Onshore Wind Farm in South Africa - Humansdorpf

46200 - Planning and Developing of a Wind Farm

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Contents

1 Introduction

"Humansdorpf" in South Africa is chosen as the case study site.
Initially, the authors enjoyed the idea of creating a wind farm in an unexplored and charming country such as South Africa is, although is known that South Africa is improving in the renewable energy field [1]. Secondly, after having briefly analyzed all the case studies and the related available sites, it has been observed that VM08, the one selected, is mostly flat and mainly covered by shrubbery. Furthermore, the low density population in the Humansdorpf area reduces the amount of constraints in term of sound and space.
Despite of the simplicity of terrain and the unoccupied space, it has been found that 4 wind farms are present around the chosen site. All the location are described in respect of the given VM08 mast.

- Tsitsikamma Community Wind Farm, 31 turbines with total capacity 95MW, located on the South-West.
- Kouga Wind Farm, 32 turbines for 80MW total capacity, located on the South-West.
- Oyster Bay 43 turbines with total capacity 140MW, located on the East.
- Gibson Bay, 37 turbines for 111MW total capacity, located on the South-West.

The presence of these could be both an advantage and a disadvantage; while the available space is more limited, in order to avoid the turbulent effect left from the close wind farms, it has been used some already existing facilities such as substations or roads in order to decrease the total cost.

References

[1] https://oxfordbusinessgroup.com/news/south-africa%E2%80%99s-push-renewables

2 Wind Resource Assessment

2.1 Identification of Potential Sites

To identify potential locations for the wind farm, the following constrains are considered:

- The distance from the met mast (blue circle in Figure 1): The area within about 11km radius from the met mast were considered as ideal sites . Due to the change in terrains in the northern part of the met mast, it is considered that placing the wind farm within the range would be conservative where the similarity principle applies well.
- Existing wind farms (green): There are 4 operating wind farms and 2 proposed wind farms in the region[1].
- Archaeological/palaeontological sites (red):The considered area is rich in archaeological findings. The archaeological site near the met mast is not allowed to develop. The are important findings from the site along the coast and it is assumed that developing this area will be difficult[2].
- Residential houses: Residential houses are presents around the site. A cluster of houses (more than 2 houses) is highlighted with a green placemark. A yellow placemark represents a single house. Purchasing may be an option if it is necessary to achieve the optimal wind farm design.
- Environmental impact: A study is carried out for negative impact and later mitigation on flora, fauna and landscape. The details will be discussed in section 5.

Figure 1: Spacial Development Framework in Kouga Municipality, South Africa

2.2 Topographical Inputs

Two maps, namely elevation map and roughness map, were created in order to obtain the flow model at the project location.

A map of 45x45 kilometers has been selected, in order to have flexibility in the wind farm layout which will take place at the later stage of the planning, while maintaining the minimum clearance between the border of the potential wind farm site and the map's boundary. The map was imported using "SRTM ver2 Database" feature of Map Editor.

Terrain Surface	Roughness z_0 $[m]$
Water	0.0002 (default)
Sand	0.003
Farmland	0.030
Bush of Forest	0.200
Low Forest	0.800
City	1.000

Moreover, in order to model the different roughness over the soil, roughness change lines were created through Google Earth Pro (`.kmz` file), to be imported afterwards into WAsP. Then the roughness was adjusted using the values in Table 2.2.

Lastly, aiming to have a better visualization of the real features of the ground, a background map was inserted; in this way the wind farm layout process has resulted more user-friendly and visible.

Figure 2 shows the completed map.

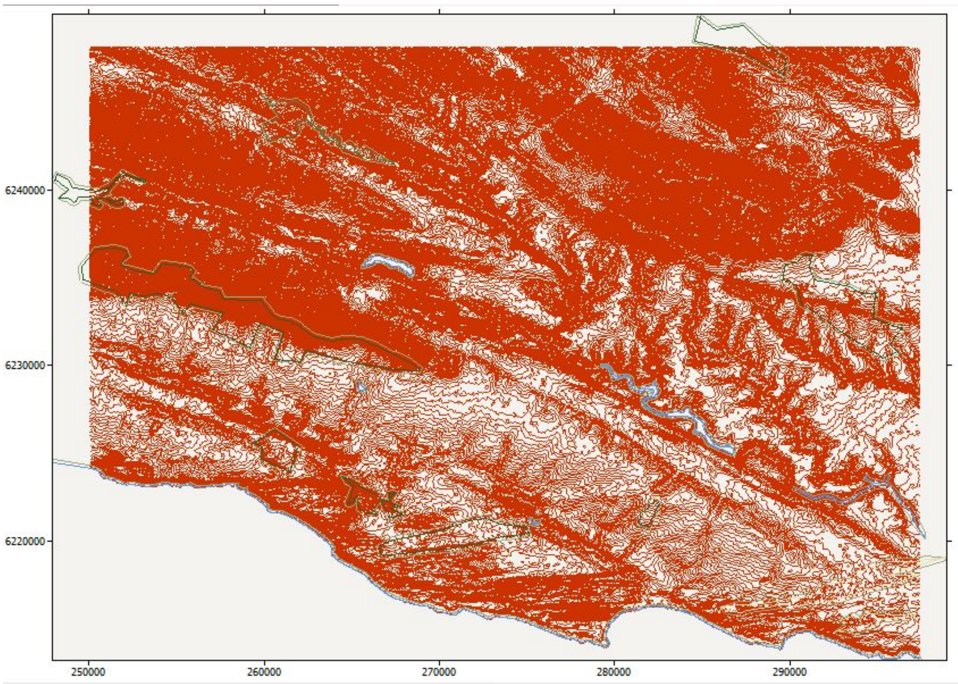


Figure 2: Vector Map in WAsP software

2.3 Wind Data Modelling

Wind resource assessment is performed in the initial stage of the project. Wind data is collected online: `www.files.dtu.dk`.

WAsP Climate Analyst tool is used to create Observed Wind Climate for period between 01/08/2010 and 01/01/2017.

2.3.1 Wind Data

A meteorological mast is located at coordinates -34.10996° N and 24.51436° E. The mast is equipped for measurement of wind speed, wind direction, air temperature, air barometric pressure and air humidity.

Wind speed is measured by cup anemometers at height of 10, 20, 40, 60 and 62m.

Wind vanes are present at 20 and 60m height.

The closest met mast to the reference mast is located at a distance of 222km and at amplitude of 1037.98m a.s.l. in the mountainous area versus reference mast at 112.89m a.s.l..

Therefore, cross-prediction between two masts would be not credible due to incompatibility of geographical locations.

In order to make sure that the wind data is accurate, representative and reliable, special consideration is made

regarding surroundings of the mast. It is not observed significant obstacles in the area with exception to scarce trees at approximately 320m from the mast.
Surrounding trees and bushes are not considered as an obstacle object but roughness element due to the distance to these objects exceeding 50 obstacle heights. Tree height in the area is approximately 6m. Dense forest is located at a distance of approximately 1.8km from the measurement mast and it is regarded as a roughness element. Anemometer data is available at level more than 3 times the height of a tree.
Height of anemometer should be similar to turbine hub height. The calculations are based on measurements taken at the highest point of mast at 62m. The highest point is chosen because there is least distortion to free wind speed.
Additionally, the vertical level of mast measurement should be preferably larger than 2/3 of hub height. In this case, the hub height should not exceed 90m a.g.l..

Visual inspection of obtained wind data is performed and it is checked if following conditions below hold:

- Each year of the utilized time series should contain at least 90% of data. For this reason, year 2013 is excluded from the analysis due to its data recovery rate is recorded at 67%.
- To avoid seasonal bias, it is important to use data for a full year. Full years of data only were selected with start and end dates corresponding to a calendar year. Therefore, year 2010 with recordings available from 01/08/2010 is omitted from analysis.
  Evidence of seasonal bias for south Africa climate is shown in the study [3].
- Data is also checked for constant values. It appears that no data behaves in this manner.
- Data should not contain any sudden spike in value. The highest wind speed at 62 m is observed to be 26.8 ms^{-1} and this can be explained by gusts.

Following findings are recorded:

1 Comparison between data at different heights is performed. It appears that the trend in data is aligned with expectations. So, e.g. the mean wind speed is observed to increase along the vertical direction, from 5.4 ms^{-1} to 7.2 ms^{-1} . Refer to figures 20, 21, 22, 23, 24 for details in Appendix A. The prevailing wind direction is consistent with all the measurements, being 270°.

2 Direction time traces are checked for two vanes at 60 and 20 meters. The discrepancies on directions are compared. Following findings are observed: significant discrepancies in the mean wind direction during night hours or early morning hours during July and August. This can be explained by meteorological phenomenon of decoupling. Due to time limitations, this is not studied in depth.

3 Calm class $(0 - 1ms^{-1})$ for wind speed in the histogram look realistic and follow Weibull distribution.

4 Data fitting with Weibull distribution is robust. Difference between fitted data and source data at 62m height for mean wind speed is 0.14% . Difference between fitted data and source data for power density is 0.23%. Both variances are within acceptable limit and do not exceed 1%.

5 Mean wind speed is 7.21 ms^{-1}. For each sector of the wind rose the mean wind speed varies greatly, according to the wind roses in the following figures. This pattern is repeated for each anemometer making the data more credible and more reliable.

2.3.2 WAsP analysis and calculation

The data is analyzed using the WAsP tool Climate Analyst 3.1.
After an initial check for data reliability (details in previous chapter), the data has been selected based on data recovery. It is worth to notice that having direction measurement only for heights 20m and 60m, where the former is applied for height 10m and the latter for height 40 and 62 meters.
After data selection 4 or 5 years of measurements are available for each anemometer. Notice that no data

patching was necessary.
An observed mean wind climate is generated for each anemometer height, and a new data check is performed. The observed wind climate for height 62m is saved and imported to WAsP. For this height an observed extreme wind climate is saved as well, it will be necessary for future computations.
The observed mean wind climate (Omwc) is now imported to WAsP. Omwc and the terrain analysis are used in conjunction to generate a general wind climate. Notice that WAsP uses the given data to extrapolate a wind shear profile, but this profile might not fit the measured data at each anemometer height. The heat flux value is than changed regarding the mean values found in the Climate Analyst for each anemometer height.

To find the correct value a Matlab code has been generated. The following method is implemented:

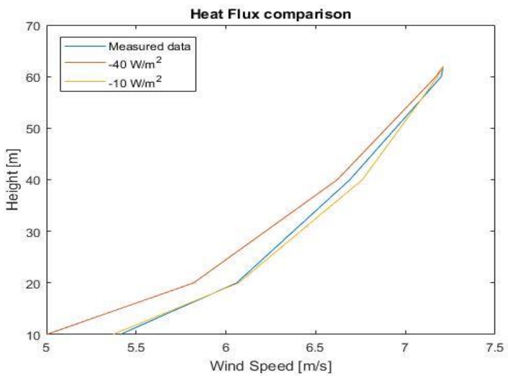
1 Data of mean wind speed at desired heights is collected trying different heat flux values in WAsP.

2 Compute the difference between the measured values and the WAsP extrapolation.

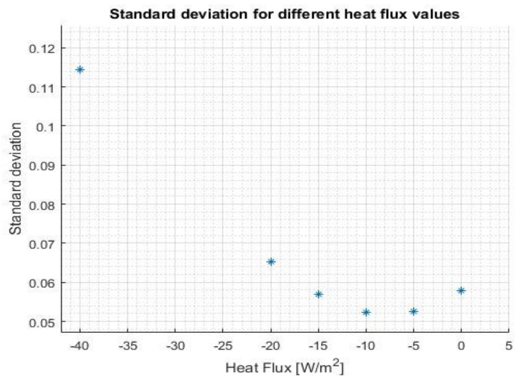
3 Compute the standard deviation of such difference.

4 The heat flux value that gives the less standard deviation is to be used.

Results are shown in the following figures. By comparing the wind shear model on figure 3a to the measured data it is clear that the model will not represent fully the measured wind shear profile by just changing the heat flux. In fact that the land roughness might be slightly different from the assumed, the air density will change during the year and that the heat flux is actually not a constant value.



(a) Wind shear profile for different Heat Fluxes



(b) Heat Flux standard deviation comparison

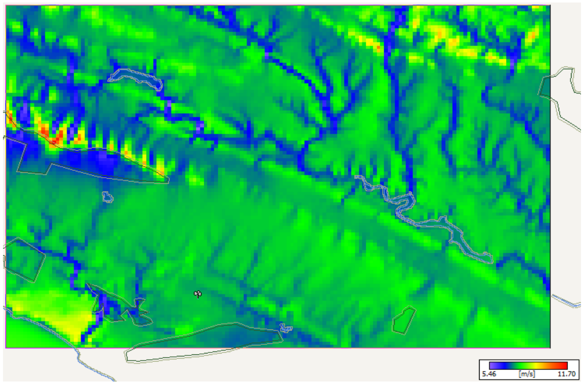
Figure 3: Heat Flux

From figure 3b it is clear that the wind shear profile that gives the least standard error belongs to heat flux equal to $-10\ Wm^{-2}$. This value is then used through the whole case study.

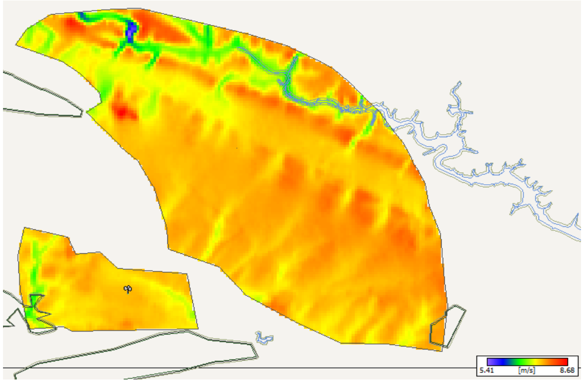
2.3.3 Predicted wind climates and resource map

Having an observed mean wind climate and a terrain analysis it is possible to make WAsP predict the wind climate reliably for any point on the map up to approx. 10-15 km from the mast. This procedure will be used to compute the wind climate for each turbine hub.
WAsP will also be able to compute a wind resource map to have an overall information on wind availability on the map. An example is given below.

A detailed resource map for the available space for the wind farm is also computed.



(a) Resource grid for a larger area



(b) Resource grid for a smaller area

2.3.4 Sensitivity Analysis

It is useful to know for which parameters the model will give us a relative big variation in AEP with a small variation of such parameter. This information will be used later for estimating the uncertainties of the model, affecting the economics (chapter 7). Notice that these parameters are site dependant.
Nominal AEP (including wake losses from our farm and neighbouring farms): 147.8 GWh.

Parameter	Variation	Predicted AEP [GWh]	Variation in AEP [%]
Wind speed calibration	+1%	149.9	1.42
Anemometer height	-1%	148.7	0.61
Adapted atlas height	Changing default atlas height to anemometer and turbine hub height	147.3	0.35
Wind direction offset	+10°	149	0.81
Background roughness	Doubled to 6cm	148.9	0.74
Background roughness	Halved to 1.5cm	146.9	-0.61
Mast location	+10m West	148.3	0.34
Mast location	+10m East	148.4	0.41

Table 1: Sensitivity Analysis

As shown in the table 1 the model is most sensitive for wind speed calibration, meaning uncertainty in wind measurements.

2.3.5 Uncertainty estimates on wind speed

Using the knowledge gained in this wind resource assessment it is possible to estimate the uncertainties given by the wind resource measurement and modelling. The results are available in table 2.

2.3.6 Wind farm additional losses

Apart from the sources of uncertainty discussed above, it must be noted that the wind farm will be subject of technical losses and other sources of AEP loss discussed in section 3.4.2 and wake losses discussed in section 3.4.1 .

2.3.7 WAsP limitations

Following the uncertainties mentioned above, it is clear that Wasp is not a perfect model.
Vertical extrapolation is unrealistic when the predicted site is too high relative to the anemometer height. For this reason, we choose a turbine of hub height 80m.

Uncertainty	Sigma [%]	Reason
Wind measurements	3.00	High AEP variation in sensitivity analysis
Long-term climate correction	1.00	High number of analyzed years
Year-to-year climate variability	3.00	High variation in year-to-year mean wind speed
Vertical extrapolation by flow model	2.00	Average difference in predicted versus measured mean wind speeds and reasonable dependency on background roughness
Horizontal extrapolation by flow model	2.00	Average dependency on mast locations

Table 2: Uncertainty on wind speed

Computing far wake losses is difficult for WAsP in our site since the far wake model is unreliable. It is believed that WAsP will overpredict these losses.
Air density and heat flux are clearly not constant for almost any time spawn: this is a concern since this site is subject to different mean wind speeds both on a season cycle and on a daily cycle.

References

[1] Kouga municipality. (2015). Spacial Development Framework. Retrieved 17 January, 2018, from http://www.kouga.gov.za/download/2798

[2] Nilssen, P. (2013). Heritage / Archaeological Impact Assessment Proposed Gibson Bay Wind Farm Grid Connection, Kou-Kamma and Kouga Local Municipalities, Humansdorp District, Eastern Cape Province. Retrieved 14 January, 2018, from http://www.sahra.org.za/sahris/sites/default/files/heritagereports/KLM250%20Draft%20AIA%20V3,%203Oct13.pdf

[3] "Strong wind climatic zones in South Africa", A. C. Kruger, A. M. Goliger, J. V. Retief and S. Sekele, Wind and Structures, Vol. 13, No. 1 (2010) 000-000.

3 Wind Farm Calculations

3.1 Wind turbine type and IEC class

The wind turbine class is given by extreme wind conditions and from turbulence intensity.Calculation for turbulence intensity are given by WAT (see section "Site assessment: extreme wind and turbulence intensity"), while the extreme wind conditions are computed in WAsP Climate Analyst tool (see Section 2.3.2).
Following the IEC 61400-1 it is found that to be able to withstand the ambient conditions the turbine should be at least class IIB. Notice that wake effects will increase the turbulence intensity on the turbines. Since this is related to the wind farm layout, an iterative process might be necessary.
Given the information covered in the next sections, the wind turbine Siemens 2.3MW − 108 is chosen. It belongs to class IIB, given that the added turbulence intensity due to wake effects is small enough.
It has been ensured that Siemens deliver in the country. [10]

The tower height must be of 90m or less, as shown in section 2.3.1. The standard height for the chosen turbine is 80m, which will make sure that the vertical extrapolation from WAsP is reliable.

3.2 Wind turbine generator input

The necessary generator file regarding the chosen turbine is available at Campus Net.
This file will be added to WAsP and WAT for computation. Similarly, each neighbouring wind farm is simulated using its own turbine generator. Due to an incompatibility from WAsP 11 to WAsP 12 the files will need to be manually converted. Some wind turbines will also include Ct values greater than 1: WAsP 12 will not work properly with these values and they need to be manually changed as well.

3.3 Wind farm design and layout

Given the available space shown in Section 2.3.3, although it is possible to use this space freely, some consideration must be noted:

1. The space at the top left (after the road) is very close to an existing wind farm, increasing the wake losses and its related turbulence intensity.
2. Placing turbine on both sides of the river or the road will present a problem when cabling. An overhead line will be necessary increasing visual impact.
3. The space at the bottom left (near the mast) is too small to place a significant number of turbines. Although this is not a constraint, this solution is not preferred.
4. The space between the river and the first row of houses just below it will force a horizontal oriented wind farm, increasing the wake effect and its related turbulence intensity greatly.
5. For noise and regulation constrains the turbines should not be placed closer than approximately 300-400 meters from the houses. This value mainly depends on the turbine height and noise.

These points reduce the available space greatly. On top of these constrains the following considerations are kept in mind:

1. Placing the turbines on straight lines is preferred due to visual impact
2. Cabling distance must be kept at a minimum
3. Ground occupation and trampling during construction, operation and dismantle should be minimized. This includes road building.

4. Specific environmental constrains
5. Wake effects

This lead to choosing the following wind farm layout, where two vertical rows of turbines are placed approximately 3.5 km apart. The turbines spacing is 4 rotor diameters (432 m). The proposed wind farm is highlighted with a yellow boundary.

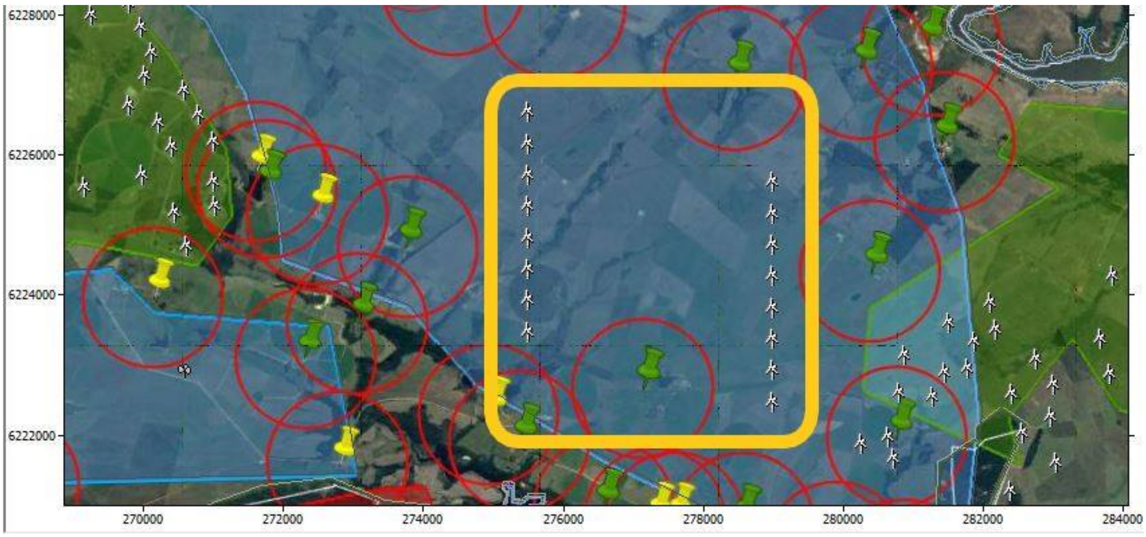


Figure 5: Final layout

Following the same procedure, two alternative layouts are proposed, in figures 25 and 26 in the Appendix A.

3.3.1 Layout optimization

For three proposed wind farm layouts, advantages and disadvantages are given in the following table 3:

Layout	AEP [GWh]	Advantages	Disadvantages
Final	147.8	Versatile, low visual impact, low wake loss	Sparse, cabling
Alternative 1	147.6	short cabling, low visual impact, less land use	closer to houses
Alternative 2	182.3	higher capacity, compact	Visual impact, noise, wake losses

Table 3: Layout summary

The layouts are designed to address different needs. All of them are economically feasible with high capacity factor (37%-38%). The choice of the main layout resides in its versatility, allowing a moderate tolerance in turbine placement without affecting neither AEP nor TI. This is especially useful in case the land owner requests to avoid certain spots.(Stakeholders concerns are described in section 6.1) The alternative layout 2 is considered if visual impact and noise are not a major concern for residents.
This report will show further calculation for the final layout only.

3.4 Annual Energy Production (AEP)

The AEP was calculated using WAsP. The gross AEP, net AEP, P_{50} and P_{90} are summarized in Figure 6. The net AEP is 147.8GW. The details of wake losses, additional technical losses and uncertainties are discussed in following sections.

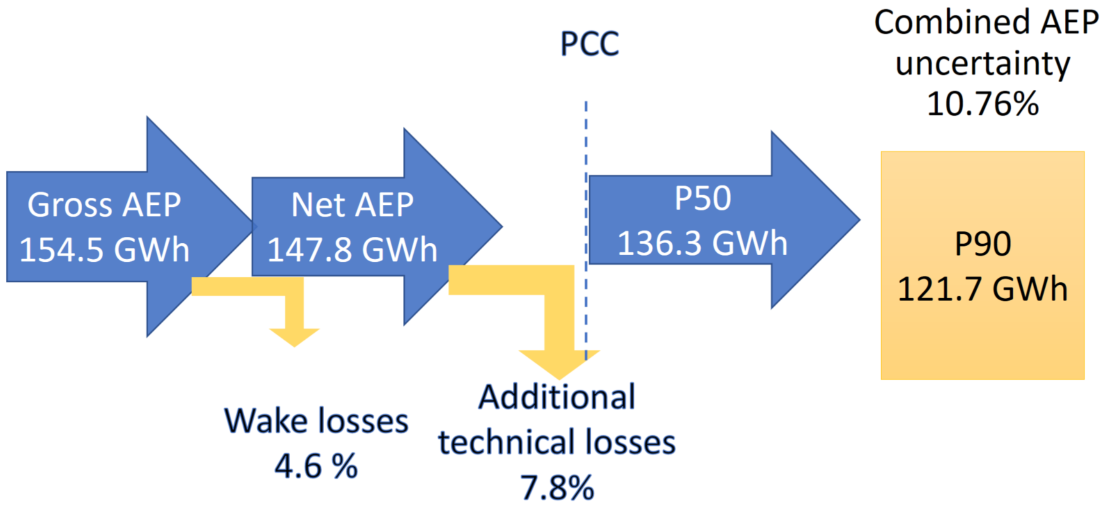


Figure 6: AEP

3.4.1 Wake losses

Existing wind farms

There are four existing wind farms near the proposed site. Table ?? summarizes existing wind farms.The location of each farm is indicated in Figure 7. It should be noted that hub heights of wind turbines at Tsitsikamma Community Wind Farm and Gibson Bay farms were not available. Estimations were made based on the manufactures' specification

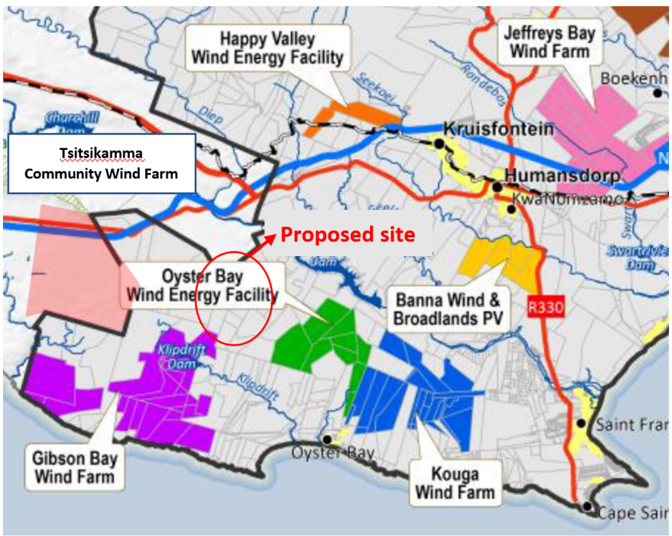


Figure 7: Wind farms near Humansdorpf: source[1],edited

Name	Capacity [MW]	Model	No of turbine	Hub height [m]
Tsitsikamma Community[2][3]	94.8	Vestas V112-3.0 MW	31	84[7]
Gibson Bay[4]	111	Nordex N117/3000	37	91[8]
Oyster Bay[5]	140	Vestas V117 3.3MW	43	91.5
Kouga[6]	80	Nordex 2.5MW N90	32	80

Table 4: Existing wind farms

In order to consider wake effects caused by nearby wind farms, the four wind farms are modelled into WAsP.

Since there was no final layout of wind turbines at Oyster Bay Wind Farm was available, the location of wind turbines are decided based on the drafted design in EIA report by Savannah Environmental Pty Ltd[9]. For the rest of wind farms, turbines are placed at the exact locations which were observed by Google Earth.

The effect of each wind farms to the proposed wind farm was investigated.The result is shown in Figure 8 together with approximate distance from the proposed site. The total wake losses of 4.6% were observed. The internal wake loss accounts for 1.8%. Oyster Bay Wind Farm has the highest impact on the proposed wind farm due to its proximity.Though Tsitsikamma Community Wind Farm is located on the west, which is the prevailing wind direction, the effect is not as high because of larger distance. The effect from other two wind farms are small.

There are two proposed wind farms in the region. They are Happy Valley Wind Energy Facility and Banna Wind & Broadlands PV as shown in Figure 7. These farms were not taken in account in the calculation as layouts of these farms are not available. Considering the distance and the prevailing wind direction, the wake losses are expected to be low.

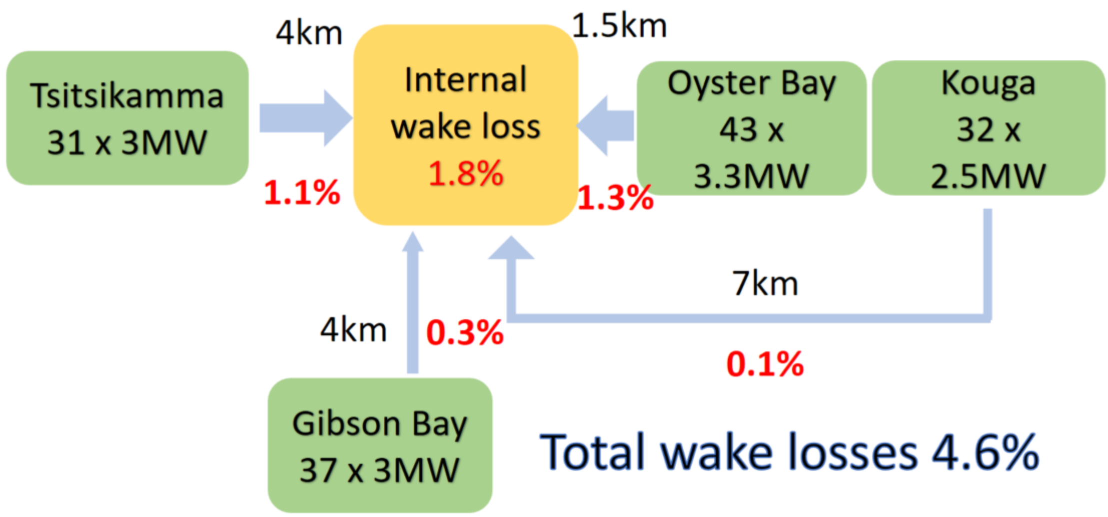


Figure 8: Wake Effects

3.4.2 Additional technical losses

The additional technical losses are estimated to be 7.8% and Table 5 shows the breakdown. By subtracting additional losses from the net AEP, P_{50} was calculated. No sector management is necessary for any proposed layout.

Availability	Turbine	3%
	Balance of plant availability	1%
	Grid availability	1%
Electrical Efficiency	Operational electricity efficiency	1%
Turbine performance		1%
Environmental		1%

Table 5: Additional technical loss

3.4.3 Uncertainty estimate

In addition to the 5.20% of uncertainty on wind speed, the following uncertainty factors on AEP were consider (Table 6). The additional uncertainty is estimated to be 7.42%. This results in the combined AEP uncertainty of 10.76%. P_{90} was calculated based on this figure.

Uncertainty	Sigma [%]	Reason
Power curve	6.00	Pc given for the standard air density
Power metering	1.00	Typical value
Wake-loss modelling	4.00	Complicated wake effects due to nearby wind farms, unknown layout of Oyster Bay Wind Farm
Technical losses	1.00	Typical value
Air density	1.00	Computation by WAsP 12

Table 6: Additional uncertainty factor

References

[1] Kouga municipality. (2015). Spacial Development Framework. Retrieved 17 January, 2018, from http://www.kouga.gov.za/download/2798

[2] Kou-kamma Municipality. (2017). Tsitsikamma Community Wind Farm. Retrieved 17 January, 2018, from http://www.koukammamunicipality.gov.za/tsitsikamma-community-wind-farm/

[3] Vestas central europe. (2013). News release from Vestas Central Europe. Retrieved 17 January, 2018, from https://www.vestas.com/en/media/ /media/0920721f2d534b01bb23c3e706f8b44f.ashx

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[9] Savannah Environmental Pty Ltd. (2011). Final Environmental Impact Assessment Report: Proposed Wind Energy Facility and Associated Infrastructure on a site north of Oyster Bay, Eastern Cape Province. Retrieved 14 January, 2018, from http://www.ekf.dk/da/om-ekf/CSR-i-EKF/Documents/Oyster%20Bay%20-%20EIR%20-%20Main%20Report%20(Nov%2011)_EIA.pdf

[10] Siemenscoza. (2018). Siemenscoza. Retrieved 19 January, 2018, from http://www.siemens.co.za/en/news_press/news2009/july_16_2009_2.htm

4 Connection to the electrical grid

4.1 Status of existing electrical grid

Eskom is the major Transmission System Operator (TSO) in South Africa responsible for 95% of the South African electricity in accordance with supply and demand requirements. [1]
In order to select feasible and less costly route to the main grid, detailed review of existing routes from neighbouring wind farms is done.
The main challenge in gathering this information is due to absence of a common database of substations and major power lines in South Africa. Therefore, information is sourced from various reports such as Environment Impact Assessment or Feasibility Studies and references are provided in the document.

Most of neighbouring wind farms in Kouga region are connected to Melkhout Substation (132 kV/66kV). The capacity of the existing Melkhout substation is 120 MVA, and this capacity is not expected to increase. [2]
The next popular destination is Diepriver Substation. It has a smaller capacity of 2*20 MVA and is connected to Melkhout Substation by 132 kV distribution power line. Another distribution line within Kouga area at 66 kV stretches between St.Francis and Melkhout Substation and it is further to the east from the planned site.
It is worth to mention that both Melkhout and Kouga substations are visible from Google Earth.

Existing wind farms utilizes existing distribution lines or build their own power lines until Point of Connection (POC) to the main substation.

- Kouga Wind Farm built a 33 kV/132 kV substation to link the wind farm to the Eskom power grid. The cost is estimated to R150-million.
- Oyster Bay Wind Farm utilise existing Kouga Wind Farm Substation to connect to main grid.
- Gibson Bay and Tsitsikamma wind farms connect to Wittekleibosch Substation and further to Diepriver by 132kV power line.

The scope performed in this report is to obtain the permission in order to connect to already existing power lines, in order to decrease the overall cost as well as decrease the negative impact on environment. For this purpose it has been selected Kouga Wind Farm substation.

4.2 Map of electrical lines and connections

In figure 9 is shown the electrical connection for the presented project. It is worth to explain the legend:

- The *white star* represent a single wind turbine Siemens 2.3 MW-108. The inner voltage output is 690V, that can be stepped by a dedicated transformer up to 33kV.
- The *green symbol* represent the substation that the developer have to build to gather wind turbines' cables. In this case is not needed the transformer, due to the fact that the voltage input into Kouga Substation is 33kV.
- The *red line* represent the underground cable. Each wind turbine is connected in parallel (to maintain the rated voltage at the extremities) and than plugged into the "Possible Substation".
  The total length of the underground cable is 10.7 km.
- The *green line* highlight the over head lines (OHL), of 33kV capability, that passes along the road. This solution has been chosen for aesthetic reason.
  The total length of the over head line is 14 km.
- The *blue flag* represent the Kouga Substaiton; inside are present further a transformer, that step-up to 132kV and a switch gear.

Although could seem costly to assemble a dedicated transformer to each wind turbine, it is worth to remember that the higher the voltage the lower the loss through the cable. Moreover, this solution is the most common nowadays.

In order to connect into the grid, it must be verified the strength of it. A roughly calculating could be done by knowing the short circuit power. The ratio r must be inner the range $2\% - 20\%$, where

$$r = \frac{Capacity[W]}{ShortCircuitPower[MVA]} \tag{4.1}$$

Due to the fact that the Kouga Substation admits 3 wind farms, the capacity in equation 4.3 is the sum of the capacity of all the three wind farm. Thus

- Kouga wind farm, 81 MW capacity.
- Oyster bay, 140 MW capacity.
- Presented wind farm, 37MW capacity.

for a total capacity of 257 MW.
The short circuit power, for a voltage line of 33kV, varies from 300MVA to 2500MVA. It has been checked that in the range 1300MVA - 2500MVA the ratio is valid.
As a result, it has been assumed that the grid is strong enough. Furthermore, it has been neglected any issue related to the over exceed of input cables; in a real estimation, the TSO is in charge to measure the input power in the substation and state if the total capacity input exceed the capacity of the substation.

$$r_1 = \frac{257}{1300} = 19.7\% \tag{4.2}$$

$$r_2 = \frac{257}{2500} = 10.3\% \tag{4.3}$$

Figure 9: Map of connection to grid

4.3 Electrical equipment required

The region presents few possibilities of utilizing existing infrastructure and it has been assumed feasible to build overhead lines of 33kV directly routed to Kouga Substation (33kV/132kV step-up transformer).
In this case, the power lines do not have to be costly due to shorter distance to the close-by substation. Alternatively, there are possibilities to connect to existing distribution lines of 66kV, located in Tsitsikamma wind farm, but due to the lack of the exact position and other specifications available on the web, it has been decided to reject this latter option.The advantage of connecting to existing infrastructure is related to challenges encountered in the planning phase: seek of landowners consent according to Environmental Impact Assessment Regulations published in Government Notice No. R. 385 of 21 April 2006; Basic Environmental Assessment and impact evaluation according to National Environmental Management Act (NEMA No. 107 of 1998) ; hire-in of external contractors for construction of new facilities.
The typical electrical layout of wind farm consists of two parts: collection system and transmission system.

- Collection system includes all electrical equipment necessary to gather the power from all wind turbines.
- Transmission System is responsible for transporting the power to POC

The following figures in 10 give the general idea of a wind farm layout and the generator assembled.

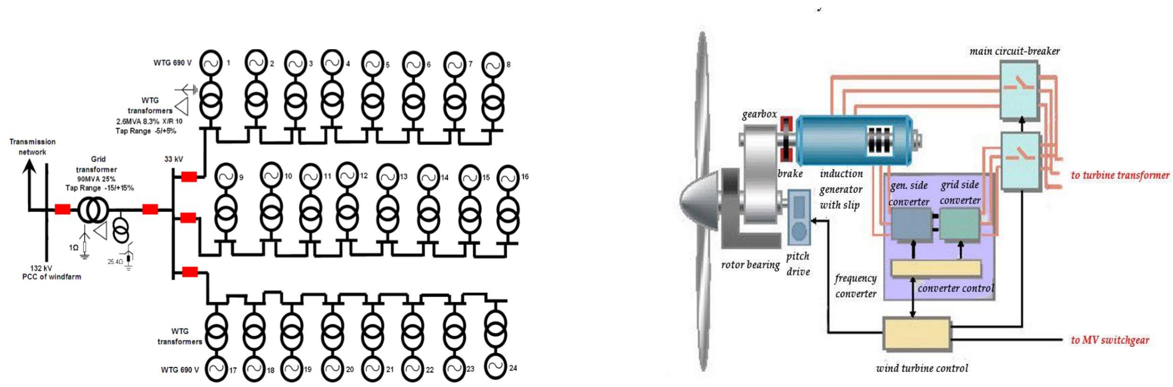

Figure 10: Generator and wind farm layout

Induction generators compared to synchronous generators are more popular because they have a simpler construction and they are relatively low-priced and may be connected and disconnected from the electrical grid network with relative ease. Fixed speed generators are cheaper and more robust then variable speed units although they have the disadvantage of absorbing reactive power. Variable speed WTG are more efficient and able to capture more wind energy by varying the speed of the machine while increasing the wind speed.
The selected generator for the project is doubly-fed induction generators (DFIG). This type supplies reactive power and allows increased energy yield at low wind speeds for turbines rated higher than 1 MW; furthermore DFIG are now the most commonly used machine. (6)

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5 Environmental Impact Assessment

An Environmental Impact Assessment (EIA) must be performed, according to the local legislation [1]. This fundamental document provides information to decision makers and stakeholders about:

- Consideration about the site, in terms of topography, flora and fauna.
- Estimated effects of the proposed wind farm on a specific area, in terms of environmental impact, noise and visual impact.
- Suggested mitigation and alternative measures to reduce the impact.

This document is needed according to the amendment of the National Environmental Management Act (Act No. 107 of 1998) (NEMA), for the activities that "may have a potential impact on the bio-physical environment, socio-economic conditions, and cultural heritage.". [2]

5.1 Description of the site

The site belongs to the sector labeled by the World Geotedic System (*WGS*) WGS 84, UTM zone 35 south. The closest city to the proposed wind farm is a small town called Humansdorp, in the district of Eastern Cape, South Africa, around 30 km away from the met station.

The area considered is primarily flat and covered by shrubbery, having an average height of 200 meters above the water level. Nevertheless, it can be noticed from figure 1 that both mountains and valley are present, that however cover the smallest percentage of the total area.
In addition, the location is mainly used for agriculture and pasture, despite the high presence of wind turbine around it. It must be checked if the construction of a new wind farm will decrease the farm production as well as the potential new road.
Despite of those initial issue to be verified, it is a rule of thumb that the footprint of a windmill onshore is largely small, thus the available field for agriculture won't be much affected.

The population of Eastern Cape counts around 6 millions people, that are mostly concentrated around the cities near to the coast, such as Port Elizabeth and St Francis Bay. The average density is around 40 citizen per km^2. For a comparison, in Denmark the population density is 129 ab/km^2.
The figure 27 in Appendix A shows the distribution of population.
This reduced number of resident around the wind farm area decreases the social environmental impact, in terms of noise and visual impact. Despite of the latter, some farms, factories, and stations were found in the surroundings. [3]

It is worth to say that it has been divided the performed EIA in two steps: a general planning, where it has been verified if the chosen location can allow a wind farm project, and further a project planning, where it has been ensured that the proposed wind farm matches the chose location.

5.2 Analysis of the principal environmental issues

In this section will be highlighted four issues that the authors found relevant for the chosen site.
Secondary issues will be presented in a brief analysis in Section 5.3.

5.2.1 Flora and Fauna

Fauna and flora in South Africa are extremely eclectic and various, including mammals, birds, reptiles and raptors, as well as fynbos (various local plants). In order to preserve this diversity, special prevention must be included in the report.
In order to have a comparison,it has been checked for existing EIA of Kouga Wind Farm, Jeffrey Wind Farm

and Gibson Wind Farm.[2]

The endangered animals can be sorted in a list and for each specie the authors has made some assumptions in order to know if the proposed wind farm will affect the local fauna [4].

Animal	Threat	Mitigation
Cape Volture	Loss of habitat, collision with cables and wind turbine during hunting.	Underground cables or Double Loop Bird Flight Diverters [5]
Blue crane	Loss of habitat, collision with cables.	Underground cables.
Golden Moles	Loss of habitat, nest destruction.	Recognize the nest by surface observation and avoid local construction.

Table 7: Endangered animals during wind farm developing

In addition to the wild animals, it has been found many National park and restricted areas in the chosen location. The closest National Park is Tsitsikamma National Park, far 80 km away from the met station, while the closest Natural Reserve called Huisklipis located 6.5 km away from the same reference point.
South Africa is also a wide heritage area; only 22 km away from the met station, is present a restricted archaeological area called Klasies River Caves where has been found by archaeologist and anthropologist some findings belongings to the Middle Age.
For the design of the layout the minimum distances required by the Municipal legislation has been taken into count. For instance, minimum distance of 4 km from the coastline as well as from national park and archaeological site, 2 km from railways and 10 km from the city.
A minimum clearance of 95 m must be respected from the power line of 132kV. This has been assessed by Eksom.

Furthermore, it has been considered the environmental impact on the birds living in the surrounding area.
It has been used a sensitivity map [6] to patch the most risky locations. Briefly, the darker the patched area, the worst the impact on the local avian fauna, in term of species, migration, mortality during collision.
It is possible to highlight (figure 28 in Appendix A) that the most risky area is toward the norther part of the map, on the mountains.
The lighter squares are lower risk area, thus it has been assumed reasonable to proceed with the wind farm layout.
More than birds, the bats are the most in danger creatures; insect are inclined on flying around the wind turbine, and thus bats goes near-around to find food. An interesting proposed solution in order to mitigate the problem, is to paint up wind turbines and drive the insects away [7].

5.2.2 Accessibility

The "accessibility" states the easiness to reach a given location. In figure 11 it is possible to notice the already available roads to access to the wanted farm.
Although the viability is already good and the improvement is in progress, as confirmed from Kouga Wind Farm website, in order to reach the new wind farm some different ways must to be traced.
This procedure must be included in the EIA because it affect the environment. As previously stated, the area is mainly employed for farms, and the lack of big building is an advantage. Moreover, the wind turbines are not placed on steep mountains hence the flat soil will helps the operation.
A possible mitigation is replanting. It is then possible to estimate the total built up area and create urban island for refreshment.
Finally, the operation of new roads will affect marginally (due to the consideration previously mentioned) the habitat.
Tracing new additional roads is an operation that increases the total cost and further it is clear that some special permission to operate will be needed by the developer. As explained in section 5.2.4, the two involved sides has to find an agreement to the usage of the roads. As a matter of fact, the construction of road or the

agreement with the engaged competitor must be included in the cost report. It is worth to say that build up new routes increases the overall value of the area, as well as is a free usage for the public.

Figure 11: Available road

Assuming to build new track inner the wind farm area, it has been estimated 28km road. These are linking horizontally and vertically the 2 wind farm rows.
It has not been found a reference to a cost per km unit in South Africa.

5.2.3 Visual impact

The wind farm lies on a wide open space; it is clear thus that the wind turbines change the landscape. Furthermore, the chosen windmill is massive and tall with a hub height equal to 80 meters.
The wind turbines however are seen mostly when proceeding the main road, as shown by the figures 12a and 12b. The hearty-placemarked road spreads over a low inclined valley; toward that street it is possible either to clearly see the proposed wind farm when the road is cleared from trees, or to see the trees along the road that hide the windmills.
It is not possible to find a way of mitigation, although the aforementioned considerations make the location not too invasive. The only mitigation performed is to set up a symmetric wind farm layout, where the turbines, all the same model, rotate with the same frequency.

(a) Point of View - 1

(b) Point of View - 2. The red arrow indicate the location

Figure 12: Available road

It must be taken into count a minimum distance from the roads.
Due to a lack of available literature, it has been assumed that the same legislation valid in Denmark, is also valid in Eastern Cape. Hence a minimum distance of 250 meters has been calculated.[8]

Lastly, it has been assumed negligible shadow flickering, due to the high presence of wind turbines in the area and the small presence of residents. Many dwellings in the area are factories and warehouses designated to operations inner the wind farm.

5.2.4 Permission required

In order to fulfill the local legislation requirements, many and various permission are requested in order to perform the wanted project. As an example, Life Cycle Assessment, Noise Impact Assessment, Waste Assessment, Water Assessment etc. A wide overview of the needed assessments can be found in the EIA of the close wind farm named Oyster Bay [5].
In the presented wind farm, the developer firstly must obtain the permission for using the land for 20 years. Then, he must address permission related to creating new additional roads in taken property, erecting the wind turbines, utilizing the space for a warehouse to store materials, thus a sort of agreements must be performed from both the interested parts.
This kind of task is very time consuming, and sometimes the project has to be changed because of the impossibility of obtaining the wanted green light.

5.3 Analysis of the remaining environmental issues

In this section are going to be detailed some secondary issues, that are going to be briefly described.
These topic has been found either less deepened in the literature or less relevant for the presented project.

5.3.1 Noise impact

It is clear that during the installation some noise will be produced. It is recommended [9] that during the day a maximum sound level of 45dB must be heard from the houses.
The windmill chosen has an output noise sound around 105 dB in its the close vicinity.
It has been found an useful tool to verify the sound limitation [10]; in this way it has been checked that the noise is always lower then the limit near any surrounding house.
The sound propagation depends also from the wind direction, thus checking the local wind rose, mainly the East side will be leeward. A proposed mitigation, although is not properly a task of the developer, is to add some feature on the blade to decreases the sound, or also to fold the blade toward the tip.

5.3.2 Water and Electricity

In order to guarantee the requires service for all the operations, it must be ensured the supply of water and electricity.
Water distribution is a central topic for Africa. Although the high presence of underground water resources, in many African locations the distribution of water is not supplied yet. The figure 29 in the Appendix A shows that water is supplied in the chosen location [11]. Furthermore, placing the windmills does not threaten the hydric underground bacin.

Electricity supply, on the other side, is less easy to obtain in the met station area. According to Eksom web page [15], some new transmission line are going to be created in the period 2015-2024. However, in order to perform the current project, has been confirmed from the authors the possibility to connection to existing wind farm stations.

5.3.3 Tourism

The beauty of landscapes in South Africa is surely the main reason to visit the country. The tourism nowadays is very high, and contribute of 10 % of jobs in the country [12].
Despite of that, Humansdorp area is not populated even from tourist, and the negative impact triggered by the wind farm could be assumed negligible. On the other side, is true that creating a new wind farm will add new work place for locals. Nevertheless, if agreed from both parts, local community could gain a percentage to

be part of the wind farm project. [13]
Lastly, it is worth to mention that it has been regulated a job equity for employees with African provenience and European provenience. [14]

5.4 Conclusion

In this section it has been assumed and checked the majority of the causes that have a negative influence on the terrain and on the environment.
It has been deeply studied four major risk, such as endangered flora and fauna, accessibility, visual impact and method to obtain permission.
The worst issue could be the construction of new roads and the required permissions to pass through private property. Although the negative impact on the environment of the former, it worth to be said that using already existing path it is a way to mitigate the issue, as well as replanting.
The flora and fauna on the other side have not been considered in high danger ans possible mitigation has been mentioned in the table. Lastly, the visual impact has been mitigated by choosing underpopulated territory that includes already 4 wind farms, as well as make the windmills rotate at the same frequency.

Although the possibility of negative impact on the terrain , it is worth to state that operation of a wind farm does not release CO_2, and if the world is aiming to a non fuel dependent economy, wind energy is surely a good starting point to invest and research. Furthermore, South Africa will benefit for sure in terms of green energy and work place, and potentially could become a global leader in the energy field, as stated by Ute Menikheim, head of energy for Siemens in southern Africa.

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6 Social Issues

The project causes the environmental impact as well as the social impact. In this section, stakeholders of this project are identified and possible impact to the community is discussed.

6.1 Stakeholders

The major stakeholders are classified into 6 groups.

1. Government, Authorities
2. Non Profit Organization (NPO), Public Benefit Organization (PBO)
3. Community-based organization, community representatives, residents
4. Industries
5. Landowners
6. Media

In the following section, characteristics, concerns and engagement strategies for each group are described. More detailed stakeholders were identified for each group and they are listed in Appendix B with their concerns and values.

Government, Authorities

Different levels of government bodies, namely national, provincial and local levels, will be considered as stakeholders for the project. There will be different levels of involvement and some are indirectly involved in the project.
For governments and authorities, their major concerns are:

- **The project complies with legal requirements**
- **The project is not in conflict with plans/visions of the government body** : In South Africa, local municipalities are required to make Integrated Development Plan (IDP) [3]. The Kouga Local Municipality has developed the IDP for 2017 to 2022 [4], and execution of the proposed project will be difficult if the project hinders the IPD largely. It is also possible that the project is stopped if it causes conflict with plannings of other provincial or national government bodies.
- **The project brings benefits to the general public and the negative impact to the society is minimized.** If the project can cause significant damage to local industries or the environments, respective government bodies may take action to protect the benefits of citizens or the nation.

Often, the engagement with government bodies are simply for bureaucratic requirements. The project can be carried out swiftly by following the required process, submitting necessary documents and information, and complying with regulations. A wind farm project is expected to take several years or longer from planning to commissioning. It is likely that regulations change during this period. Having experts in this area will help to proceed the project with less complexity and avoid possible delay of the project.

NPO, NGO

Their primary concern is the benefit of the society. NPOs or NGOs which are expected to be stakeholders are mainly environmental conservation groups who are concerned about endangered species, wildlife or local environment. Other types of NPOs/NGOs such as enhancement of local business or protection of archaeological heritage can also be involved.

The sufficient information on which a particular NPO/NGO is interested should be provided. Their concerns need to be listened and actions may need to be taken to reduce the negative impact. For example, providing an environmental impact assessment will be important in order to gain the acceptance to the project from environmental conservation groups. It should include mitigation methods to minimize the environmental impact. It may also be necessary to provide monitoring programs during the operation phase of the wind farm.

Community-based organization, community representatives, residents

Their concerns are how the project will affect the community and their own life. The area of concerns will be different from organization to organization or from individual to individual. However, in general, their concerns are visual impact, noise, impact on health, environment, economic impact and other potential benefits or negative impact which the project may bring.

Through the public hearing, they should have opportunities to raise their voice directly to the developer. The involvement of local facilitator will help positive engagement of the people from the community. To communicate better with them, the developer may provide a point of contact which residents or community organization can access to the information they want easily or address their concerns. It may also be effective to keep them updated on the project through newsletters or social media. It may be worthwhile to contact local councillors or politicians who have strong influence on the community to explain about the project and ask for their support.

Industries

Business owners are concerned about the impact of the project on their business and their their own life if they live near the proposed site. For farmers near the proposed site, changes in local traffic or air pollution, especially during the construction phase, can be concerns. If they own the land, the changes in the property values will be another concerns. For the business owners in the hospitality industry, the impact on tourism will be the major concerns.

This group should also be invited to the public hearing. As the previous group, they should be able to access the point of contact easily. As there are other wind farms operating near the area, it is also possible to invite business owners and farmers who have been affected by the existing projects to give a talk to reduce their concerns.

It is important to note that the owners and shareholders of existing wind farms should also be included as stakeholders. There are four existing wind farms, and the new wind farm will affect their energy production due to the wake effect more or less. In particular, the impact to Oyster Bay Wind Farm which is located 1.5km east of the proposed site cannot be avoided, as the prevailing wind blows from the west. It is probably necessary to compensate for their losses.

Landowners

Landowners of the projects site and proposed transmission lines are directly affected stakeholders, and they will have many concerns including impact on property value, environment, health, soil, and also financial gain. The developer will need to negotiate with them directly, providing the information of the expected impact of the project.

Media

Generally, media's concern is to give general public transparent information regarding the project. Assigning a public relation officer will be helpful to provide information to the media more strategically.

6.2 Anticipated Public Reaction

Since there are existing wind farms nearby,it is expected that people are more familiar with wind farms and their impact to their community and personal life, which may contribute to the positive attitude of the public as there will be less unknown factors for them. However, this does not mean there will not be opposition. The resident of St Francis Bay, which is about 15km away from the town of Humansdorp, opposed the construction of a wind farm near their community[5]. They were concerned about impact on tourism, visual impact and cumulative impact of installing many wind turbines in Kouga region (ibid). If the people experienced negative impact due to the existing wind farms, the public perception towards the project can be negative. Some people may be concerned about cumulative impact of wind farm projects in the area, as were residents of St Francis Bay.

6.3 Social Benefits of the Project

The project will bring some benefits to the community. During the construction phase, the project will create employment for the locals. The inflow of workers from other region will bring the benefits to hospitality industries. Roads may be upgraded if it is necessary for logistic reasons. During the operation phase, the community will not benefit as much as the construction phase, though some employments will be created for operation and management of the wind farm. Local employees will benefit from obtaining new skills and training.

There will be expectation to contribute to the development of the community, as existing wind farms has been supporting projects for local communities[4]. For example, Kouga Wind Farm invested into local facilities including a clinic, hospice and library (ibid).

It is ideal to contribute to projects which meet the need of the local community. Although it is hard to identify what are these needs by desktop study, suggestions include:

- Scholarships for higher education, renewable energy engineering
- Creating a botanic garden which compensates the flora lost by the project
- Hosting socializing or educational events in collaboration with other existing wind farms

6.4 Political Climate for the Project

Policies in South Africa are in favor of developing new wind farms. In addition to the favourable national frameworks towards energy sector which is described in Chapter 8 further, the Eastern Cape Sustainable Energy Strategy aims to create "the most enabling environment for sustainable energy investment and implementation in the country"[6]. With the successful implementation of the Strategy, Eastern Cape is now emerging as energy hub of South Africa.

6.5 Conclusion

In terms of social considerations, it is concluded that the proposed project is feasible. Some oppositions from the local people are expected, and sponsoring or initiating community projects is most likely the expectation that the community has towards wind farm developers. National and provincial support the development renewable energy.

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7 Economics

The project economy is dependent on the ability to secure Power Purchase Agreement (PPA) with Eskom (TSO). To get the contract, project bid needs to be submitted as a part of Renewable Energy Independent Power Producer Procurement Programm (REIPPPP). Additionally, project needs to be financed by the entrance into direct agreement (DA) with investors. Refer to Figure 13 Scheme of Agreements.[1]

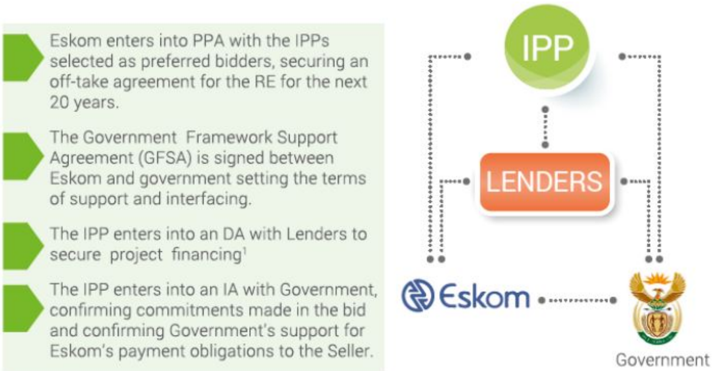

Figure 13: Scheme of Agreements

According to World Wildlife Fund (WWF), the average tariffs bid for wind were $R0{,}66/kWh$ in Round 3 of REIPPPP. [2]This figure used as a selling price of electricity per kWh. Project costs as shown in Appendix C: Simple Cost of Energy, comprise *Capital Expenditures* and *Operational Expenditures*. Capital Expenditures include [3]:

- Costs related to bidding process (Bid submission, EIA, Permits);
- Project Management & Legal Costs;
- Consultancy;
- Civil Works at Site;
- Wind Turbines Production and Installation;
- Electrical Works and Connection to Grid;
- Local Content and Social Benefits;
- Contingency at 5% of initial investment for unforseen future expenditures;

Costs related to Bid submission and legal compliance are taken from WWF Report (2014) with a lower estimate of $R5$M. [2] This is a relatively small project (16 turbines with $36.8MW$ capacity) and some permit costs can be reduced due to less infrastructure development (it is assumed that existing substation of neighbouring Kouga Wind Farm can be utilised for connection to main Grid). Electrical, Civil works and Project Management are primarily performed locally and are estimated based on local rates. Cost of Electrical Works is taken from Project data of subcontractor, Ram Electrical and Civil for Kouga Wind Farm.[4] Scope of work includes Installation of 32kV cables for 32 wind turbines or twice as few as in the current project. Scope excludes work related to connection to main grid and $R1.5M$ is added to the base cost of R5M to account for Grid connection. Remaining works related to Civil Works and Project Management given local content of services, are estimated based on proportional dependency suggested in the literature. Refer to Figure 14 Typical cost breakdowns for onshore and offshore wind.[3]

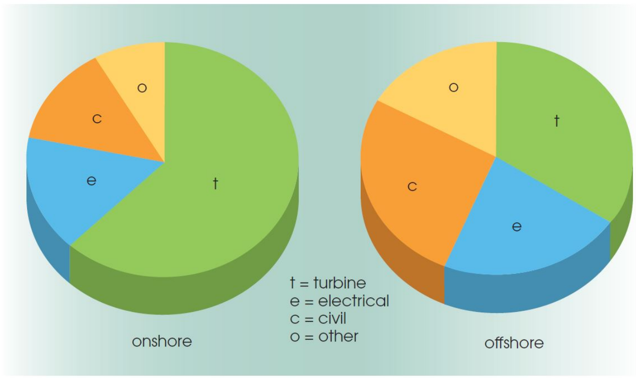

Figure 14: Typical cost breakdowns for onshore and offshore wind.

As can be seen from the Figure 14, Wind Turbines Fabrication and Installation Cost normally comprise the largest portion of capital expenditures. However, one of pecularities about the market in South Africa as addressed in WWF Report (2014), is limited facilities for manufacturing of wind turbines. That is one of the reasons why cost of energy of wind turbines has not plunged as drastically as for provolotics. Latest China's expansion as a bulk, low-cost producer of solar PV modules made significant and rapid adjustment in the cost of solar energy including South Africa (SA). On the opposite, wind being most mature RE technology in SA, is very dependent on global commodity prices such as steel, copper and cement. Wind turbine structures are generally imported to SA, and only generic components such as towers can be manufactured locally in an economical way. In Round 3, solar PV bidders committed to 54% local content, as compared with 47% for wind. Five local PV panel manufacturing facilities and one for the production of wind towers have been set up so far (Eberhard et al 2014).[2] It is assumed that wind turbines are imported from abroad. The cost for 1 MW is taken from report by the European Wind Energy , as per Figure 15 Cost structure of a typical 2 MW wind turbine installed in Europe.[5]

	INVESTMENT (€1,000/MW)	SHARE OF TOTAL COST %
Turbine (ex works)	928	75.6
Grid connection	109	8.9
Foundation	80	6.5
Land rent	48	3.9
Electric installation	18	1.5
Consultancy	15	1.2
Financial costs	15	1.2
Road construction	11	0.9
Control systems	4	0.3
TOTAL	1,227	100

Figure 15: Cost structure of a typical 2 MW wind turbine installed in Europe

It is also assumed that manufacturing abroad will require progress follow-up by highly qualified specialists and therefore, consultancy cost is also included into the estimate. Finally, the scorecard in the bidding process also contains 'pure' corporate social responsibility requirements, including the donation of at least 1% of revenue to qualifying socioeconomic development.[2] This estimate has also been included into cost estimate together with local content impact.

Project analysis is prepared for investors' review and presented in Appendix C. *Simple Cost of Energy* is $R0.24/kWh$ vs. *Levelised Cost of Electricity* (CoE) by WWF was at $R0.82/kWh$. These figures cannot be directly compared but it gives a certain indication. *Levelised CoE* is a combined cost of several sources of energy. It also includes cost of fuel and cost of capital and is more complex than *Simple CoE*. In general, as stipulated in the WWF report CoE is higher than the tariffs that were bid in 2013, erring on the high side. The LCOE calculation for solar PV seems too conservative by some margin. The CoE in the current project can be regarded as relatively low due to relatively high capacity factor of wind farm of 38%. Jeffrey Bay Wind Farm in the same area after start of its operation has a capacity factor of 41% which is mentioned as one of the highest.

Operational expenditures include *Operation and Maintenance* (OM) costs and estimated at 2% of initial capital investment. The CoE calculations give only crude estimates of profitability because they fail to allow for the time scales over which costs are incurred and income is generated. A major feature of wind energy, like other forms of renewable energy, is that the initial capital and installation costs produce by far the largest negative cash flow. This is followed by many years of smaller cash flows projected to present value by use of *discount rate*. [3] *Discount rate* in this project represents the weighted average cost of capital on the basis of a project finance structure with a debt-to-equity ratio of 75:25 and it is set to 10.4% including inflation rate of 5.5% p.a. As shown in Appendix C: Project Analysis, *Net Present Value* (NPV) of project is estimated at R79.3 M or apprx. 5.2M *Euro*. Discount Rate (10.4%) is less than *Internal Rate of Return* of 12.4%. This might be a positive sign for future investors.
Sensitivity analysis with respect to Discount Rate, Capital Investment and Electricity Tariff is included into Project Analysis, Appendix C. As shown on the graph, NPV result is more dependent on changes in Electricity Tariff than Discount Rate.
Following mechanisms of improvement of financial performance are studied and suggested below :

- As projected by WWF, bid tariffs are anticipated to raise over a period to $R0.88/kWh$. This will boost the revenue figures. In the latest report by Department of Energy and Department of Treasury dated to 31 December 2016, the latest average bid tariff is estimated to $R0.75/kWh$. Refer to Figure 16 Projected Bid Tariffs by WWF;
- Due to economical situation in SA and anticipated raise of inflation rate, it is low probability of decrease of discount rate in the future.[2] Moreover, unless the company is financially rigid with strong balance sheet, individual investors will keep their expectations on return high;
- The major cost driver, the cost of wind turbines, can be reduced by using local production facilities. At least, tower can be manufactured by use of local labour. According to the literature [7], tower can make up 18-19% of total wind turbine cost. Refer to Figure 17 Cost Breakdown of Wind Turbines;
- It is also feasible to use local personnel during operational and maintenance works of individual components. This will contribute to higher cash flow in the future and its higher NPV;
- Financial result is based on contingency value for unforeseen future expenses. Removal of this cost element will improve overall financial result.

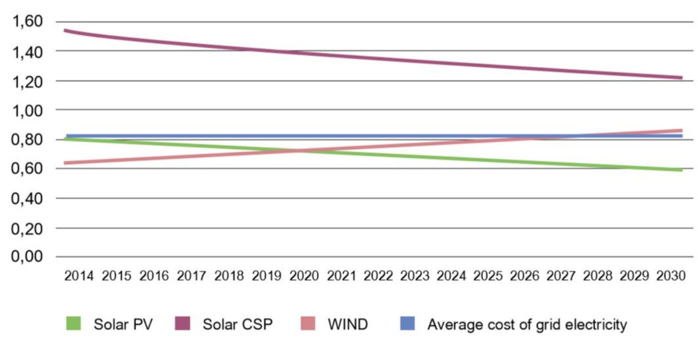

Figure 16: Projected Bid Tariffs by WWF

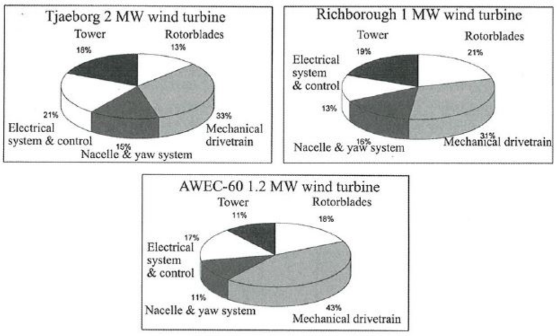

Figure 17: Cost Breakdown of Wind Turbine

Therefore, developer's expectations about project success stays optimistic and it is anticipated to proceed further to bidding round.

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8 Regulation and Permits

8.1 Legislation

As a developer of Wind Farm, one should be aware of political, socio-economical and legal systems of the selected country. South Africa has done significant steps towards promotion of Renewable Energy through wide range of National Policies, Plans and Programs. After National Policies and Plans are defined, they are communicated further down to *Provincial* and *Local* levels which establish their own short- and medium-term plans. [1]
National Policies are represented by two types of documents : dealing with energy supply issues and combating global climate change. Our primary focus is with the first type of documents listed below.

- **The White Paper on Energy Policy** (1998), published by Department of Minerals and Energy (DME), identifies key objectives for energy supply within South Africa, such as increasing access to affordable energy services, managing energy related environmental impacts and securing energy supply.

- **The White Paper on Renewable Energy** (DME, 2013), supplements the previous policy, and sets out Government's Vision, policy principles, strategic goals for promotion and implementation of Renewable Energy. of Minerals and Energy (DME), identifies key objectives for energy supply within South Africa, such as increasing access to affordable energy services, managing energy related environmental impacts and securing energy supply. As stated in the document, "...Wind energy is a clean, renewable resource and should be developed in South Africa on the basis of national policy as well as provincial and regional guidelines."

- **The National Development Plan** (NDP), launched in 2012 by National Planning Commission, identifies the need for South Africa to invest in a strong network of economic infrastructure. *Energy infrastructure* is a critical component. The NDP requires the development of 10 000 MWs additional electricity capacity to be established by 2025 against the 2013 baseline of 44 000 MWs.

- **The Energy Act 2008** obligates the Minister of Energy to develop and publish an *Integrated Resource Plan* for energy. Therefore, Department of Energy with the National Energy Regulator of South Africa (NERSA) has compiled the **Integrated Resource Plan** (IRP) for period between 2010 and 2030. In line with the national commitment to transition to a low carbon economy, 17 800 MW of the 2030 IRP target are expected to be from renewable energy sources, with 5 000 MW to be operational by 2019 and a further 2 000 MW (i.e. combined 7 000 MW) operational by 2020. Refer to Figure 18 Target Energy Sources. [2]

- As a further step towards energy infrastructure development, The Department of Energy's (DoE) **Independent Power Producers Procurement Programme** (IPPPP) was established at the end of 2010 as one of the South African government's urgent interventions to enhance South Africa's power generation capacity. The primary goal is to secure electricity from renewable and non-renewable energy sources from the *private sector.*[3]. IPPPP has been designed to go beyond the procurement of energy to also contribute to broader national developmental objectives such as job creation, social upliftment and the broadening of economic ownership.

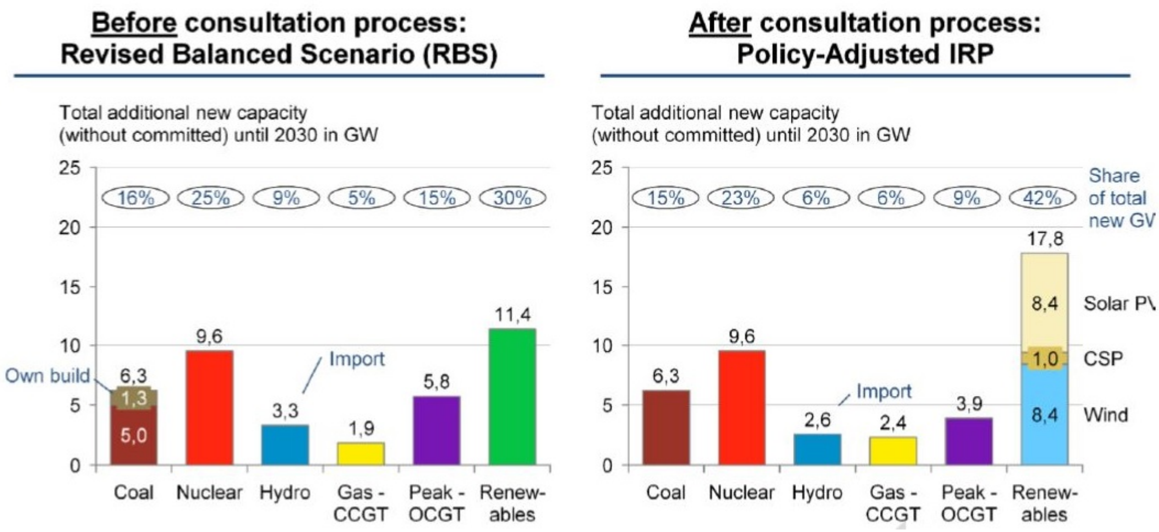

Figure 18: Target Energy Sources

As per 31 December 2016[3]:

- 6422 MW of electricity had been procured from 112 RE Independent Power Producers (IPPs) in seven bid rounds;
- 2902 MW of electricity generation capacity from 54 IPP projects has been connected to the national grid;
- 13098 GWh energy has been generated by renewable energy sources procured under the REIPPPP since the first project became operational.
- Created 29888 job years for South African citizens, or 33916 jobs (FTEs) for South African citizens;
- Carbon emission reductions of 13.3 $Mton$ CO2 to date.

REIPPPP is realised through *multiple bid windows* by submission of *Bid-in tariff*. Bidders are qualified and scored according established criteria.[2] 70% of scoring is given to price whereas 30% is accounting for Social Economic Development. [4] A complete list of criteria is listed in Figure 19. [5] As a developer, one should be aware of additional costs incurred due to these requirements. At least 1% of revenue should be allocated to Social Economic Development.[6]

Table 1 Economic development thresholds and targets for wind projects in South Africa's REIPPP program

Factor and criteria	Threshold (%)	Target (%)
Job creation		
South Africa–based employees who are citizens	50	80
South Africa–based employees who are black citizens	30	50
Skilled employees who are black citizens	18	30
South Africa–based employees who are citizens from local communities	12	20
Local content		
Value of local content spending	25	45
Ownership		
Shareholding by black people in the project company	12	30
Shareholding by black people in the contractor responsible for construction	8	20
Shareholding by black people in the operations contractor	8	20
Shareholding by local communities in the project company	3	5
Management control		
Black top management	n.a.	40
Preferential procurement		
Broad-based black economic empowerment (BBBEE) procurement spending	n.a.	60
Procurement from small enterprises	n.a.	10
Procurement from women-owned vendors	n.a.	5
Enterprise development		
Enterprise development contributions	n.a.	0.6
Adjusted enterprise development contributions	n.a.	0.6
Socioeconomic development		
Socioeconomic development contributions	1.0	1.5
Adjusted socioeconomic development contributions	1.0	1.5

Note: n.a. = not applicable (no threshold set).
Source: South African Department of Energy, REIPPP program bid documents and press releases (http://www.ipp-renewables.co.za).

Figure 19: Social Economic Development Criteria

Although favourable mechanisms for RE have been put in place, as stated in The National Development Plan:Vision 2030, over 70 percent of South Africa's primary energy is derived from coal, as does more than 90 percent of electricity and a third of liquid fuels. The economy is electricity intensive and majority of population remains employed in coal mining business. Although transition of economy to more environmentally friendly is necessary, it cannot be done that fast as it can threaten the economic stability of several generations. Therefore, even in some cases CoE from wind energy is lower than CoE from newly built coal mining plants, the Government will continue to support coal mining activities in the future. This puts additional pressure on developers of Wind Farms for keeping bids as low as possible.

8.2 Permit

To proceed with the project, the following permits/approvals are required[7].

- Subdivision of Agricultural Land Act (Act No 70 of 1970): Approval from the Minister of Agriculture is needed for the subdivision of agricultural land or lease longer than 10 years.
- Cape Land Use Planning Ordinance (No 15 of 1985): The developer needs to apply for the rezoning of farm lands to an appropriate zone. The application should be made to the local municipality.
- Conservation of Agricultural Resources Act (Act No43 of 1983): The permission is needed if the project causes draining of marshes or water sponges. There are wetlands near the proposed site, thus, this permit may be necessary.
- National Environmental Management Act (Act No 107 of 1998): The developer needs to submit EIA report to Department of Environmental Affairs and the Provincial Environmental Department.
- National Environmental Management, Biodiversity Act (Act No 10 of 2004): Though this is unlikely for the proposed project, if the project disturbs the protected plant species on the site, a permit is required.
- National Road Traffic Act (Act No 93 of 1996): To transport abnormal loads through national or provincial roads, permits are required by South African National Roads Agency Limited (national roads) or Provincial Department of Transport (provincial roads).
- National Heritage Resources Act (Act No 25 of 1999): A permit may be required if the proposed site is considered as cultural or heritage sites by the Heritage Resource Authority.

In order to export the electricity to the main grid, the developer first needs to be approved as an Independent Power Producer (IPP) according to the Electricity Regulation Act 2006[8]. The application for IPP is submitted to the local Grid Access Unit of Eskom, the owner of national grid. At this point, the developer is expected to be have the right to develop the wind farm. This means the major permits and approvals necessary for the development should be obtained prior to this application[9]. If the application is accepted, the Power Purchase Agreement with Eskom will be arranged. Meanwhile, Electricity Generation License needs to be obtained from the National Energy Regulator of South Africa (NERSA)[10], and the quality of exporting electricity should comply with Grid Connection Code for Renewable Power Plants Connected to the Electricity Transmission System or the Distribution System in South Africa[11].

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9 Conclusion

The preliminary feasibility study has shown that the project is feasible: technically, environmentally, financially and does not produce a significant negative social impact.

The layout has been developed given geographical constraints and in line with technical requirements related to allowed level of noise, distance to dwellings etc. Layout optimisation has been done with consideration to reduction of turbulence intensity and maximum yield of energy production. As a result, wind farm suggested for future development, comprises of 16 wind turbines Siemens 2.3MW-108, arranged into 2 rows.The choice of the main layout resides in its versatility, allowing a moderate tolerance in turbine placement without affecting neither AEP nor TI. This is especially useful in case the land owner requests to avoid certain spots. In order to have a low priced project, it has been taken advantage of the private roads , used in the past for older wind farm activities. Indeed, any private agreement for the usage of the land or utilities, will contribute to cost savings.

The project economic analysis shows that it can be profitable investment with IRR of 12.4% above Discount Rate of 10.4% and positive NPV of R79M. The mechanisms of further financial performance improvement are suggested in the Chapter 5. To summarise, South Africa has a big potential in future development of RE projects by creating favourable legal and economic conditions and as a developer, it makes this region specifically attractive.

Contribution

	Responsible
Introduction	Lorenzo
Wind Resource Assessment	Stefano and Ekaterina
Wind farm calculations	Stefano and Naoko
Connection to electrical grid	Lorenzo and Ekaterina
EIA	Lorenzo
Social Issues	Naoko
Economics	Ekaterina
Regulation	Ekaterina and Naoko
Conclusion	Ekaterina

Table 8: Table of contribution

Despite the singular contributions stated in the table, the group performed at the same work rate. It is then assumed 25% contribution each.

Appendix A

Refers to Wind Resource Assessment

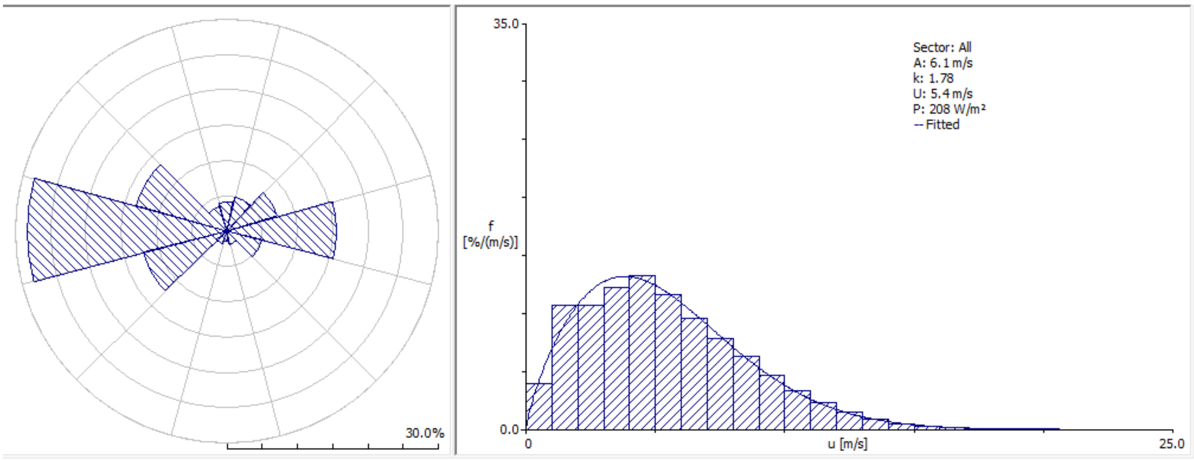

Figure 20: Wind Rose and Weibull fit at 10 meters height

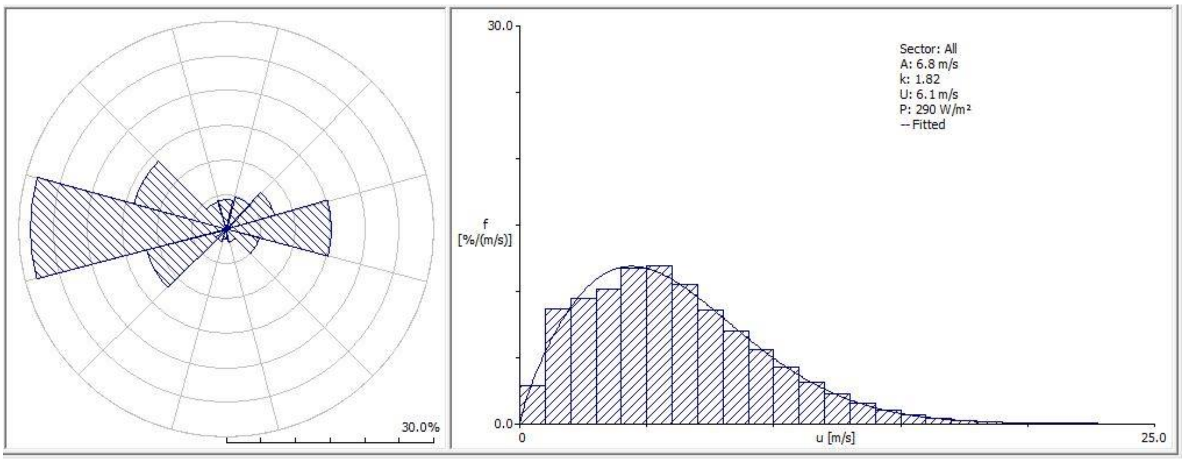

Figure 21: Wind Rose and Weibull fit at 20 meters height

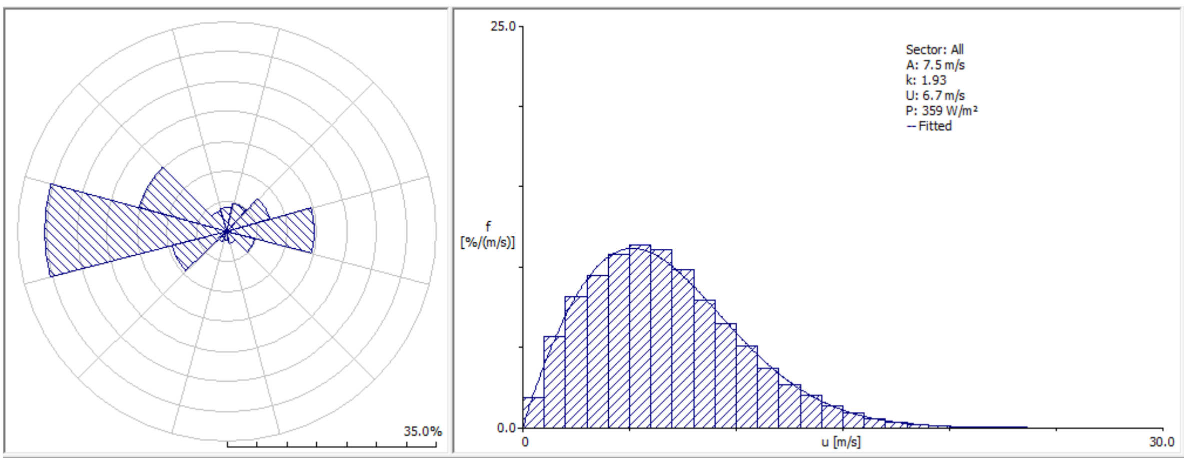

Figure 22: Wind Rose and Weibull fit at 40 meters height

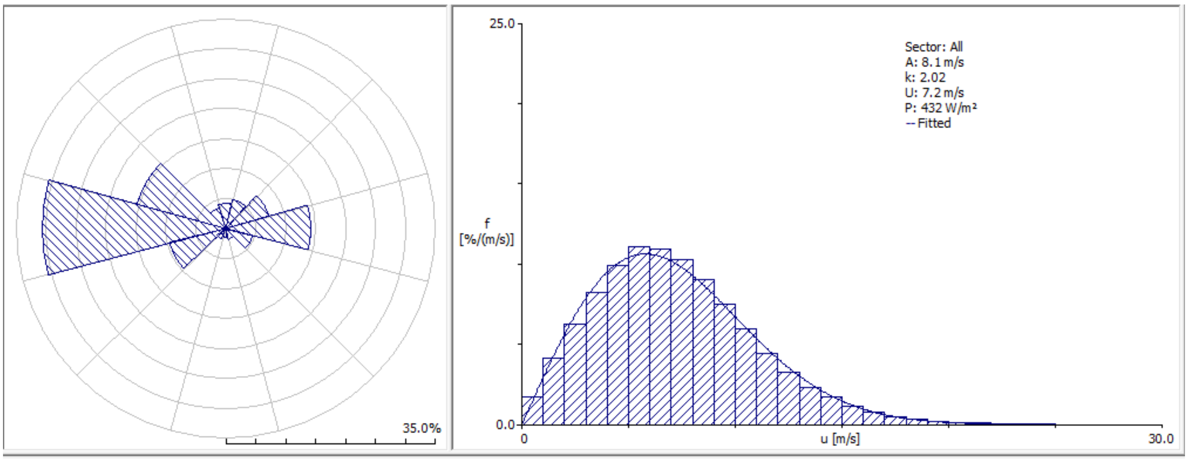

Figure 23: Wind Rose and Weibull fit at 60 meters height

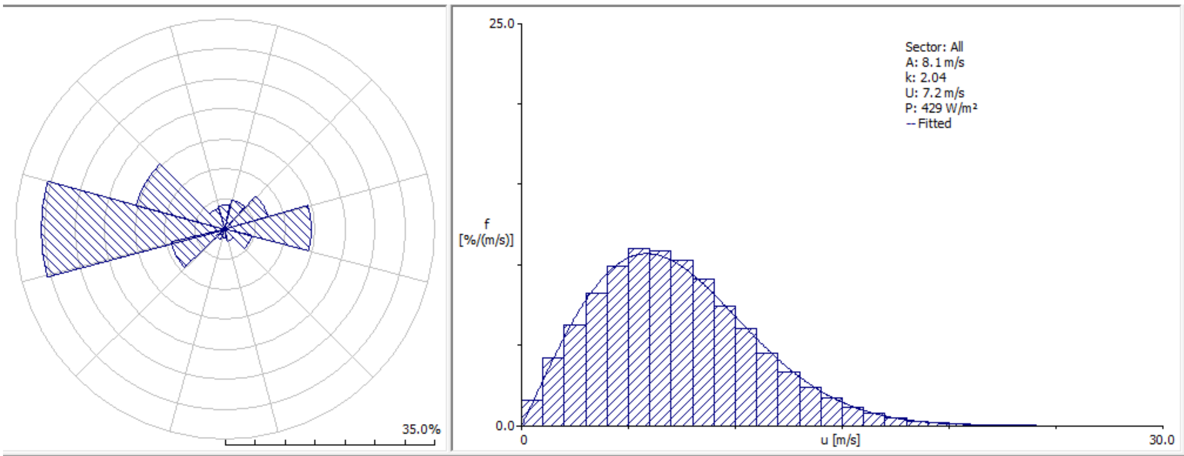

Figure 24: Wind Rose and Weibull fit at 62 meters height

Refers to Wind Farm Calculation

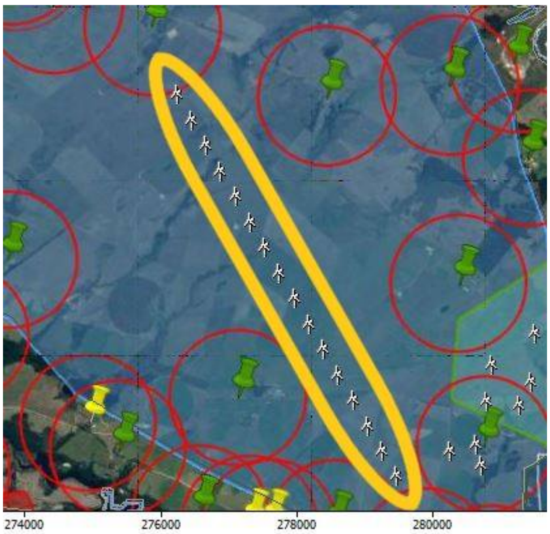

Figure 25: Alternative layout1

Figure 26: Alternative layout2

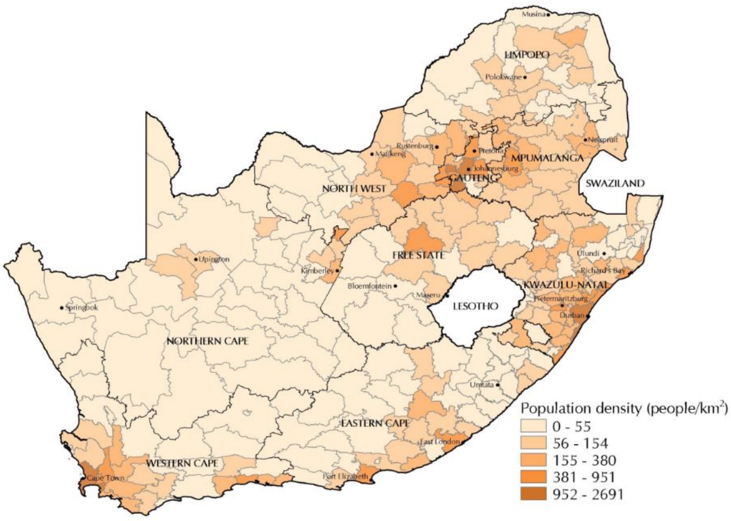

Figure 27: Density population map

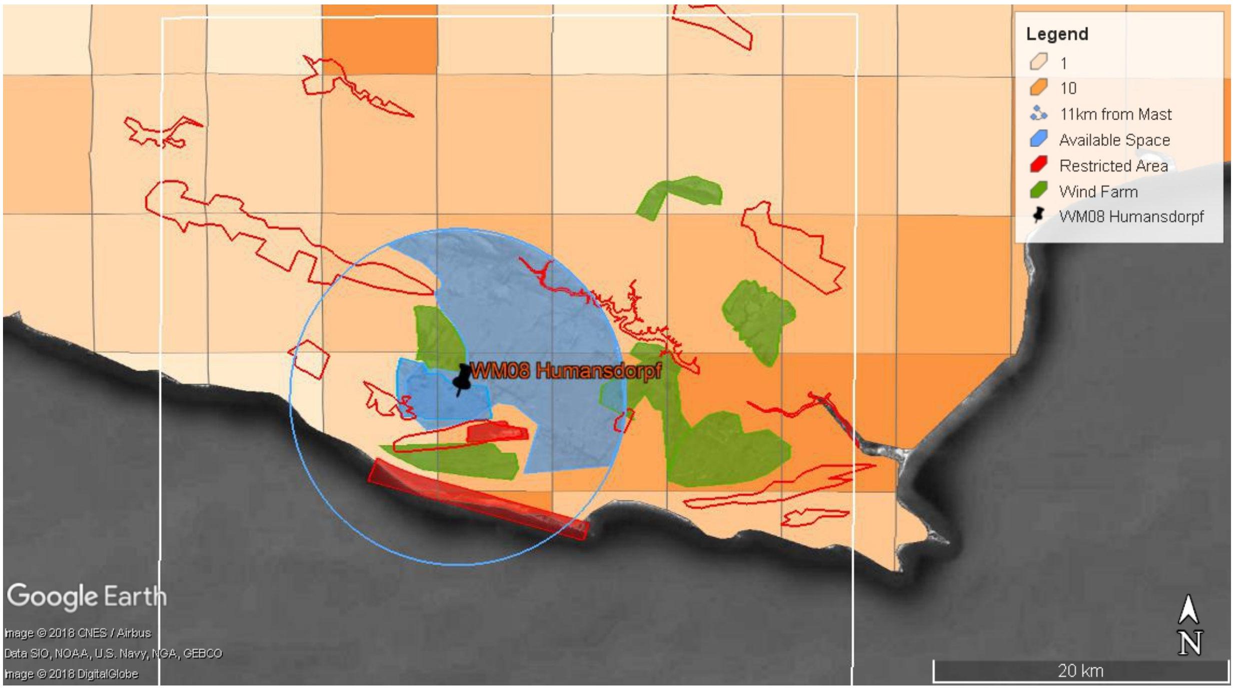

Figure 28: Avian Sensibility Map

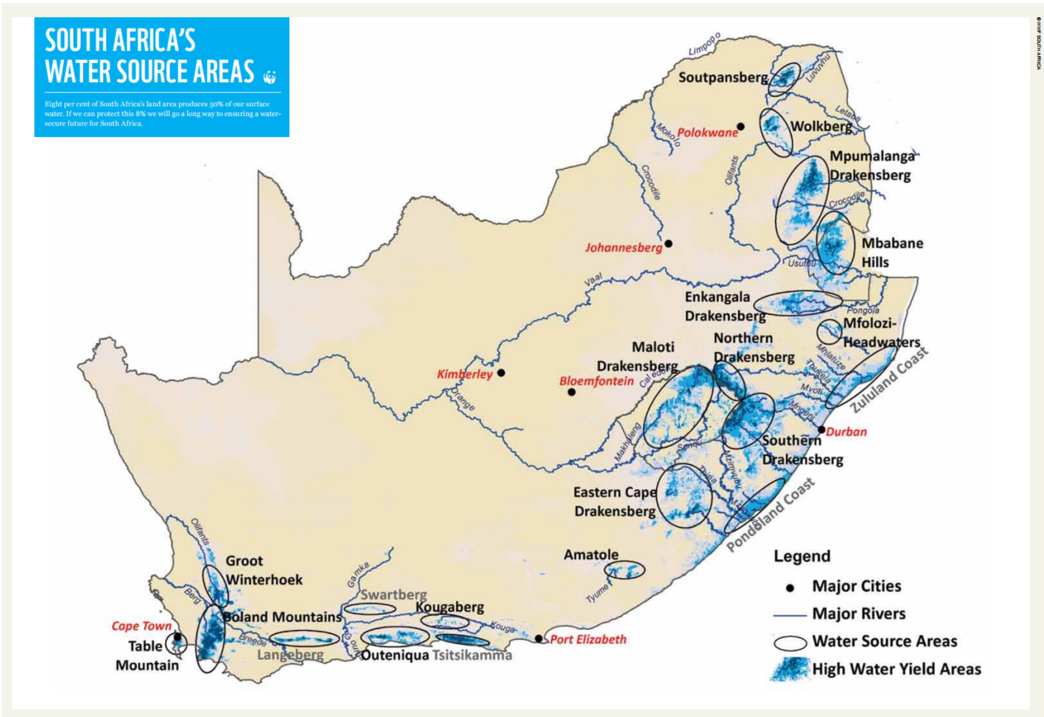

Figure 29: Map of water distribution

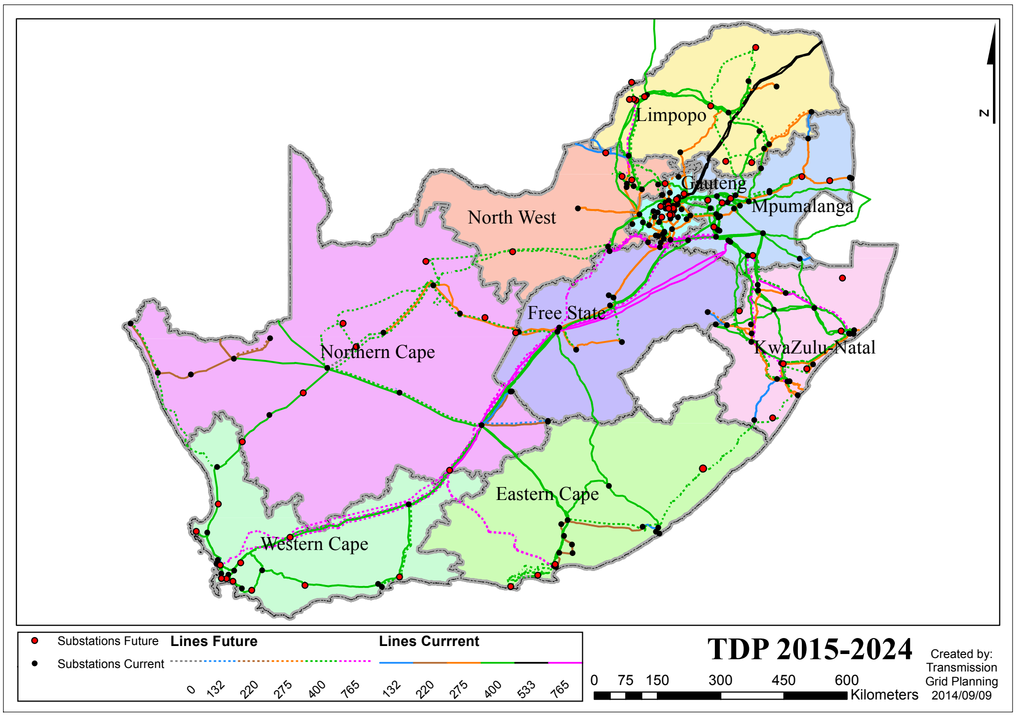

Figure 30: Map of electricity distribution