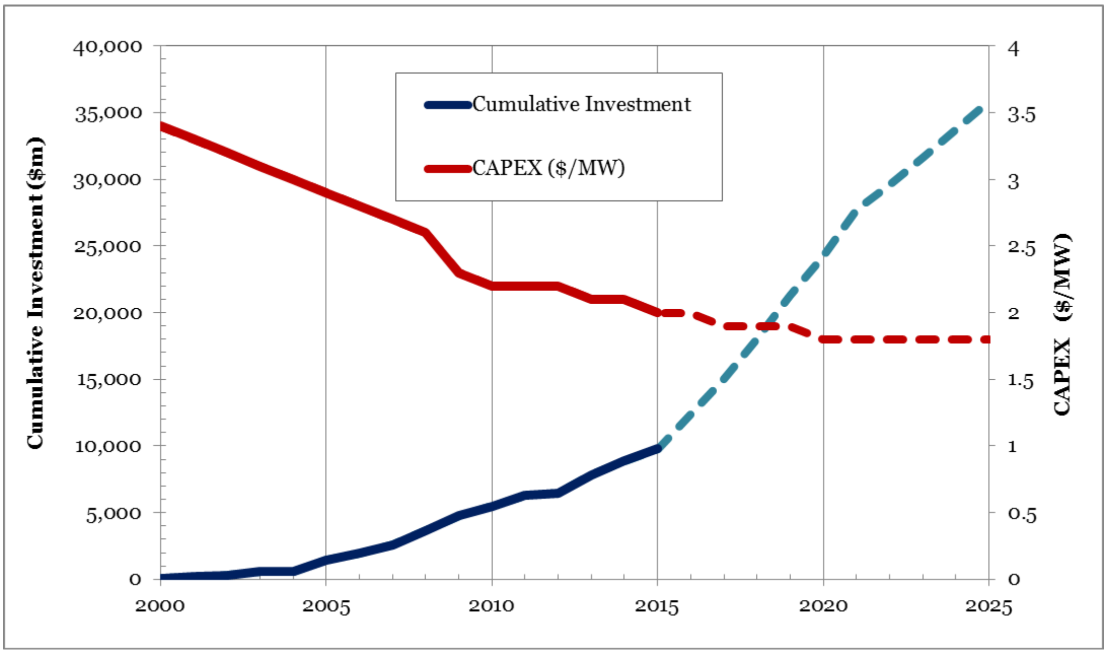

Figure 7 Reduction of CAPEX over time and projected investment to 2025.

c. ECONOMIC IMPLICATIONS

An increasing number of economists have determined that transitioning away from carbon intensive energy will bring deep economic benefits. A recent and compelling example[8] has been prepared by the Global Commission on the Economy and Climate, an international collaboration that includes leading economists from the World Bank, International Energy Agency, and International Monetary Fund together with leaders from companies such as Bank of America, Deutsche Bank, Bloomberg and Unilever. The report concludes that "countries at all levels of income now have the opportunity to build lasting economic growth at the same time as reducing the immense risks of climate change". A 10-point "Global Action Plan" is provided by the report to accelerate the transition. These points include phasing out the construction of new coal-fired power generation, introducing carbon pricing mechanisms, reversing deforestation and phasing out the vast subsidies for fossil fuels.

These recommendations are already in progress to some extent. For example, many of the world's largest corporations already assume an internal price on carbon as it affects the projects they invest in given the time horizons of those projects. These internal prices are estimated to range from $US6-80 per tonne. Although there is consensus that carbon pricing is coming, there is uncertainty over what the legislative mechanisms and pricing will be. A growing number of financial institutions are therefore either calling for certainty or commencing to divest their asset base away from carbon intensive investments. The most recent example includes the group of around 350[9] global institutional investors who represent over $24 trillion in assets who have called on government leaders to "provide stable, reliable and economically meaningful carbon pricing that helps redirect

[7] Integrated Resource Plan for Electricity (IRP) 2010-2030, Update Report 2013, South African Department of Energy.
[8] The New Climate Economy, the Global Commission on the Economy and Climate (September 2014).
[9] Press release (August 2014) – World's leading institutional investors, http://investorsonclimatechange.org/wp-content/uploads/2014/09/GISCC_SummitMediaRelease_Final.pdf

investment commensurate with the scale of the climate change challenge." On the divestment front the Rockefeller Brothers Fund became the latest in a group of over 800 institutions and high net-worth individuals who have committed to divest assets from fossil fuel companies.

A number of studies have been conducted in recent years on the cost of retaining or extending the RET in Australia. These include the ACIL Allen study undertaken as part of the Warburton[10] review. In this study a number of scenarios were explored to determine which had the least cost impact on households. The scenarios included: maintaining the current legislation with an LRET of 41TWh by 2020; amending the LRET to around 26TWh by 2020; extending the LRET to a 'real' 30% by 2030 option of around 53TWH; and 'grandfathering' or closing off the LRET to new entrants.

Figure 8 shows the modelled impact of these scenarios on annual household electricity bills for different time periods. The scenarios are compared against a 'repeal' case in which the LRET is scrapped altogether. The lowest cost option for consumers over the study period was modelled to be the highest renewables penetration scenario with a nominal 30% renewables by 2030 option. In this scenario household electricity bills are expected to be $158 per annum lower by 2030.

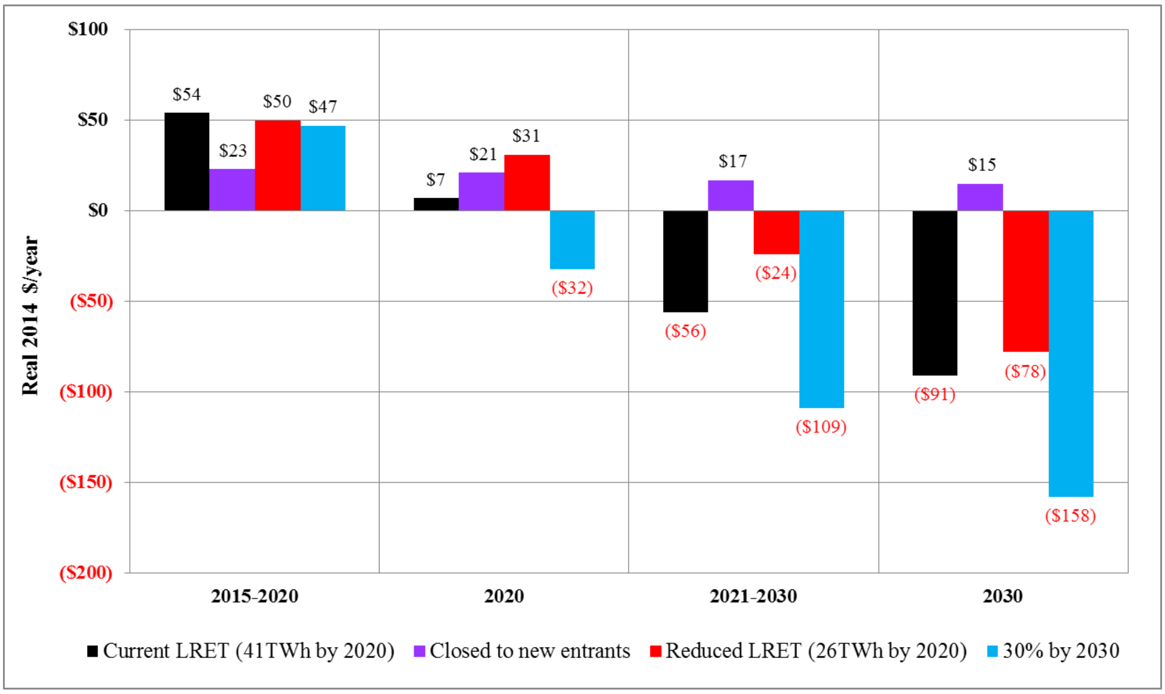

Figure 8 Annual change to household bills from various RET policies (Real 2014 $/year). Figure reproduced from ACIL Allen[11] study.

It should be noted that the scenarios modelled by ACIL Allen assume no future carbon price associated with coal or gas-fired electricity generation. This is at odds with the international consensus that prices carbon risk into investment decisions. Despite this, the ACIL Allen study provides additional evidence that large-scale deployment of renewables can be achieved over a short time period and in a manner that is cost-effective or even beneficial to consumers.

[10] Renewable Energy Target Scheme, Report of the Expert Panel (August 2014), report to Australian Commonwealth chaired by Dick Warburton
[11] RET Review Workshop – Preliminary Modelling Results (June 2014), ACIL Allen.

4. CONCLUDING REMARKS

Analysis has been undertaken of the current and projected future status of wind energy in Australia. The projections take into account Windlab's knowledge of the wind resource across Australia together with an expectation that the current RET legislation will be retained in its present form and that deep cuts to carbon emissions will be legislated in future years. A 30% by 2025 wind energy penetration scenario is presented. This scenario assumes that the 41TWh LRET requirements are met with wind alone by 2020 and that around 65TWh of wind generation is required by 2030.

In the near-term, given the abundant supply of quality wind energy locations which are already approved and ready for construction there is little if any evidence to suggest that the existing Renewable Energy Target of 41TWh by 2020 cannot be achieved. Given the consumer benefits that arise from transitioning to renewables, there is a strong case for increasing the target in future years.

Based on the evidence of locations around the world where wind already makes up a substantial portion of electricity generation and based on various future looking studies that examine the economics of large-scale renewables integration it is further concluded that there are no technical, financial or economic barriers to the rapid and large-scale deployment of wind energy into Australia's electricity supply.

In many respects these conclusions are not surprising. They are simply an extension of what has already occurred in the State of South Australia where wind energy today makes up around 30% of electricity generation and solar PV supplies an additional 6%.

The current study has not attempted to examine solar PV or to explore the situation where renewables make up very high proportions of the overall supply. Windlab expects that future research will increasingly focus on the technical challenges of moving to near 100% renewables supply. A first step in Australia was recently undertaken by the Australian Energy Market Operator (AEMO)[12].

[12] 100 Percent Renewables Study – Modelling Outcomes (July 2013), published by Australian Energy market Operator.

Appendix A: Wind Energy in China (2013)

The table below is from a Windlab internal[13] study of wind penetration rates across Chinese Provinces. The top 15 provinces for wind power generation are listed.

2013	Province		Interconnected Grids	Grid Connected Installed Capacity (GW)[14]	Electricity Production from Wind Power (TWh)	Electricity Consumption (TWh)[15]	Wind Penetration
1	Inner Mongolia	内蒙古	Northeast Power Grid / North China Power Grid	18.33	35.6	218.2	16.3%
2	Hebei	河北	North China Power Grid	7.75	14.1	325.1	4.3%
3	Gansu	甘肃	Northwest Power Grid	7.03	11.9	107.3	11.1%
4	Liaoning	辽宁	Northeast Power Grid	5.65	10.0	200.8	5.0%
5	Xinjiang	新疆	Northwest Power Grid	5.06	7.8	134.2	5.8%
6	Shandong	山东	North China Power Grid	5.02	8.7	408.3	2.1%
7	Heilongjiang	黑龙江	Northeast Power Grid	3.86	6.7	84.5	7.9%
8	Jilin	吉林	Northeast Power Grid	3.77	5.6	65.4	8.6%
9	Shanxi	山西	North China Power Grid	3.47	4.2	183.2	2.3%
10	Ningxia	宁夏	Northwest Power Grid	3.02	5.8	81.1	7.2%
11	Jiangsu	江苏	East China Power Grid	2.56	4.5	495.7	0.9%
12	Yunnan	云南	Southern Power Grid	2.44	4.4	146.2	3.0%
13	Guangdong	广东	Southern Power Grid	1.81	3.0	483.0	0.6%
14	Fujian	福建	Southern Power Grid	1.48	3.6	170.1	2.1%
15	Guizhou	贵州	Southern Power Grid	1.02	1.2	112.4	1.1%

[13] Shengyi Dai, Wind energy penetration rates in Chinese Provinces for the year 2013, Windlab internal memo.
[14] China National Renewable Energy Centre, 2013年度风电开发建设情况 (Translation: Wind Power Development Overview in 2013, CHINESE LANGUAGE), available online: http://www.cnrec.info/go/AttachmentDownload.aspx?id={0a527868-9157-4490-b2e5-07c40898b723}
[15] National Bureau of Statistics of China, available online: http://data.stats.gov.cn/english/easyquery.htm?cn=E0103

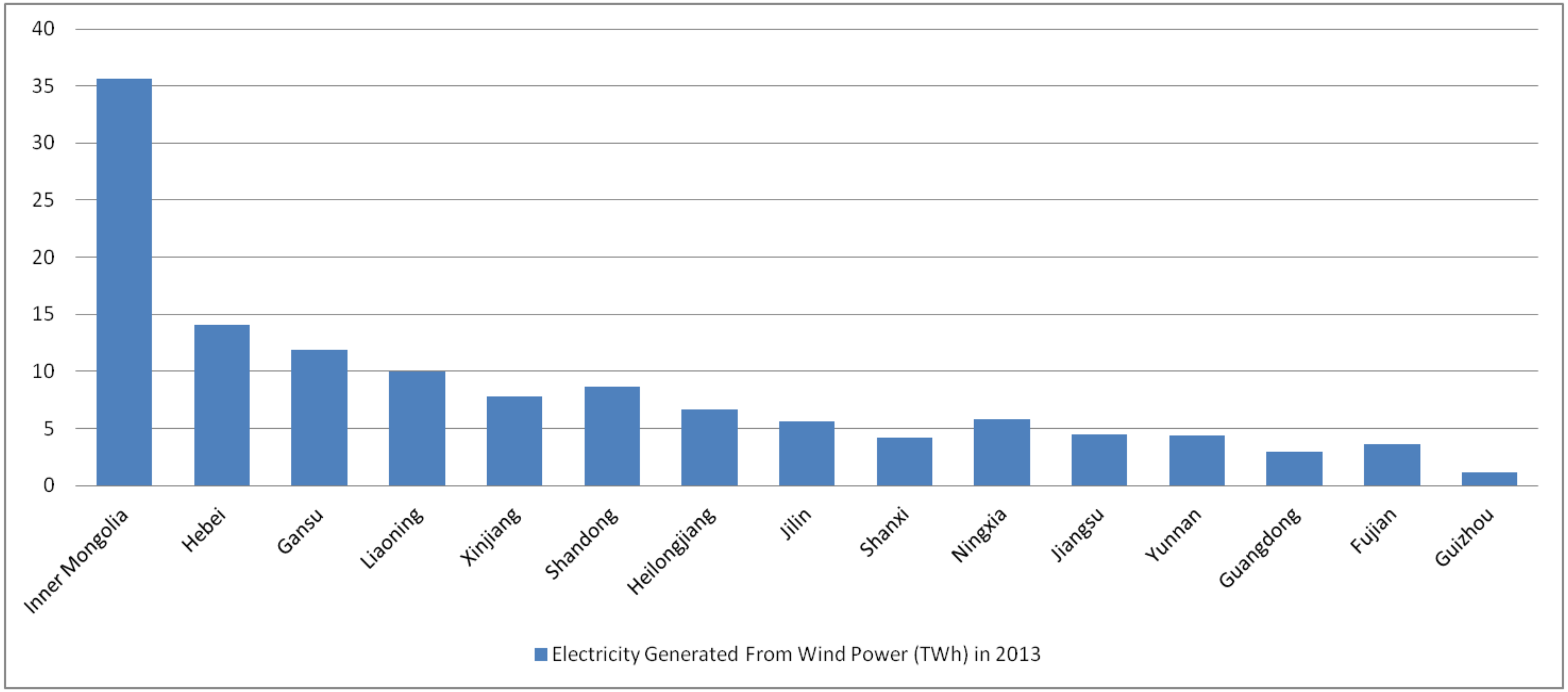

Figure 9 Wind generation in top 15 Chinese Provinces.