

**SIRAGRUNNEN, NORWAY**



**WindSim study**



Illustration of 8 MW layout with Google Earth.

**Assignment**

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# **WindSim study and comparison with Wasp results:**

SIRAGRUNNEN, NORWAY

## **Summary**

In order to check if there are meso scale effects from the mountains near the site that might change the wind climate from the reference site (Lista) to the site (Siragrunnen) that is not captured in the WASP calculation, WindSim CFD calculations is performed.

The wind conditions at the site have been calculated using WindSim (ver. 4.7.0) based on measurements from Lista Fyr. Documentation of the data and the terrain near Lista Fyr is treated in the original report on Siragrunnen.

Especially of interest is to evaluate reductions in wind speeds due to the mountain at the site relative to the reference site. Therefore wind speeds at 4 points at the site are calculated with the WindSim model which is compared to the WASP calculations.

The main conclusion is that the detailed WindSim study doesn't change any of the conclusions in the original report. It is important to notice that there is a change in the wind conditions over the site with a change in distance to the coastline – and that this difference is larger using WindSim model than when using WASP model. To verify these model calculated variations measurements could be made simultaneously in different parts of the proposed wind farm. But from a economic point of view, it seem reasonable just to measure at one point, preferable in the middle of the proposed wind farm site.

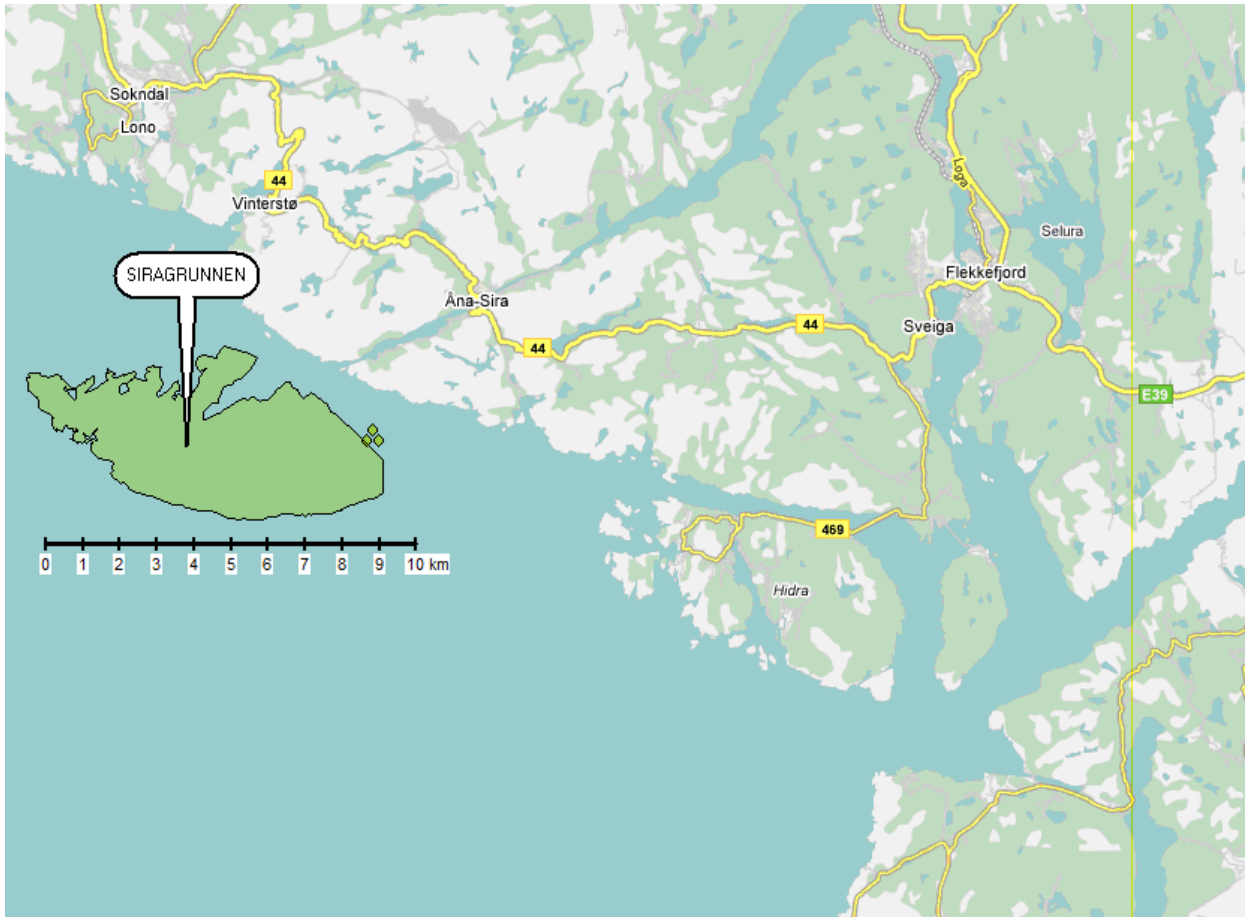
The turbulence intensity is for all sectors sector estimated to be below 15%.

## **1. Site, project and purpose description.**

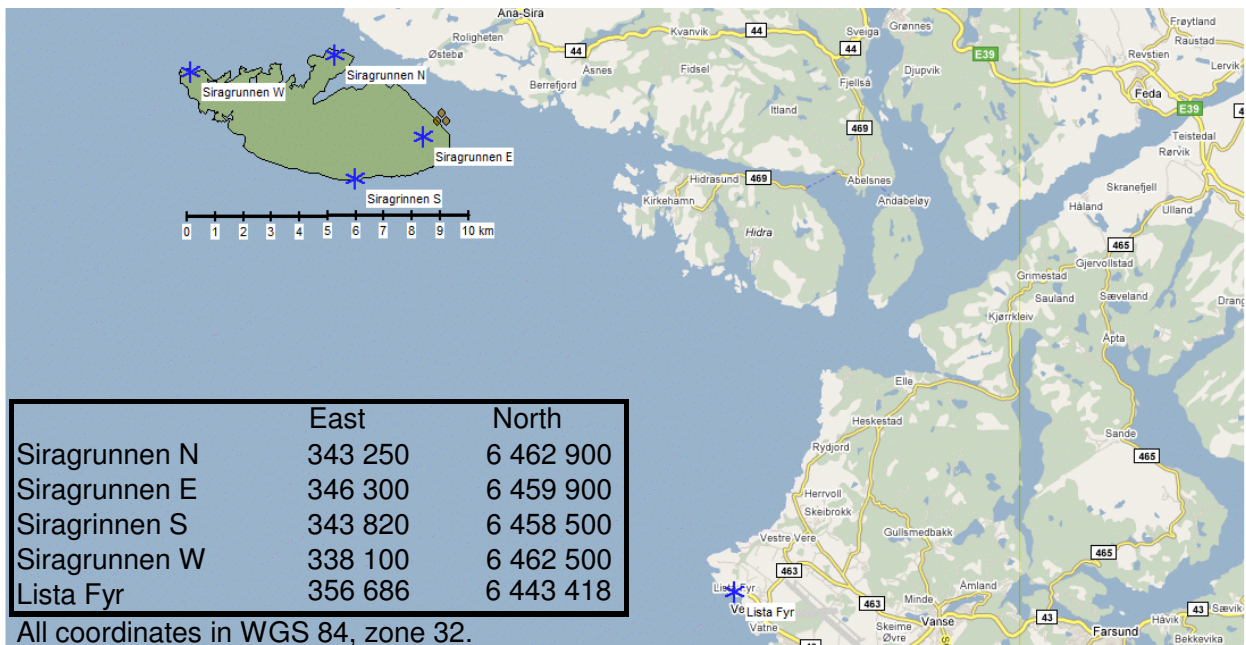
The site is located in southeast part of Norway, starting round 2 km from coastline. The area with water depths below 35 m is round 25 km<sup>2</sup>.

The purpose of this report is to describe the results from a detailed WindSim study and compare the results with the previous results from the standard Wasp study. The main purpose is to estimate the wind conditions at the site and in that way verify the WASP calculations.





**Figure 1** Map of the site, where the area with water depths below 35 m is shown.



**Figure 2** The 4 calculation points at the site and the Lista Fyr site.

## 2. WindSim model

A WindSim model has been established based on the terrain and wind data described in the original siting report. Information on wind and terrain data can be found there.

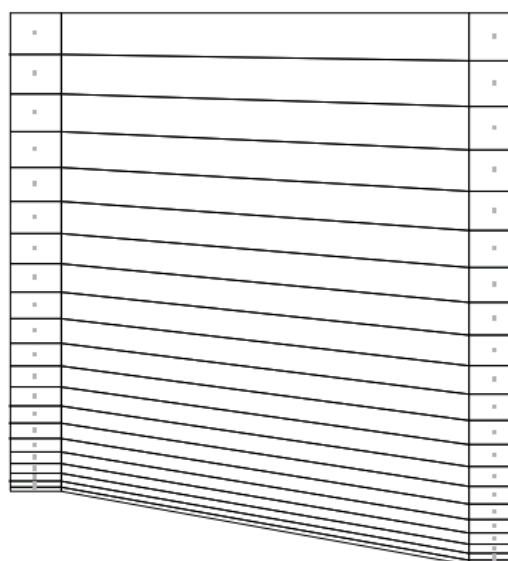
Information on how WindSim works and the reliability of the model can be found at [www.windsim.com](http://www.windsim.com).

Terrain data with a horizontal resolution of 50 meters has been imported into the model. Due to limited computer capacity the calculation has been performed with a horizontal resolution of 80 meter near Lista Fyr. A refinement technique has been used so the horizontal resolution at the site is around 290 meter. The horizontal resolution at the site is not very important as the site is offshore. But the fine resolution near the mast is a must. The total number of cells computed was around 1.000.000. Below are shown details about the horizontal resolution.

	x	y	z	total
Grid spacing, min - max (m)	76.9 - 292.3	76.9 - 291.9	Variable	-
Number of cells	216	207	20	992992

**Figure 3 Horizontal resolution of the WindSim model.**

The vertical resolution is estimated based on the highest and lowest point in the calculation area. The grid extends 2620.6 (m) above the point in the terrain with the highest elevation. The grid is refined towards the ground. The left and right columns display a schematic view of the distribution at the position with maximum and minimum elevation respectively. The nodes, where results from the simulations are available, are situated in the cell centers indicated by dots.



The vertical resolution is given in the table below.

	1	2	3	4	5	6	7	8	9	10
z-dist. max (m)	11.3	39.1	77.0	125.2	183.5	252.1	330.8	419.7	518.9	628.2
z-dist. min (m)	13.1	45.1	88.9	144.5	211.8	290.9	381.8	484.4	598.8	725.0

**Figure 4 Distribution of the first 10 nodes in z-direction, relative to the ground, at the position with maximum and minimum elevation.**

It is very important that the measuring height is included in the model. The measuring height was 10 meters above ground level and the model goes down to 11.3 meters. This will induce an error and an uncertainty in the calculations, but at this stage it is assumed to be insignificant.

### 3. Results

Based on the wind data from Lista Fyr described in the original report "EMD-Siragrunnen\_report-1-Wind-evaluation" following mean wind speeds have been estimated for the four points shown in figure 2.

	Siragr. N	Siragr. E	Siragr. S	Siragr. W	Lista Fyr
50 m a.s.l.	7,59 m/s	7,75 m/s	8,00 m/s	8,09 m/s	7,85 m/s
80 m a.s.l.	7,92 m/s	8,08 m/s	8,32 m/s	8,42 m/s	8,31 m/s
Wind speed ratio (U <sub>80m</sub> /U <sub>50m</sub> )	1,043	1,043	1,040	1,041	1,059

Figure 5 Estimated mean wind speed based on WindSim calculations.

There is an indication that the mean wind speed increase with distance from the coast. Based on the above findings and distance measurements following graph has been made.

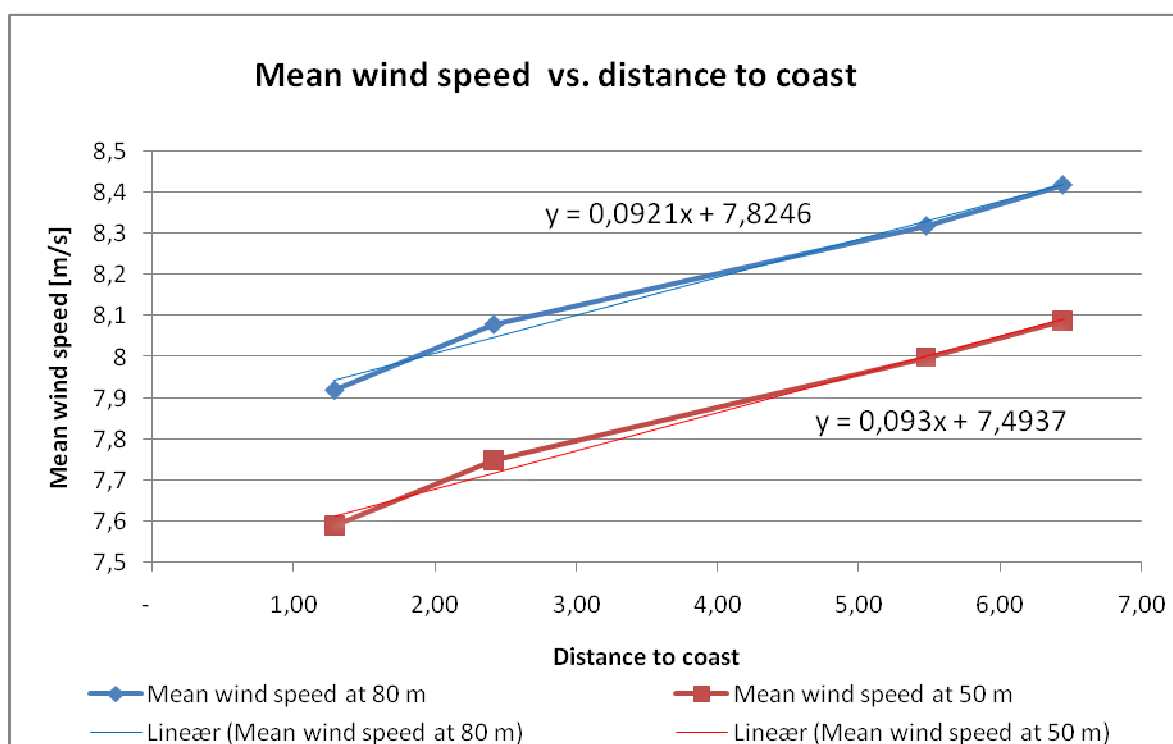
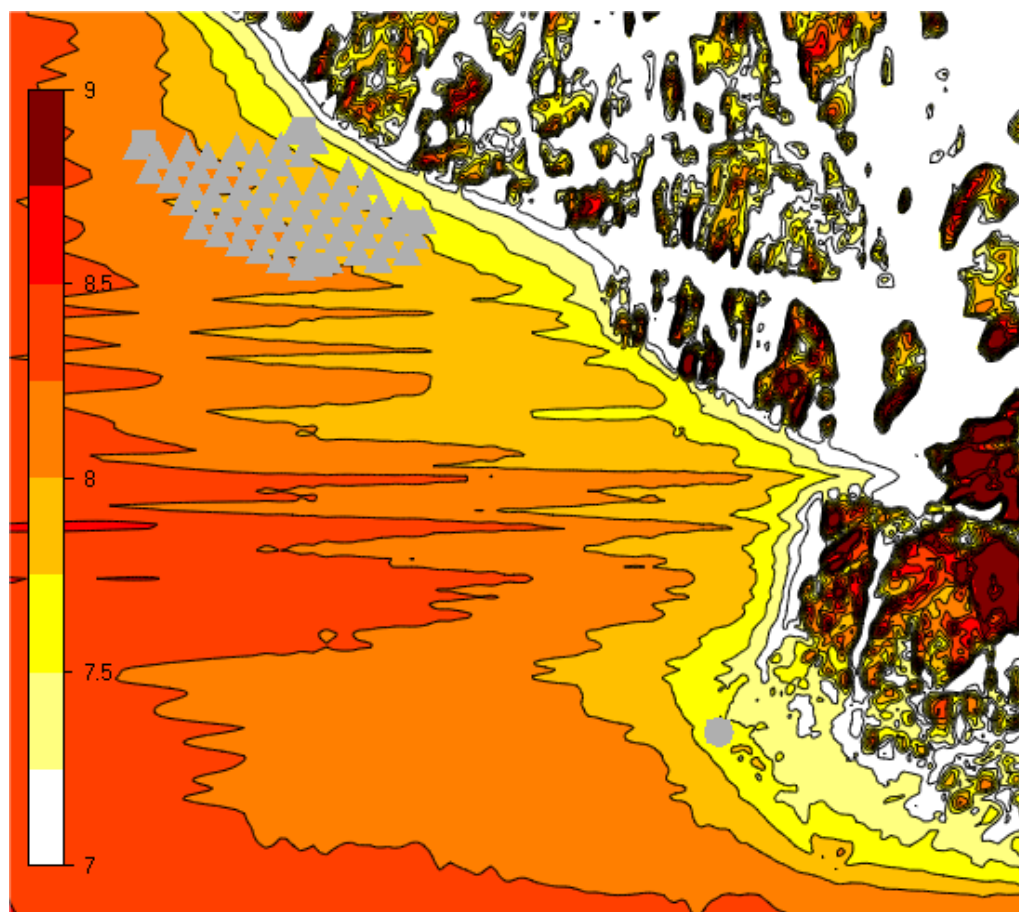


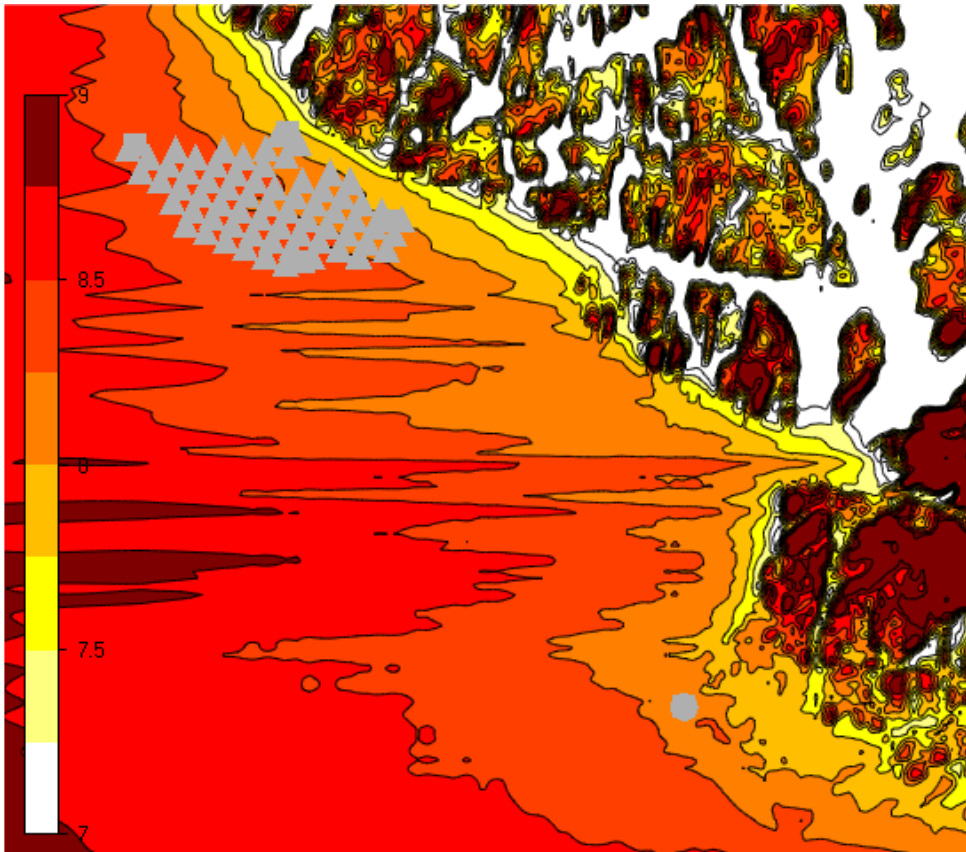
Figure 6 The dependency of distance to coast based on WindSim calculations.

Apparently there is the same dependency for both the 50 m and 80 m results. It must be remarked that these findings are based on Lista Fyr entirely and the applied WindSim model. To verify the indications a well planned measuring campaign must be made.

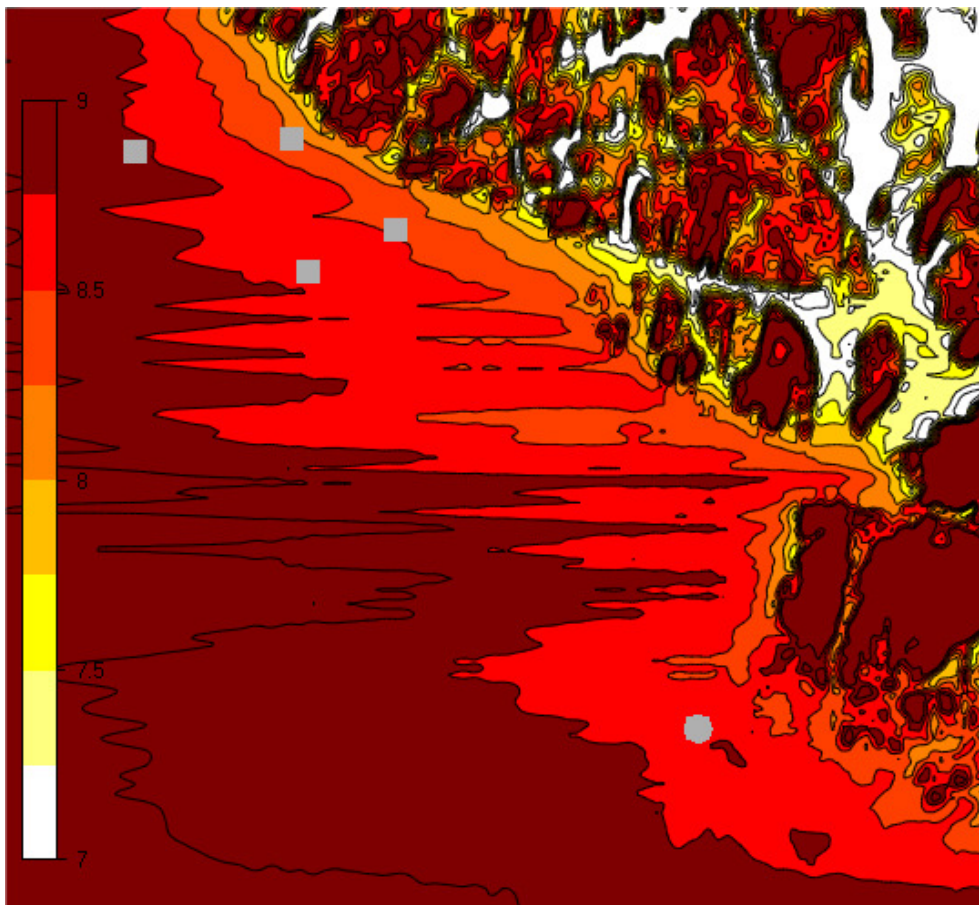
For different heights a wind resource map is calculated. Below is found wind resource maps for the heights 50 m a.s.l., 80 m a.s.l. and 125 m a.s.l. On the two first wind resource maps the proposed wind farm is indicated. The bar to the left in the figures shows the legend for the resource map in m/s.



**Figure 7 Wind resource map (based on Lista fyr) – 50 m a.s.l.**



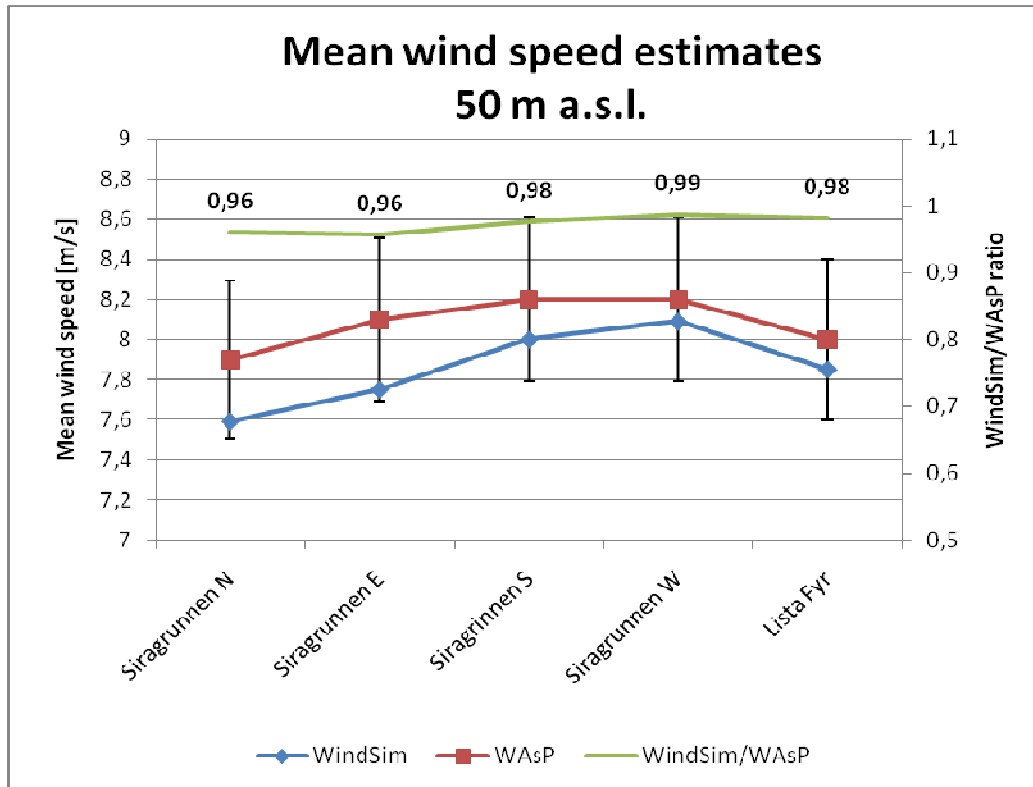
**Figure 8 Wind resource map (based on Lista fyr) – 80 m a.s.l.**



**Figure 9 Wind resource map (based on Lista fyr) – 125 m a.s.l.**

#### 4. Comparison with results from WAsP

Results from the Wasp analysis has been extracted for the height 50 m and compared with the result from WindSim at same height. Generally there is a good correlation between the two models – the overall difference (based on the five points below) is around 2,6%.



**Figure 10 Comparison between WAsP and WindSim results.**

The x-axis is sorted so that the "Siragrunnen N" is closest to the coast and "Siragrunnen W" is located farthest from the coast. There is a slight tendency that there is a larger difference between the two models near the coast. Inferred on the graph in figure 10 is also 5%-errorbars on the WAsP estimates. This uncertainty is expected to be an absolute minimum and the variations are therefore within the uncertainty. The difference between the two models must be verified by a measuring campaign where the wind speed is measured at different locations within the proposed wind farm simultaneously.

#### 5. Uncertainty

There are large uncertainties related to both the WindSim and the WAsP calculations. The main uncertainties are caused by the complex terrain around Lista Fyr, the horizontal extrapolation from Lista Fyr to the site and the extrapolation from 10 meters measuring height to hub height.

The best way to lower the high uncertainty is to establish one or more wind measurements at the site. A less expensive method would be to measure at hub height at Lista Fyr, but this would only take out the vertical extrapolation uncertainty. The uncertainty has not been quantified, but is expected to be around 10%-15% on the mean wind speed.