Assignment 5: South Australia Turbine Site Summary and Environmental Issues

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Table of Contents

Intro and Location Summary

Throughout the previous four assignments, multiple aspects of turbine design and site selection have been performed for a potential large-scale onshore wind turbine site in South Australia. The goal for this site was large in scope, with the hopes to be capable of powering a large city within the region, such as Adelaide, with its population of slight over 1 million. In recent years, renewable energy has seen large growth in all regions of the continent, with South Australia leading the way in terms of percent renewable energy production. The current sources of this energy is depicted in figure 1[1] below.

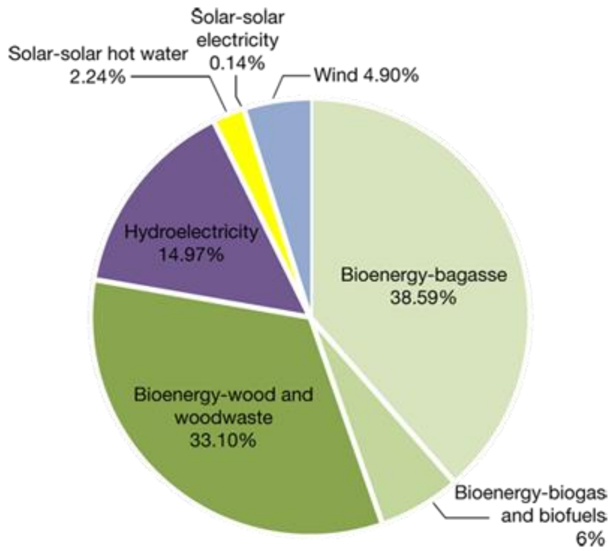


Figure 1. Australia Renewable Energy Sources During 2010’s, by Percent

In the figure above, there is only a small percent of renewable energy coming from wind resources. This is a surprising fact, as plenty of wind resources are near the Southern coast of the continent, which could be put to use with the creation of large-scale wind farms. Another interesting fact arises from South Australians paying more for electricity than other regions by up to 5 cents per kWh, even though they are ahead of the rest of Australia in terms of renewable energy production. In order to resolve this economic issue and potentially bring down the cost of energy for the region, a wind turbine site of roughly 3.25 gigawatt total capacity was proposed. Consisting of many 6 MW turbines, this project would certainly be a large undertaking and would certainly need to be verified in terms of feasibility before planning and construction could begin.

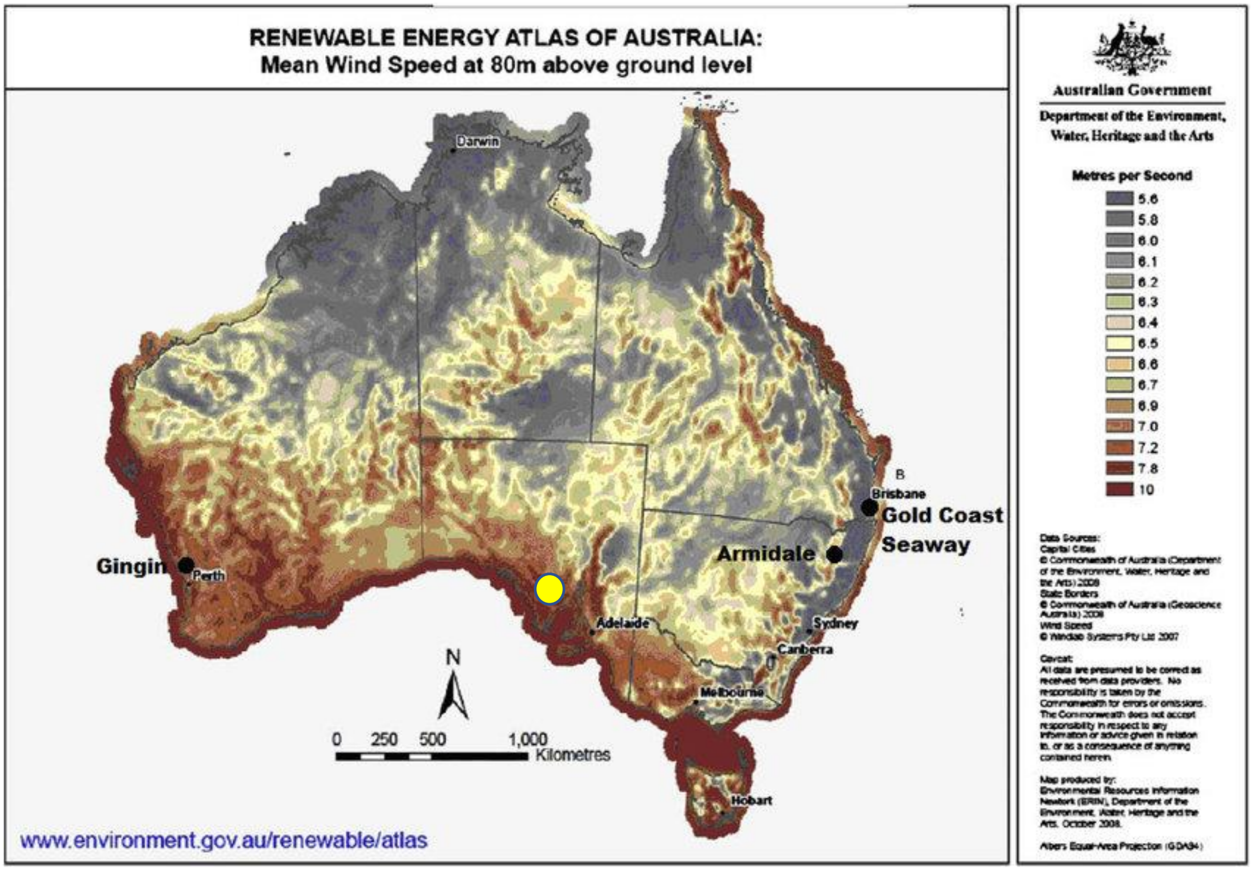


Figure 2. Proposed Region For Wind Turbine Site Construction[2].

Turbine Design Overview

Once the type of turbine needed for the site was determined, the next step involved coming up with a design that would meet the necessary performance requirements for the site. In this case, an onshore 6 MW turbine was designed, using a combination of equations specific to the energy needs and environment at the site, as well as existing data for turbines of similar scale. The size of the turbines, hub height, and RPM were estimated and compared with the GE Cypress 6.0-164 Turbine in table 1 below.

Table 1. My Turbine Design Compared With Existing 6 MW Onshore Turbine

	My Turbine	GE 6.0-164 Cypress
Number of Blades N	3	3
Blade Radius R (m)	60.7	82
RPM	15.11	12.3
Hub Height (m)	120	112-160 m

While my turbine and the GE Cypress both have an installed capacity of 6.0 MW, my estimated radius and hub height were slightly lower than most current models of the Cypress.

This seemed to be a bit of an optimistic design at first, as in order for this turbine to be able to live up to its intended power output, the expected windspeeds at the site location would need to be consistent, and the selection of airfoils for the turbine would also need to be optimized. The latter issue was taken into account by selecting a family of three different WindPact airfoil designs across the total radial span of the turbine. This would allow for the blade to be thicker at the root and thinner at the tip, which is beneficial for both the structural integrity of the structure as well as performance.

While this current design is not perfected, it is able to get a decent estimate of performance predictions and cost forecasts to determine the feasibility of the site. Further iterations could be performed on the hub height to radius ratio, rather than using the standard starting value of 2. Additionally, the three airfoils selected for the design were done mainly for convenience of software analysis, since the files were already on hand. However, the use of more modern or creation of new airfoils would be ideal for ensuring optimal, up-to-date performance for the turbine. Other minor features of the turbine’s operation could be tuned based on specific wind data taken onsite prior to construction, such as optimizing the cut-in, cut-out speeds, and RPM of the rotors.

Turbine Performance Overview

To analyze the performance of the turbine, a software known as WT_Perf was employed. This program allowed us to input environmental parameters at the site, turbine dimensions, as well as twist and chord elements of the airfoil across the radius of the blade. Once the values for the specific turbine were entered into the program, we were able to obtain an output for power (in kW) at varying tip speed ratios, which is shown below in figure 3.

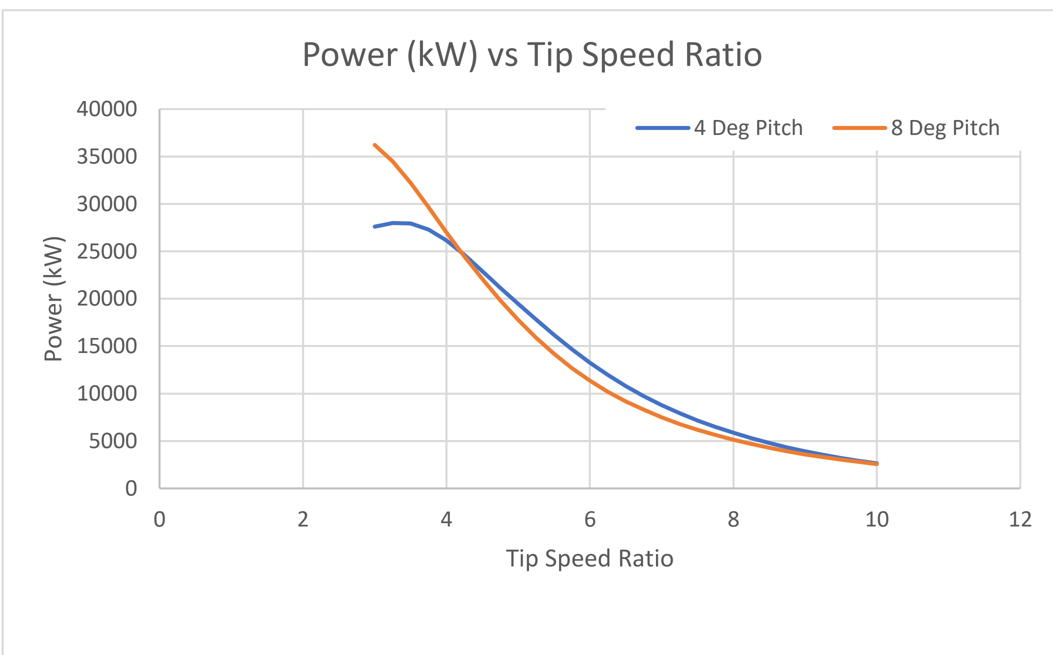


Figure 3. Power vs Tip Speed Ratio for 6 MW Onshore Turbine

This power output curve shows that at a 4 degree pitch angle, in the prime operating range around 8-10 for the tip speed ratio, expected outputs of above 6000 kW (6 MW) are certainly attainable. These outputs can be compared with those of the Cypress series turbines from the table below.

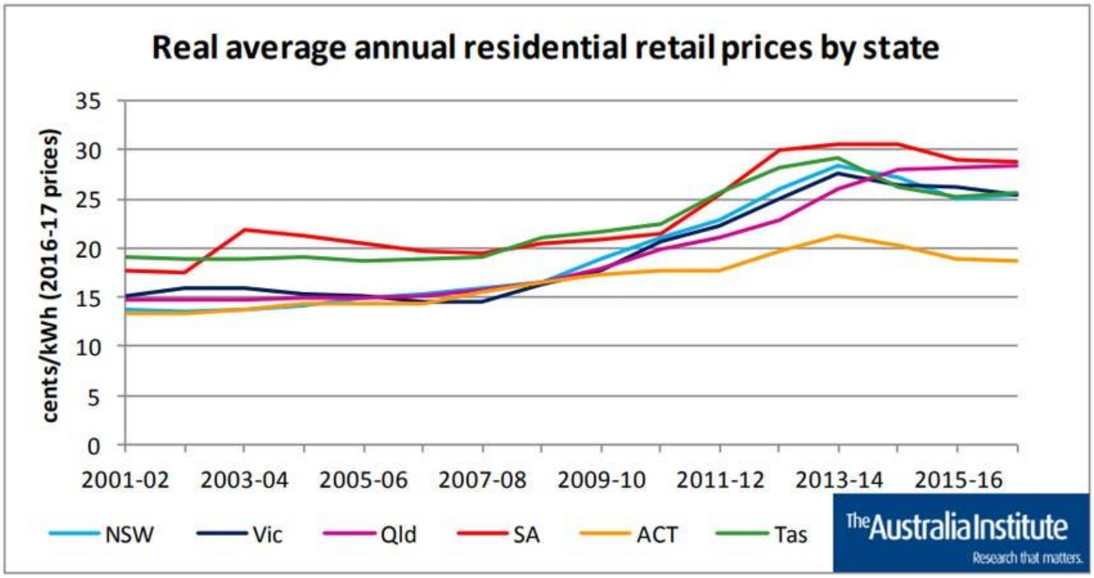
Table 2. Power Outputs for GE Cypress Series Turbines[3]

Cypress platform	4.8-158	5.3-158	5.5-158	6.0-164
Output (MW)	4.8	5.3	5.5	6.0
Rotor diameter (m)	158	158	158	164
Hub heights (m)	101, 121, 151 & 161	101, 121, 151 & 161	101, 121, 151 & 161	112, 167
Frequency (Hz)	50 / 60	50 / 60	50 / 60	50 / 60
Cut-in (m/s)	3	3	3	3
IEC Wind Class	S	S	S	S

From this analysis and comparison, my turbine has the potential to outperform existing models, while at the same time being slightly smaller in size. This could potentially have advantages when it comes to cost of energy, which was the final aspect of the turbine design to be analyzed.

Turbine Cost Overview

With the performance aspect of the turbine being verified through the use of turbine analysis software from WindPact, the feasibility of the site was now to be determined by whether or not we could be competitive with current costs of energy in the region. The figure below depicts cost trends in South Australia up to 2016[4].



Sources: ABS, *Consumer Price Index,* Table 9.
AEMC, 2013. *2013 Residential Electricity Price Trends final Report.*

Figure 4. Electricity Price Trends (in cents/kWh) for Australia

As mentioned earlier, the region of South Australia pays slightly more for their electricity than other regions. Therefore, with the addition of a large-scale farm, there is a larger margin for profit, assuming a reasonable cost of energy results from the analysis. Additionally, the prospect of lowering the cost of electricity for residents in this region allows for even more economic motivation behind the site.

Performing the cost analysis involved first using a Weibull-Betz probability distribution to estimate the energy capture per year for one of the wind turbines. This process involved multiple assumptions about the environmental conditions around the site, such as the windspeed deviation from the average anemometer windspeed. Taking into account the fact that the instantaneous windspeed is more likely to be below the recorded anemometer reading, a more realistic approach to modeling the efficiency and energy capture of the turbine across the span of a year was conducted.

With energy capture data from this first analysis, an NREL cost and scaling model was used to compute the costs of various elements to wind turbine/site materials, design, and construction, and maintenance. Certain equations required knowledge of specific components of the turbine, which are depicted in the table below, using similar parts to existing large-scale onshore turbine.

Table 3. Turbine/Hub Internal Design Specifications

Generator	Three-Stage Drive, High Speed
Gearbox	Three-Stage, Helical

After inputting the respective design parameters into the equations provided by NREl, cost estimates for capital, installation, equipment, and maintenance were output. Most importantly, a value for cost of energy, in cents per kWh, was obtained. The primary values calculated from this analysis are depicted in Table 4 below.

Initial Capital Cost	$8,795,519
Installed Cost per Kw	$1,466
Yearly Maintenance/Land Cost	$134,248
Cost In Cents/kWh	8.68

With a cost of roughly 8 cents/kWh, there is a large margin for profit given the current high price of energy in Southern Australia. At the current time, no other energy provider would be able to outcompete this wind farm when it comes to price reduction for electricity. Assuming the farm is able to be completed in 3-4 years, the number of other renewable energy sources in the region would not be yet sufficient to provide a cheaper or more reliable alternative. While current policies intend for Australia to become fully renewable by 2030, the recorded energy production in 2020 does not project that this goal will be fully met, unless a major breakthrough of new renewable sources within the region occurs in the coming years. Based on the cost, performance, and turbine design analysis, this large-scale wind site in Southern Australia is feasible, given proper funding and resources are put into the project to complete it in a timely manner. A final concern to be investigated are environmental issues, particularly avian, noise, and public policies/acceptance. These are key logistics that impact the support for construction of such a site, so these concerns have been addressed below with regards to specific environmental and public concerns within the specific region of interest.

Avian Concerns

One major issue that must be addressed regarding the environmental ethics of a large-scale wind farm is the fact that these turbines are capable of injuring and killing local bird wildlife, especially in the event that the turbine farm lies in the path of migratory birds.

Avian concerns for wind farms in Australia have been a large concern amongst environmentalists in recent decades, as the proliferation of new farms in order to meet the renewable energy targets have often been created in locations where numerous migratory and endangered bird species reside.

In the region of Southern Australia, reports show that numerous local wildlife species, such as raptors, quolls, Sea Eagles, Cranes, bats, and other local avian wildlife[5] have been impacted by the growth of the wind farm industry. Some notable migratory birds of Southern Australia include the red knot, stint, and turnstone. Each year, dozens of species arrive in Southern Australia from colder regions as far away as Alaska for the summer[6]. Although the altitude of the birds' migration is well above the height of the turbine blades, there could be a potential issue if the birds landed near the turbine site. This issue could be further escalated by the fact that my site is within 20 miles from the coast of South Australia, a place where many of these birds end their migration each year. While there is no denying that a wind farm placed anywhere in the region would have an impact on wildlife, there are measures that can be taken to limit bird injuries to a minimum.

One region for a large number of bird fatalities in the past was the widespread use of lattice structures for the turbine, which served as a great place for birds to perch and nest. As a consequence of residing so close to the turbine blades, these birds would often be killed when they leave their nest to hunt for food. However, the use of tubular steel turbines, as shown in figure 5 below, will offer much less residence for birds within the turbine structure.

Figure 5. Commonly Used Turbine Structures

In addition to using modern tubular steel structures for the turbines on site, the low RPM of the turbine should also help to reduce the chance of collisions with bird wildlife. While smaller surface area airfoils tend to need higher RPMs in order to operate and produce sufficient energy, the wide airfoils used in this design only need to run at 15 revolutions per minute, which corresponds to one revolution every 4 seconds. In the event that a bird crosses through the swept area of the blades, there is not a very large chance that they will be struck by one of the three blades. In fact, for any given point in space that the bird crosses, there would be over one second of time between each blade pass.

Because of the low cost achieved from the analysis done in assignment 4, there would also be extra money to spare for endeavors such as burying transmission lines, adding strobe lights across the tower, as well as using contrasting colors for the paint on the blade. While this would add quite a bit to the cost of the farm, it would be necessary in the event that public support was not adequate for construction. Additional measures would be taken to comply with federal wildlife conservation efforts, such as the Environment and Biodiversity Conservation Act of 1999 for Australia[8]. Further studies could also be conducted during the peak summer months for bird migration once the site is completed to address whether or not the site is adversely affecting bird wildlife in South Australia.

Noise/Aesthetics

With such a large-scale wind farm made up of hundreds of 6 MW turbines, it is clear that anywhere nearby the farm would experience a large amount of noise pollution. A large turbine produces a constant noise well over 100 dB while operating, so there will need to be a fairly large distance from the wind turbine to the nearest residential area. Luckily, the region of South Australia only consists of 1.7 million residents, with 1.3 million of them residing in the city of Adelaide. By placing the wind turbine in the location shown in the zoomed map below, there would be a National Park separating the wind farm from any nearby residence. This would ensure that any noise levels heard by the closest houses to the site would be well under 20 dB. By placing the site away from any residential area, it also removes the possibility of any aesthetic complaints about the view of the wind farm that could devalue real estate near the site.

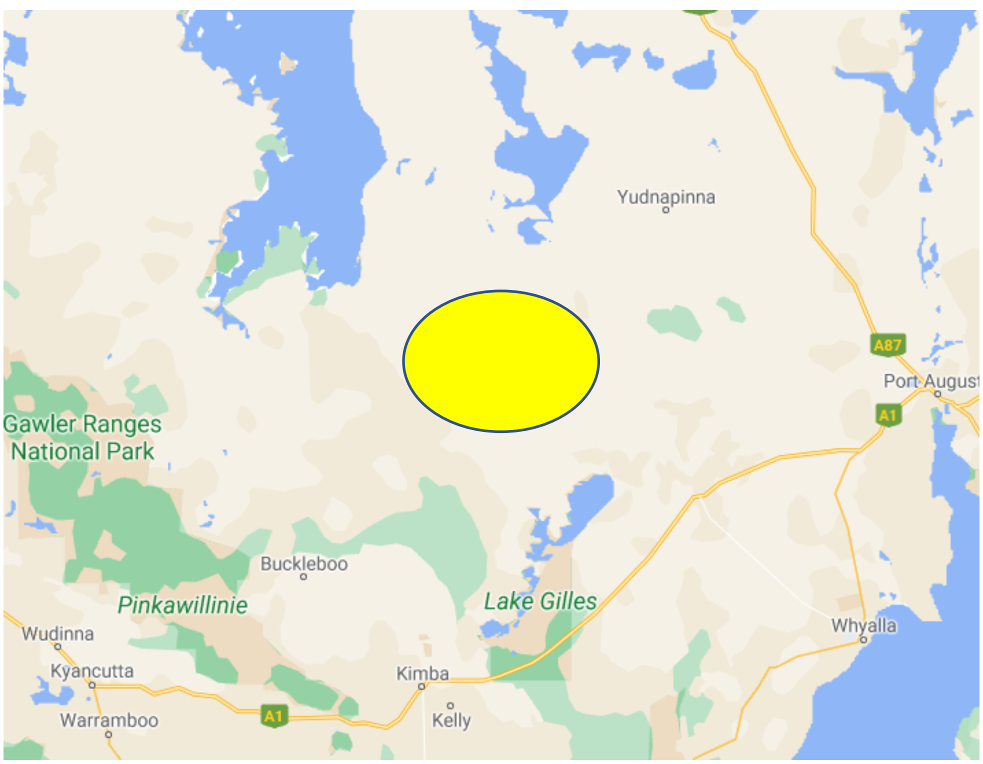


Figure 6. Prospective Location for Wind Farm Site

Public Policy/Acceptance

In terms of public policies for renewable energy, Australia has huge goals in this department, namely their aforementioned goal to achieve full sustainability by the year 2030. In order to meet this goal, multiple wind, solar, and hydro farms are being setup across the continent, both large-scale and individually-owned. Data trends from the South Australian Planning Portal[9] show an increase in wind turbine sizes over time, and policies to help ensure that these new large-scale sites are adhering to environmental and ethical regulations.

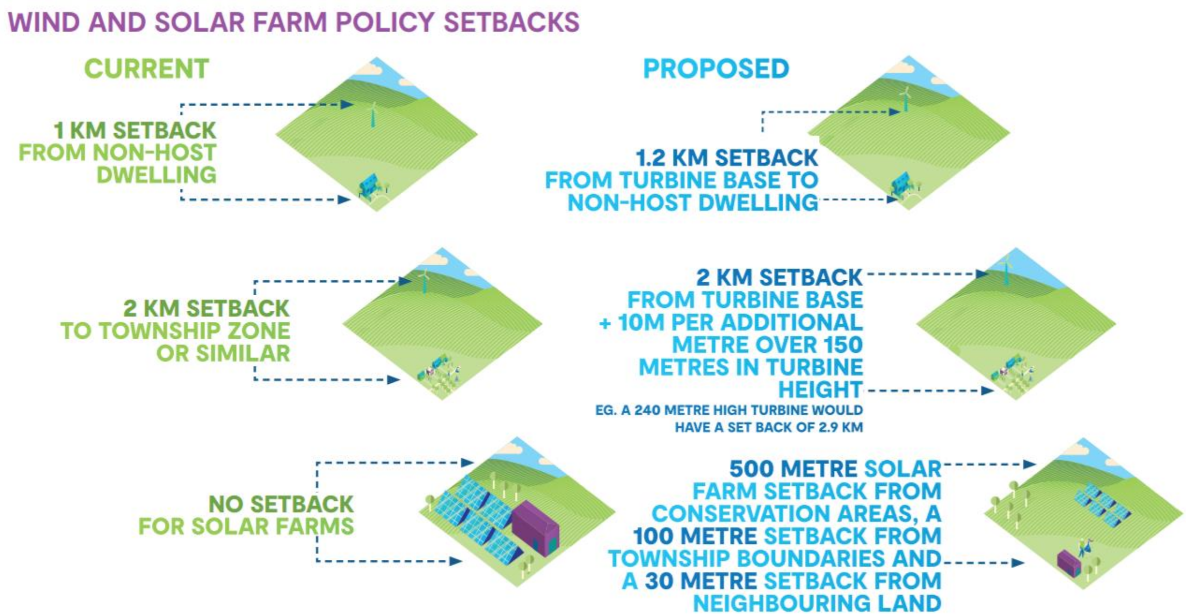


Figure 7. Suggested Public Policies Regarding Large-Scale Wind Farms

These policies that are currently being implemented fit well with the fact that my farm intends to be well over 5 km from the nearest residence or township. Adhering to these policies would also help garner public support and acceptance for these new farms. Along with support from the government's 100% renewable energy target, it is likely that there will be no obstructions to the completion of this new site.

Recent studies in rural communities of Australia[10] indicate that a vast majority of residents are in support of new renewable energy sources, as long as they are not within too close distance to their home as to cause aesthetic and noise concerns. The concern of the residents is actually less constraining than the public policy measures put into place, as the required 2 km setback is more than enough for a vast majority of the residents surveyed. With the need for a large amount of renewable energy sources in the region, and given the current environmental and economic situation in Southern Australia, I believe that this site is not only feasible, but will prove essential to providing the region with its desired renewable energy target. The positive impact this wind farm would have on the environment would heavily outweigh the slight inconveniences it could cause due to any avian, noise, or aesthetic issues.

References

[1] https://www.aph.gov.au/About_Parliament/Parliamentary_Departments/Parliamentary_Library/pubs/BriefingBook43p/poweringaustralia

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[9] https://plan.sa.gov.au/__data/assets/pdf_file/0005/572702/Renewable_Energy_Policy_in_SA_-_Infographic.pdf

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